Achievements in CTF3 and Commissioning Status

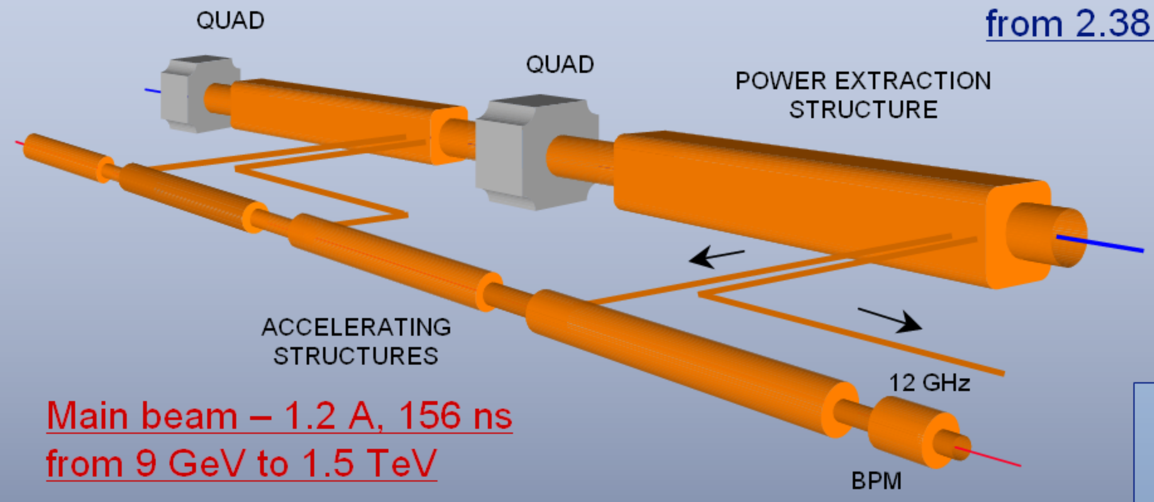
S. Bettoni (CERN) for the CTF3 commissioning team

Talk outline

- ✓ Introduction to CLIC
- ✓ CTF3 goals:
  - Past years achievements
  - 2008 milestones
- ✓ New lines installed
- ✓ Conclusions

CLIC two beams acceleration scheme

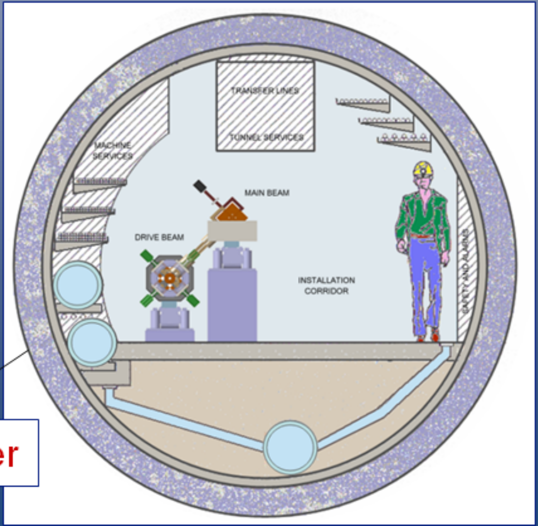
Drive beam - 101 A, 243.7 ns
from 2.38 GeV to 240 MeV



Main beam – 1.2 A, 156 ns
from 9 GeV to 1.5 TeV

Main Linac RF frequency	12 GHz
Accelerating field	100 MV/m
Overall length @ E_{CM} = 3 TeV	48 km

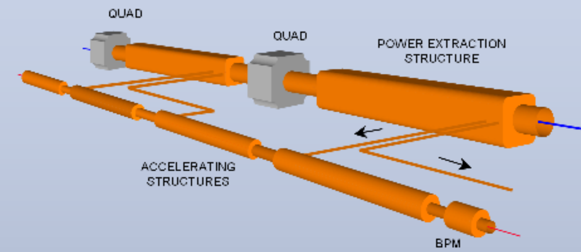
CLIC TUNNEL CROSS-SECTION



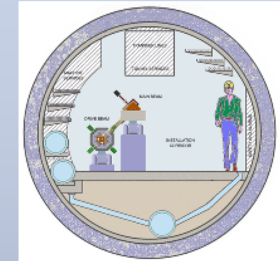
4.5 m diameter

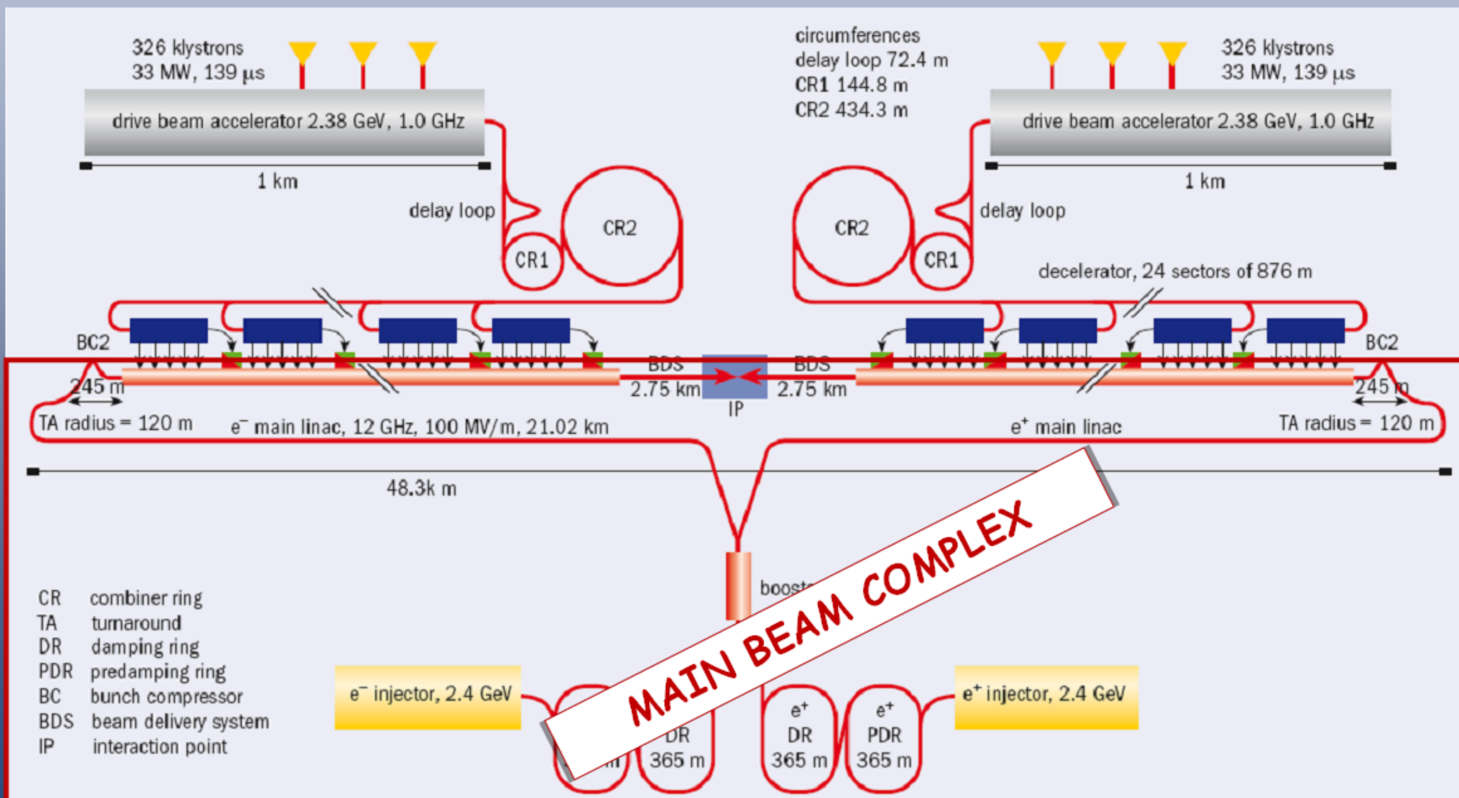
TH3GBI01

CLIC layout



QUAD
QUAD
POWER EXTRACTION STRUCTURE
ACCELERATING STRUCTURES
BPM





326 klystrons
33 MW, 139 μs
drive beam accelerator 2.38 GeV, 1.0 GHz
1 km
circumferences
delay loop 72.4 m
CR1 144.8 m
CR2 434.3 m
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CR2
CR1
CR2
CR1
delay loop
decelerator, 24 sectors of 876 m
BC2
BDS
2.75 km
IP
BDS
2.75 km
BC2
245 m
245 m
TA radius = 120 m
e⁻ main linac, 12 GHz, 100 MV/m, 21.02 km
e⁺ main linac
TA radius = 120 m
48.3k m
CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
e⁻ injector, 2.4 GeV
DR
365 m
e⁺ DR 365 m
e⁺ PDR 365 m
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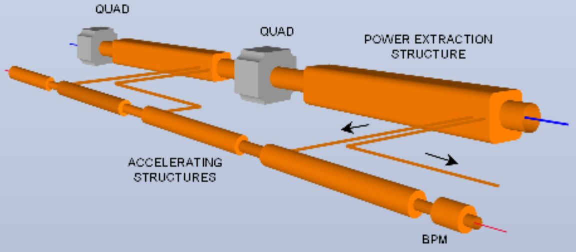
MAIN BEAM COMPLEX

CLIC layout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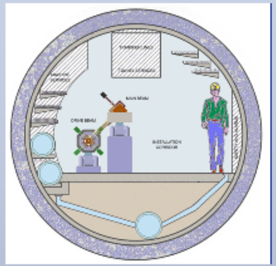

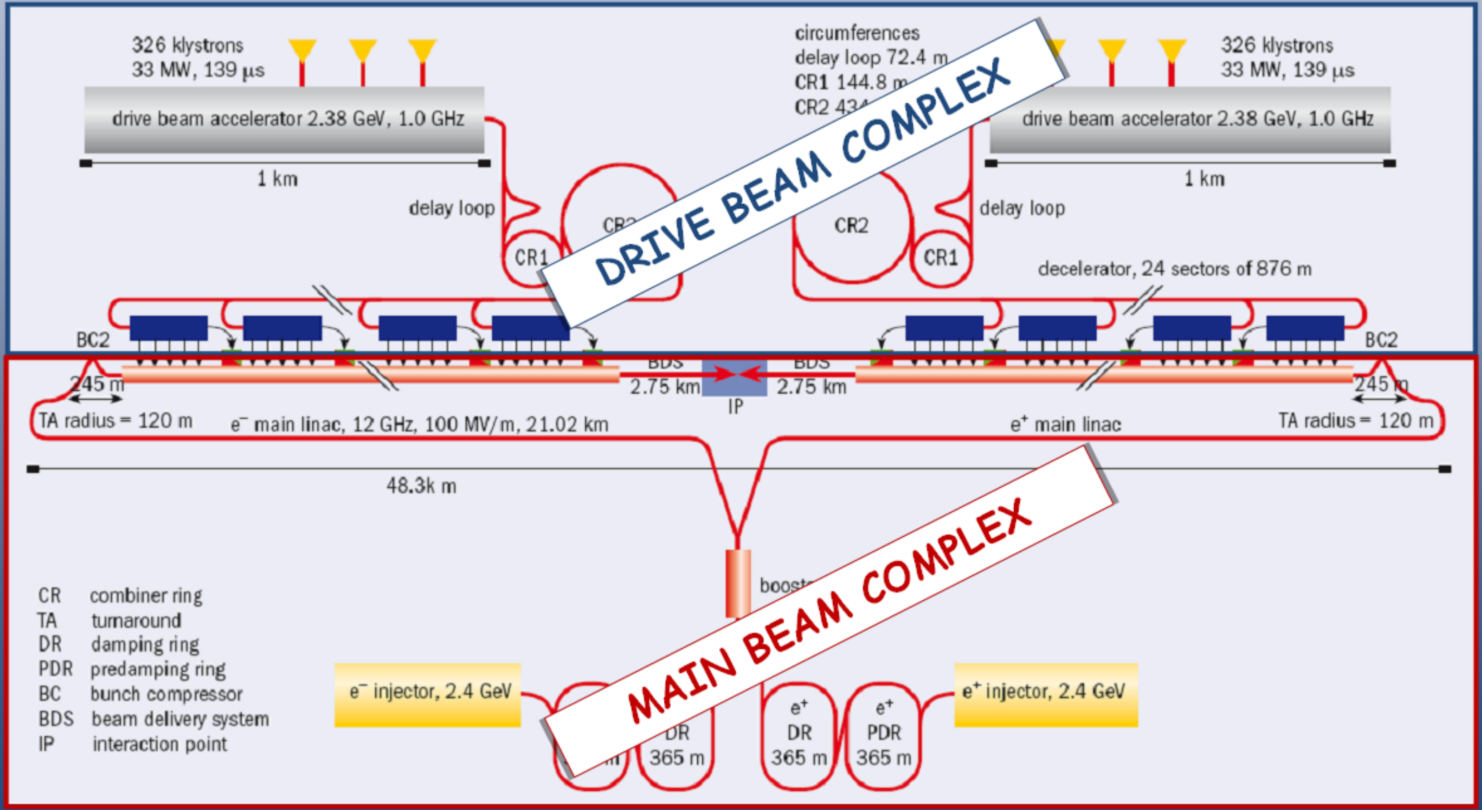
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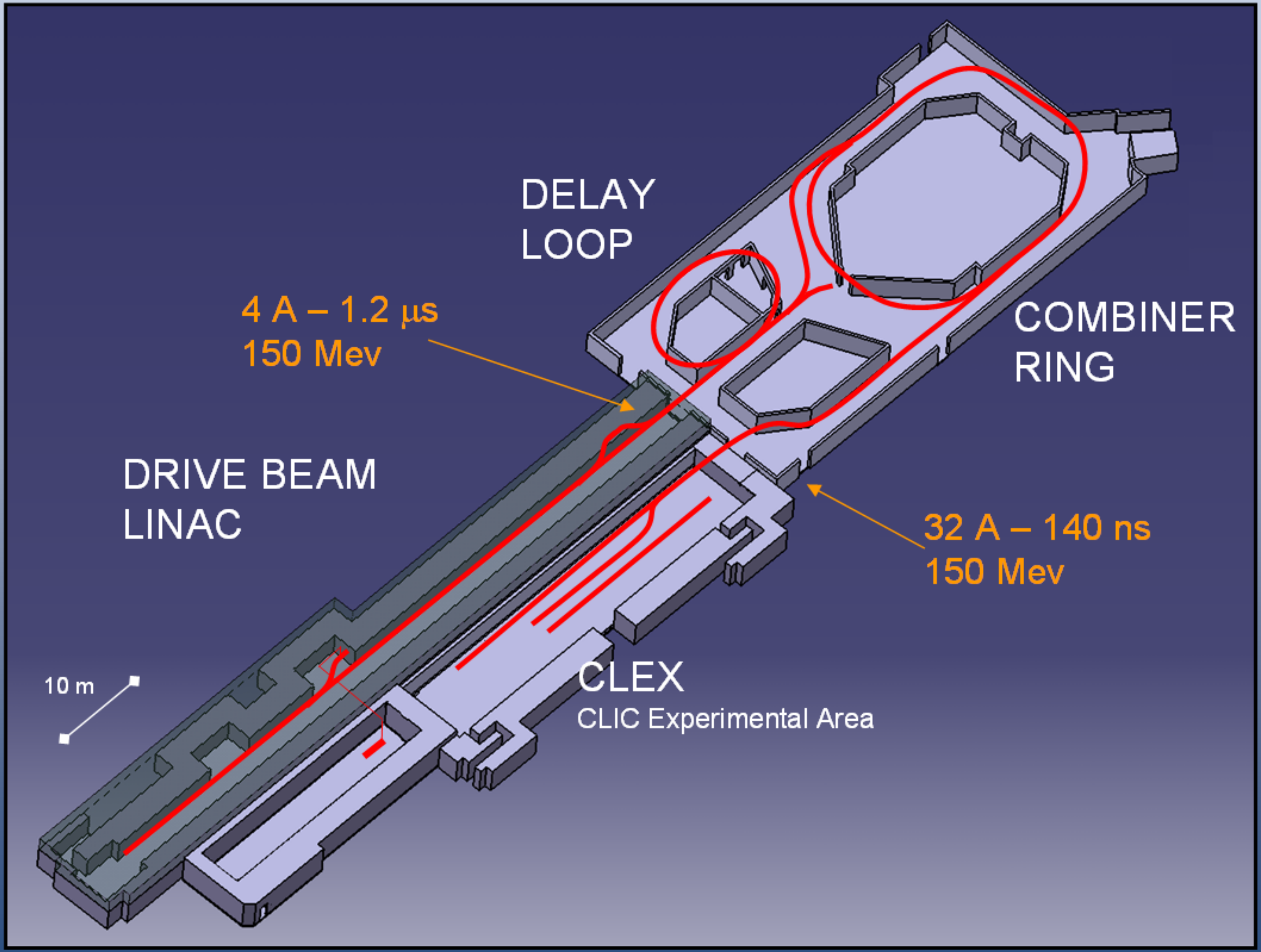
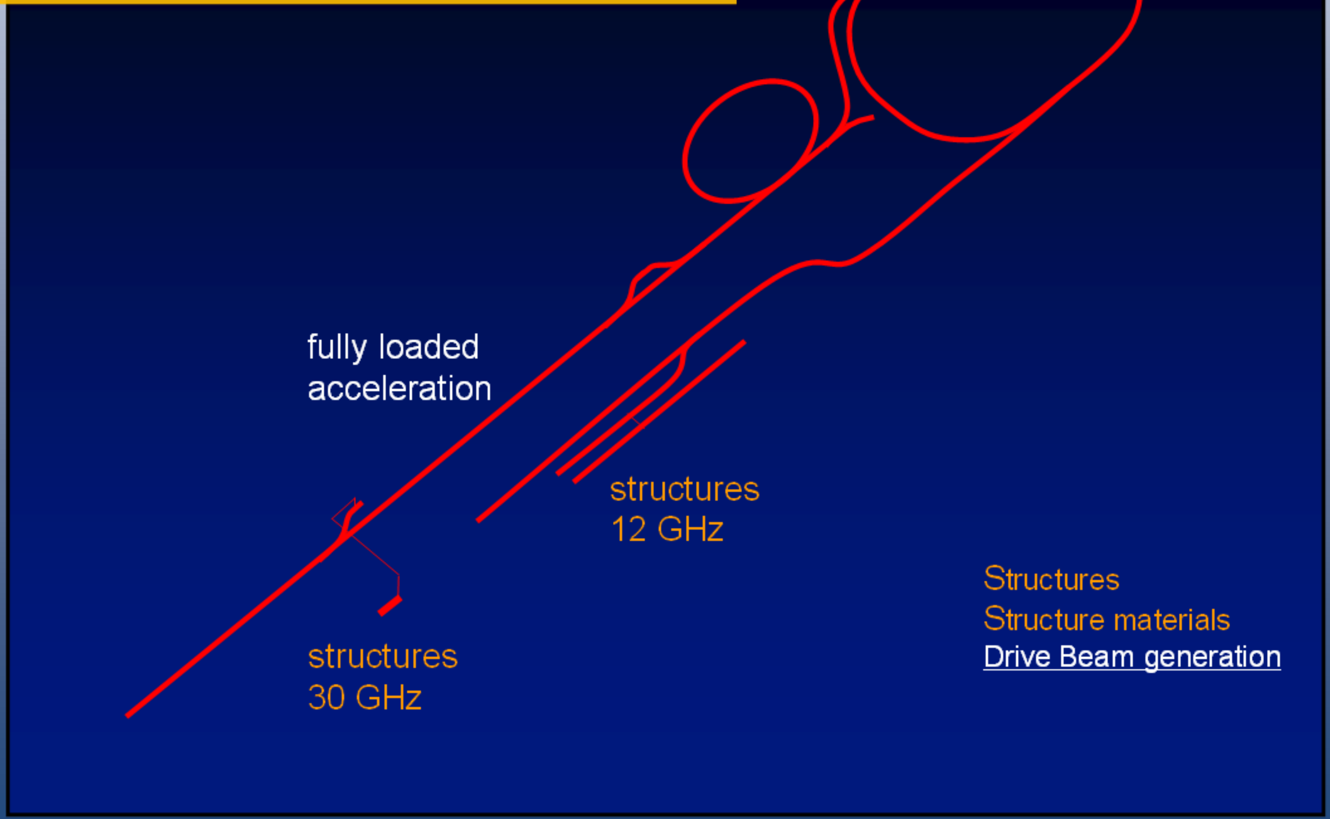
CTF3 layout


DELAY
LOOP
4 A – 1.2 µs
150 Mev
COMBINER
RING
DRIVE BEAM
LINAC
32 A – 140 ns
150 Mev
10 m
CLEX
CLIC Experimental Area

CLIC R&D issues: where?

CTF3 is a small scale version of the CLIC drive beam complex:

- ✓ Provide the RF power to test the CLIC accelerating structures and components
- ✓ Full beam-loading accelerator operation



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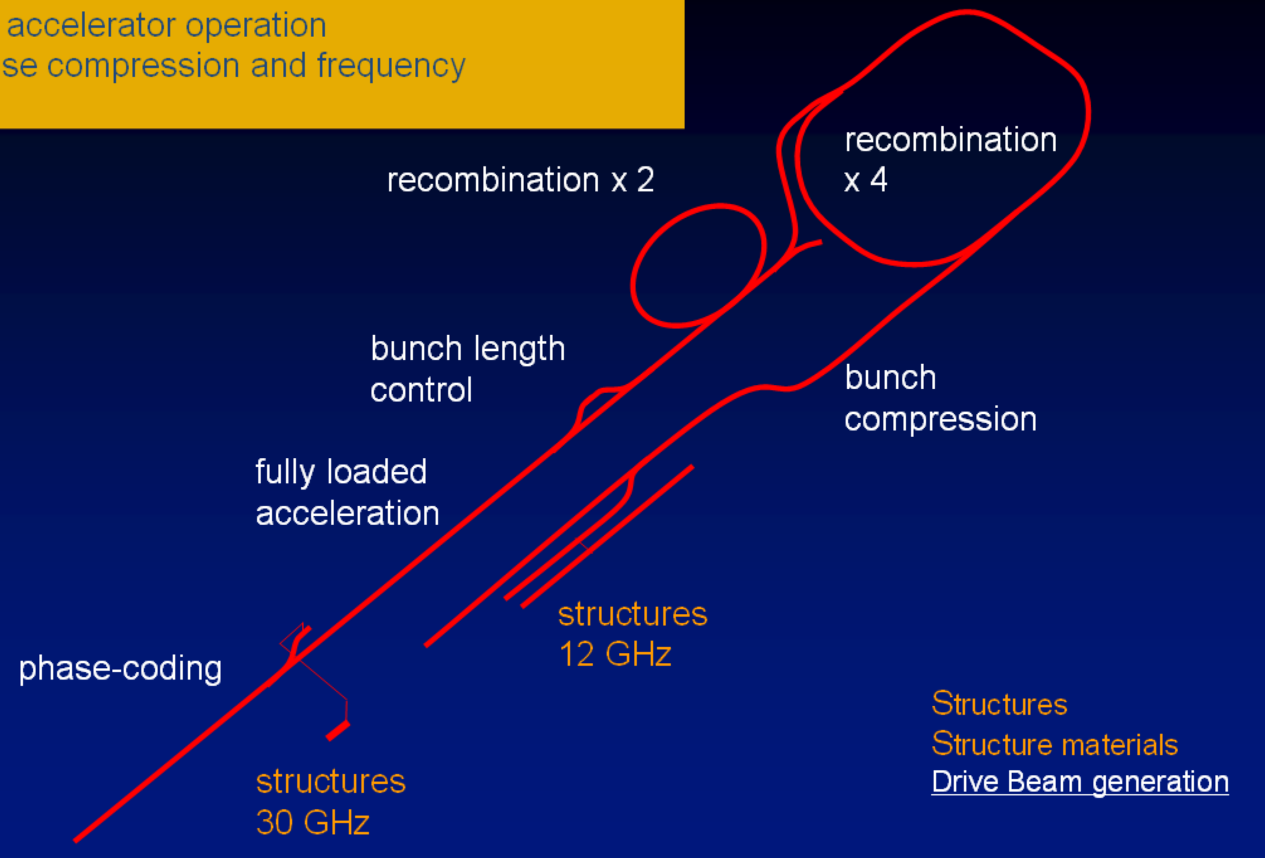

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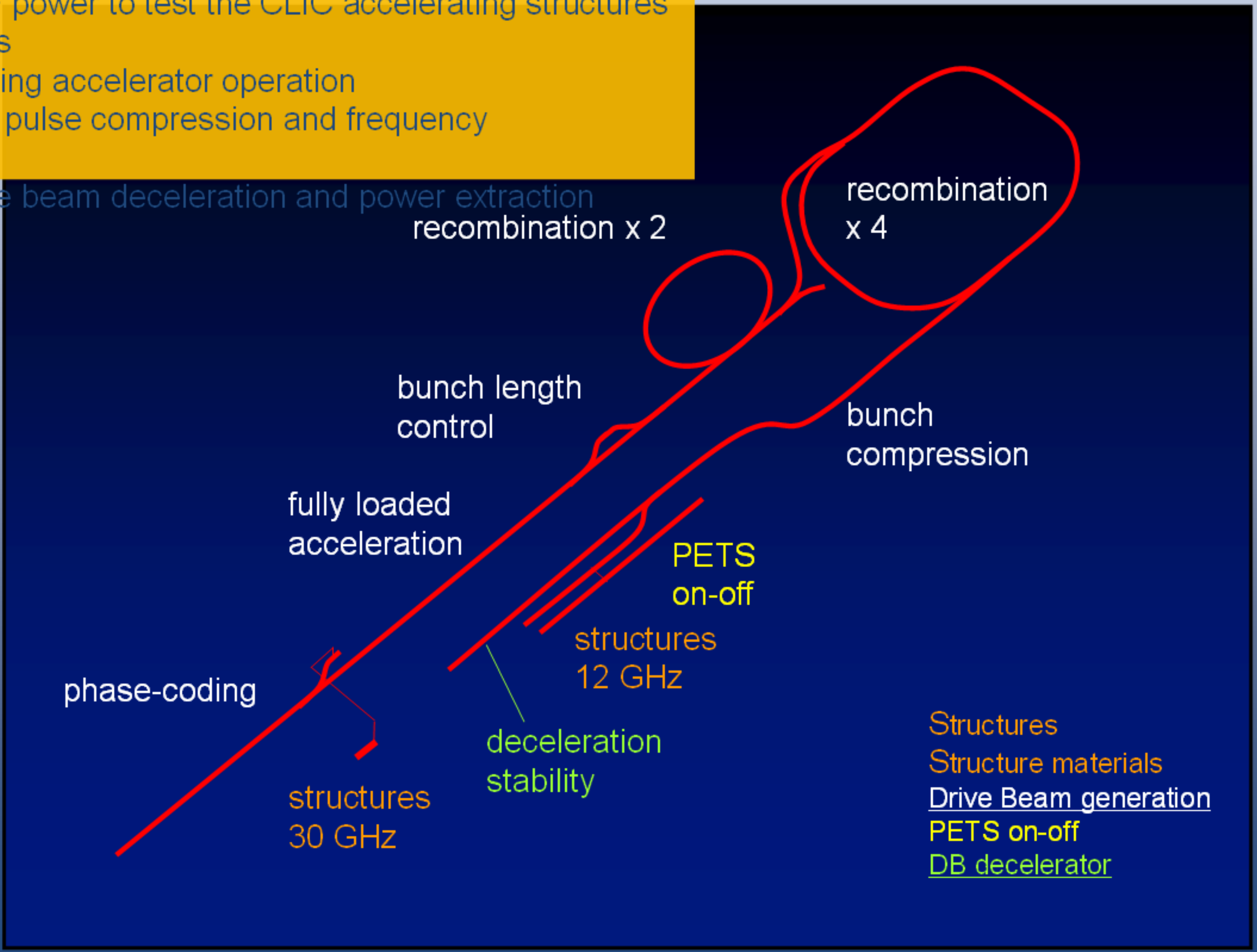

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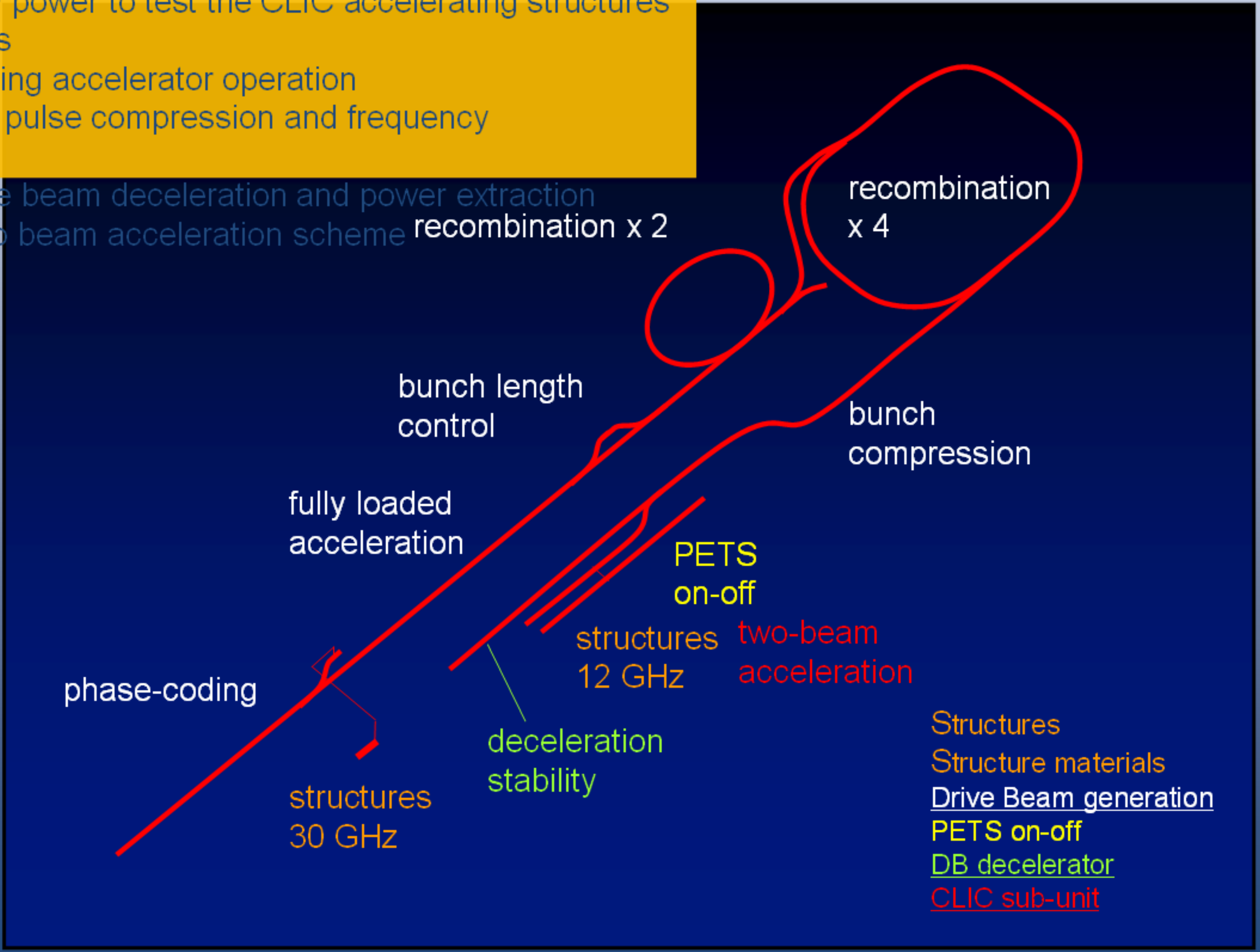

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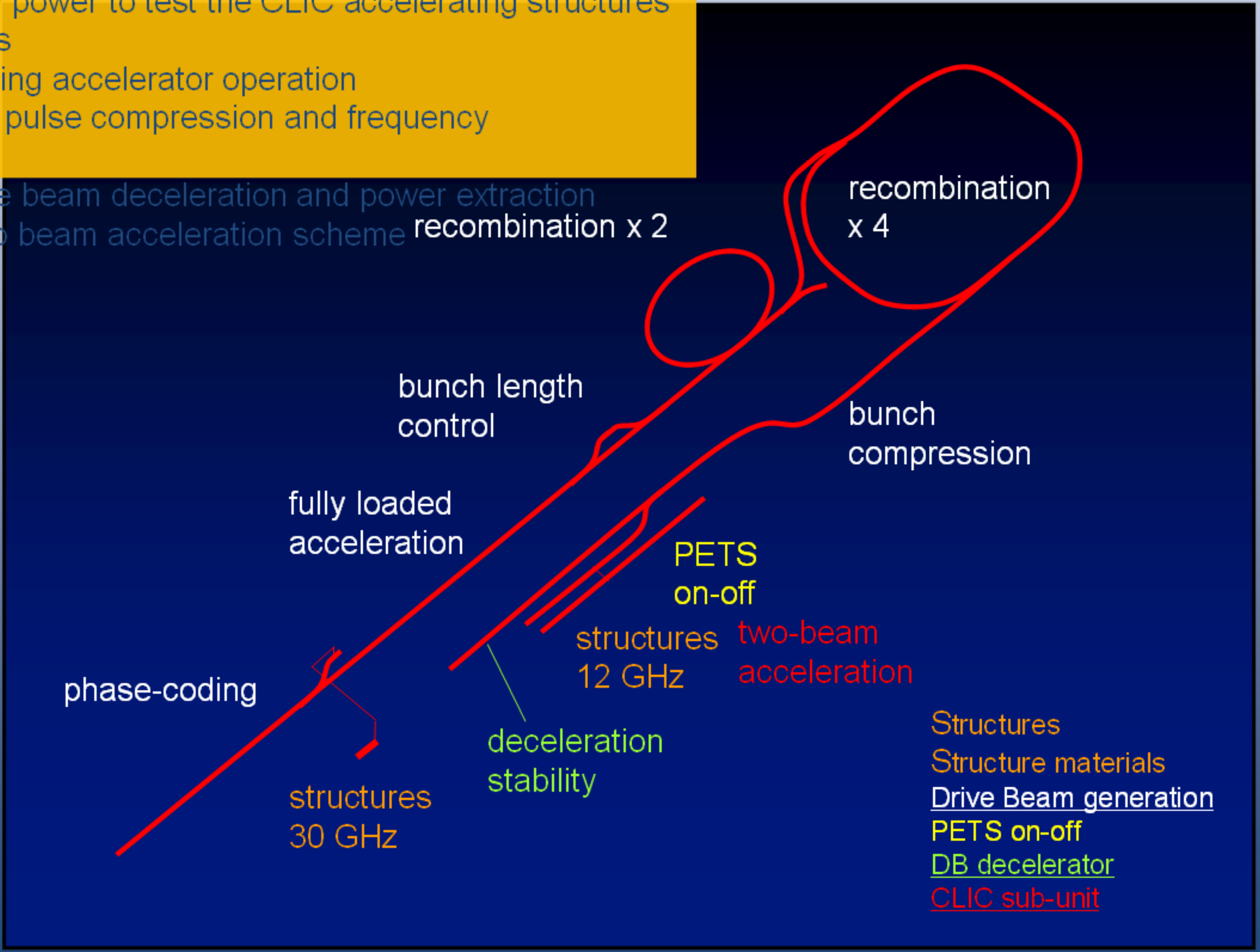
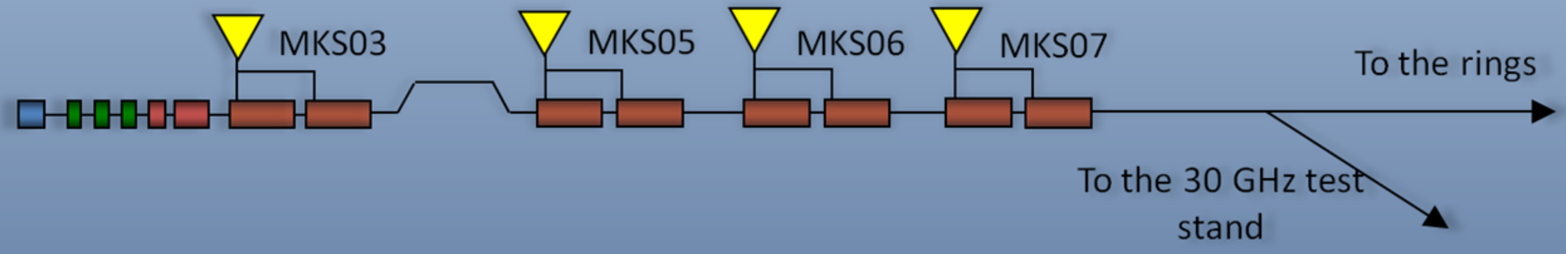


Achievements in the last years

It has been already demonstrated/done (2004-2007):

- ✓ Provide the RF power to test the CLIC accelerating structures and components (since 2005)

Beam routinely sent during the week-ends to the PETS structures



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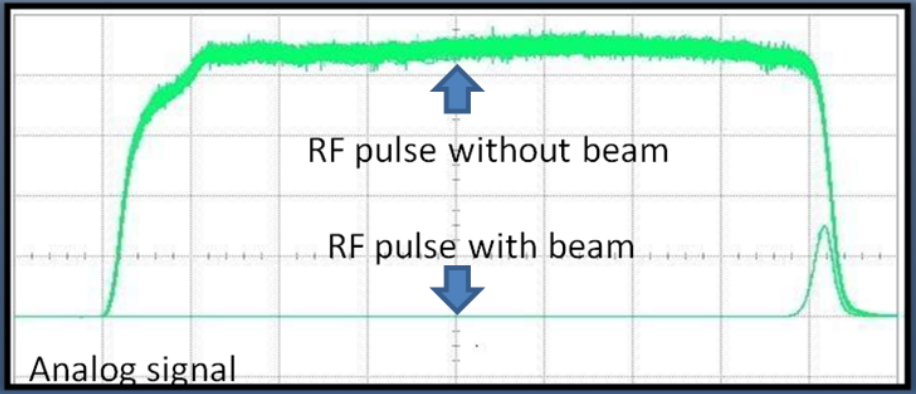
Measured RF to beam efficiency: 95.3 %

Expected from the theory: 96%



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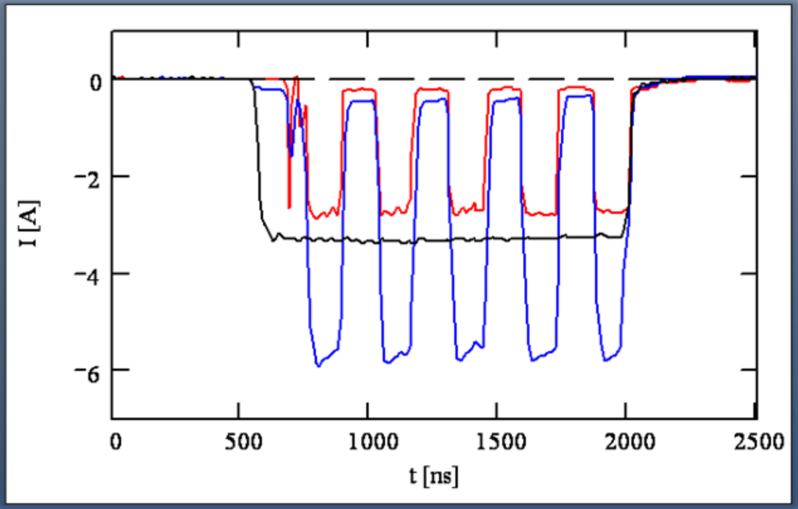
Successful demonstration of the DL operation!



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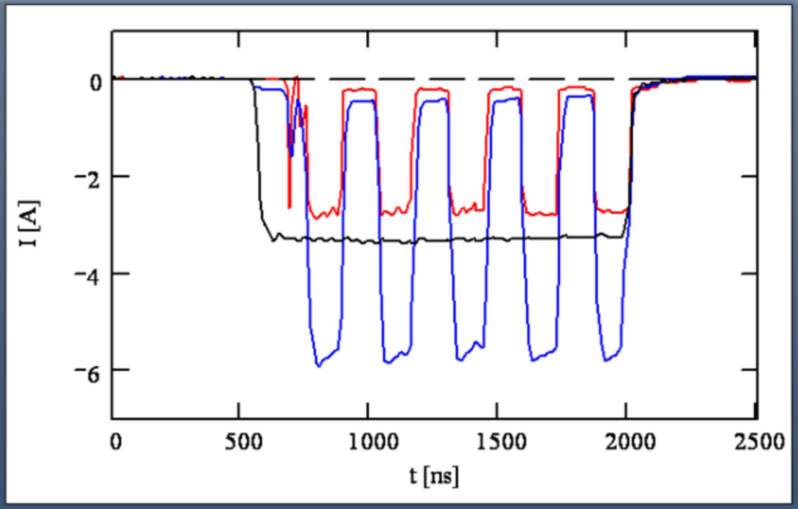

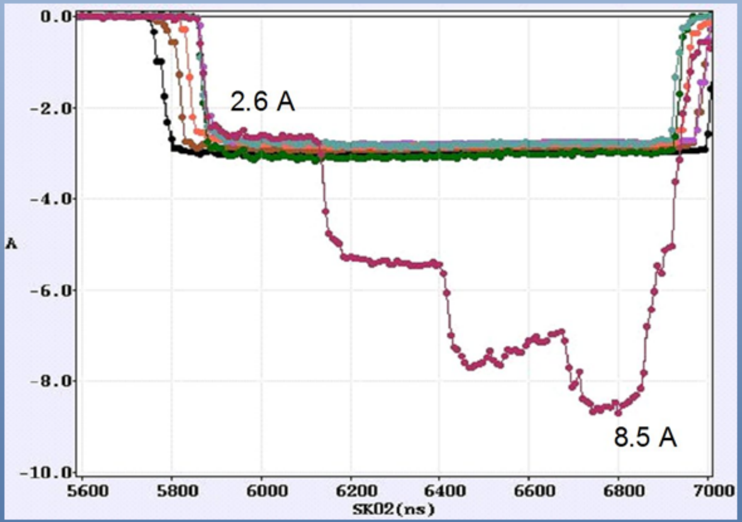

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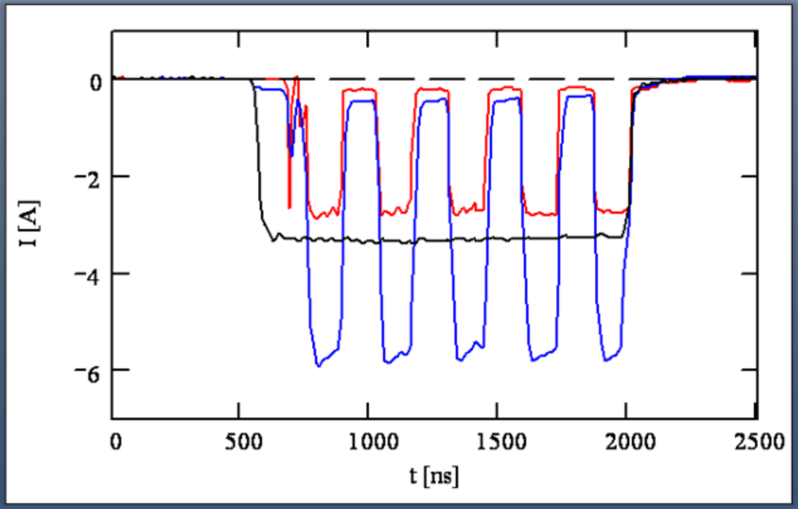
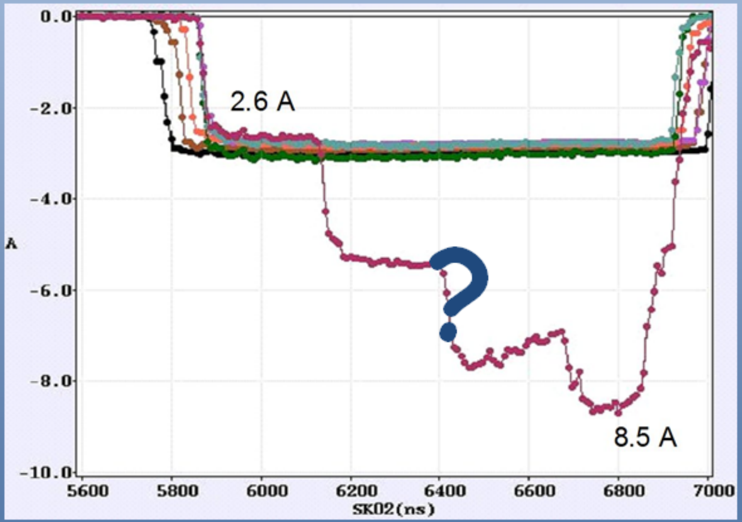
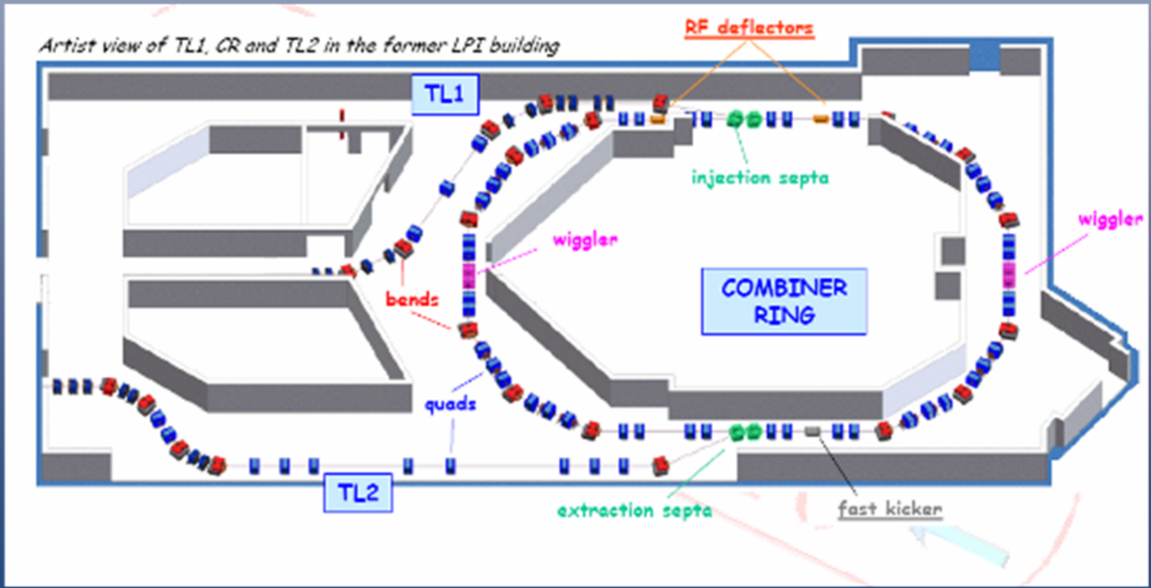




2008 milestones: factor 4 recombination in CR



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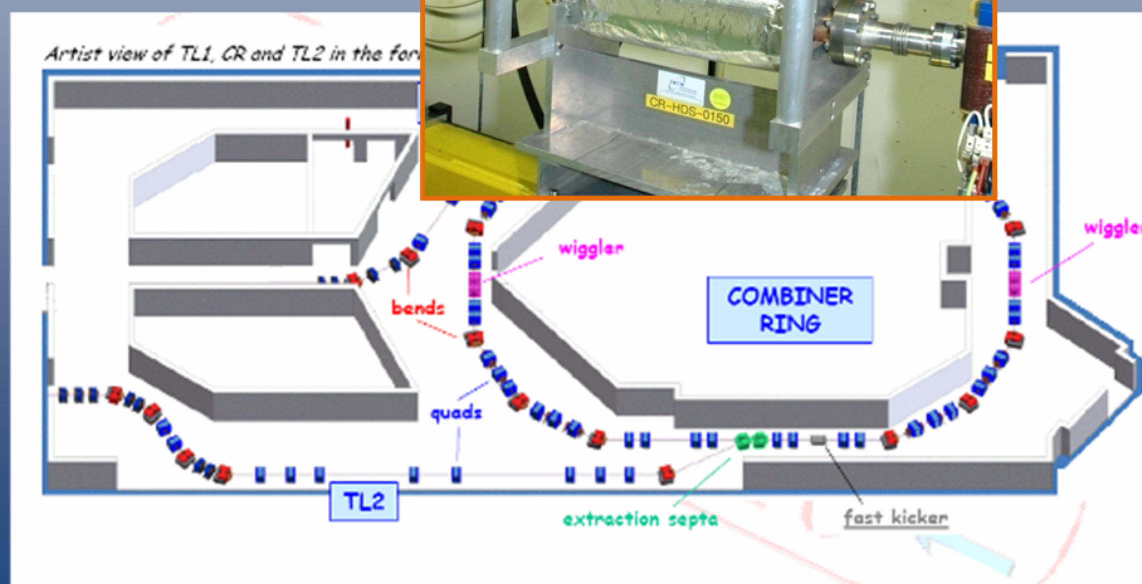

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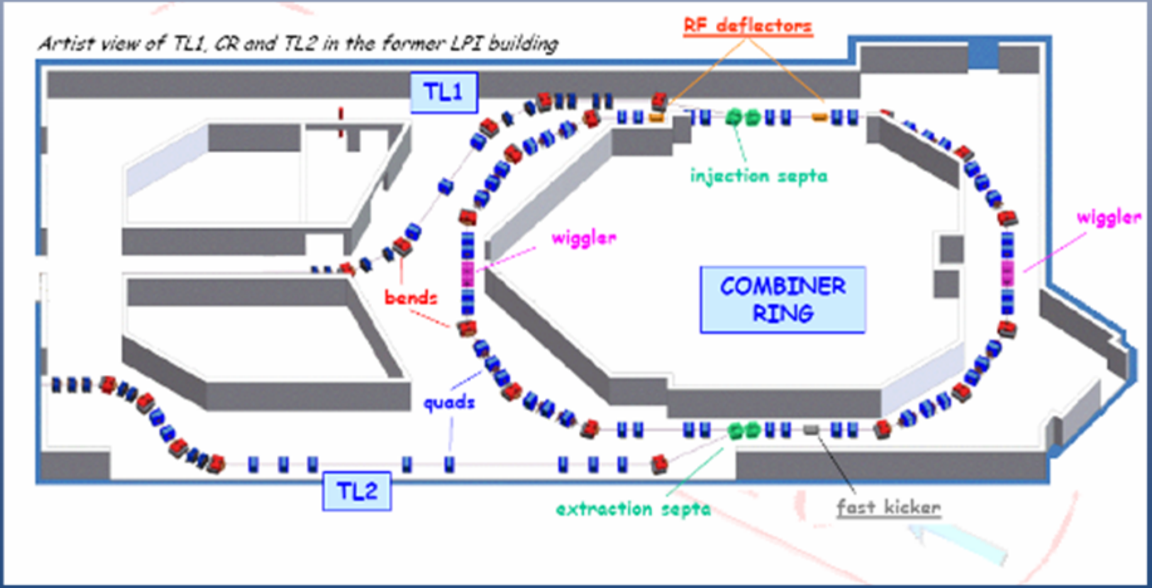

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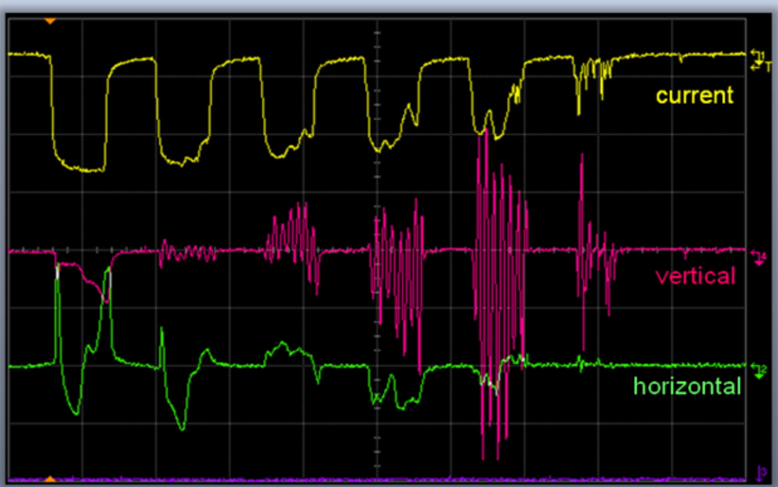

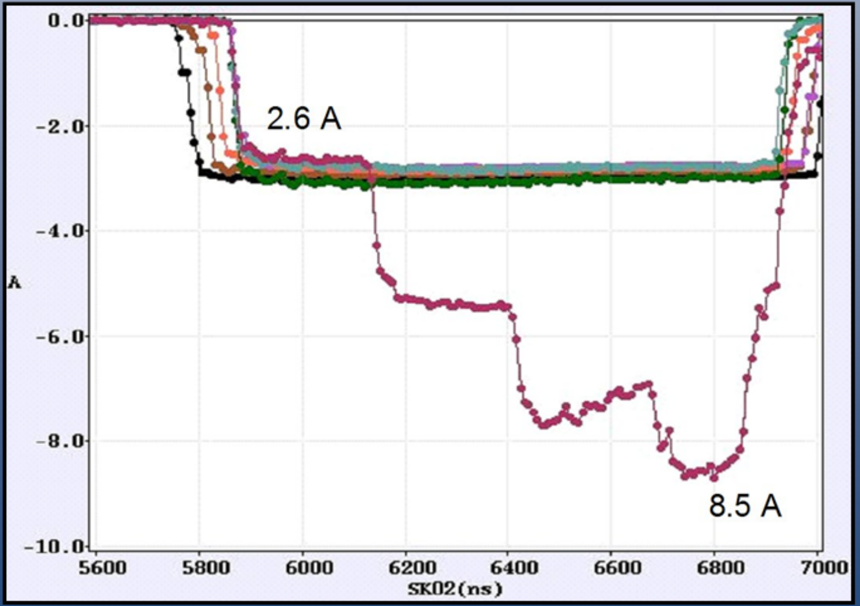

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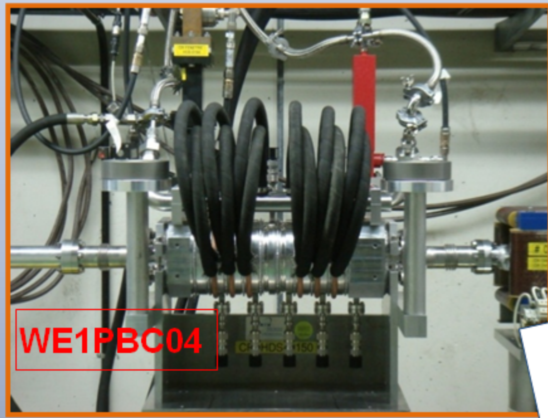
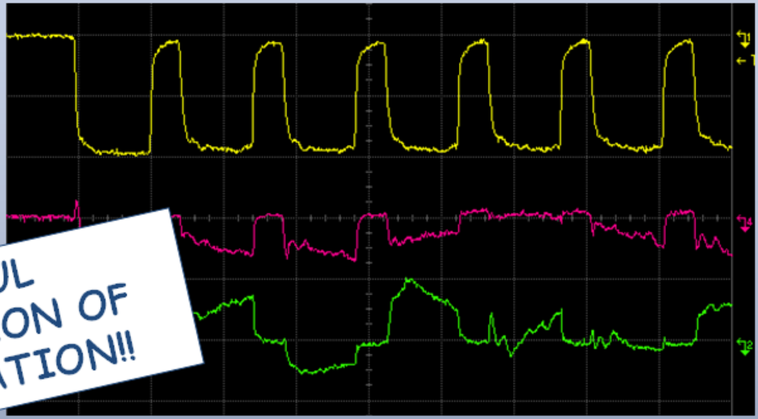
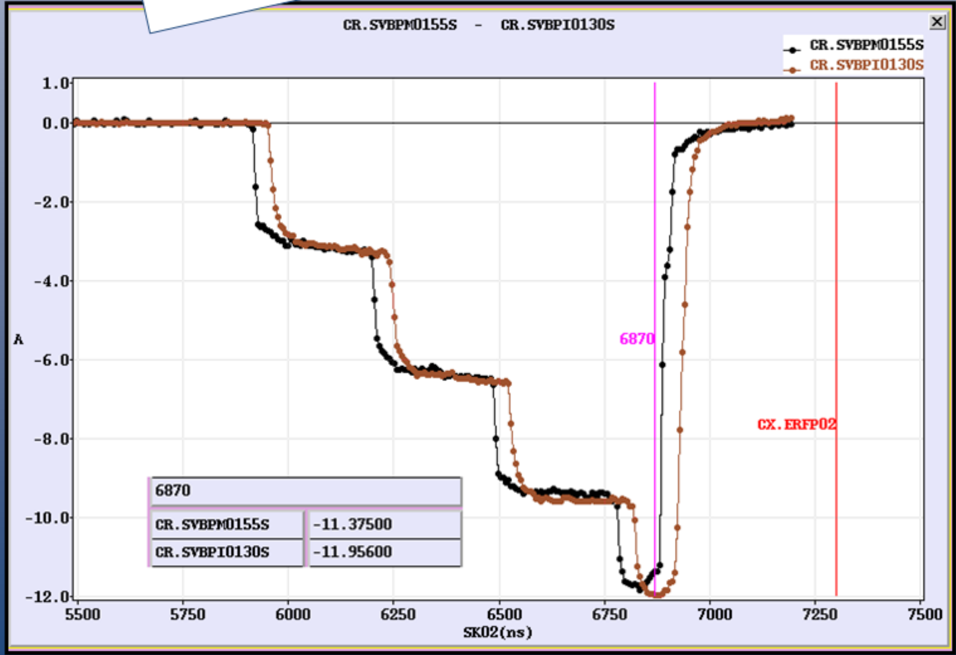




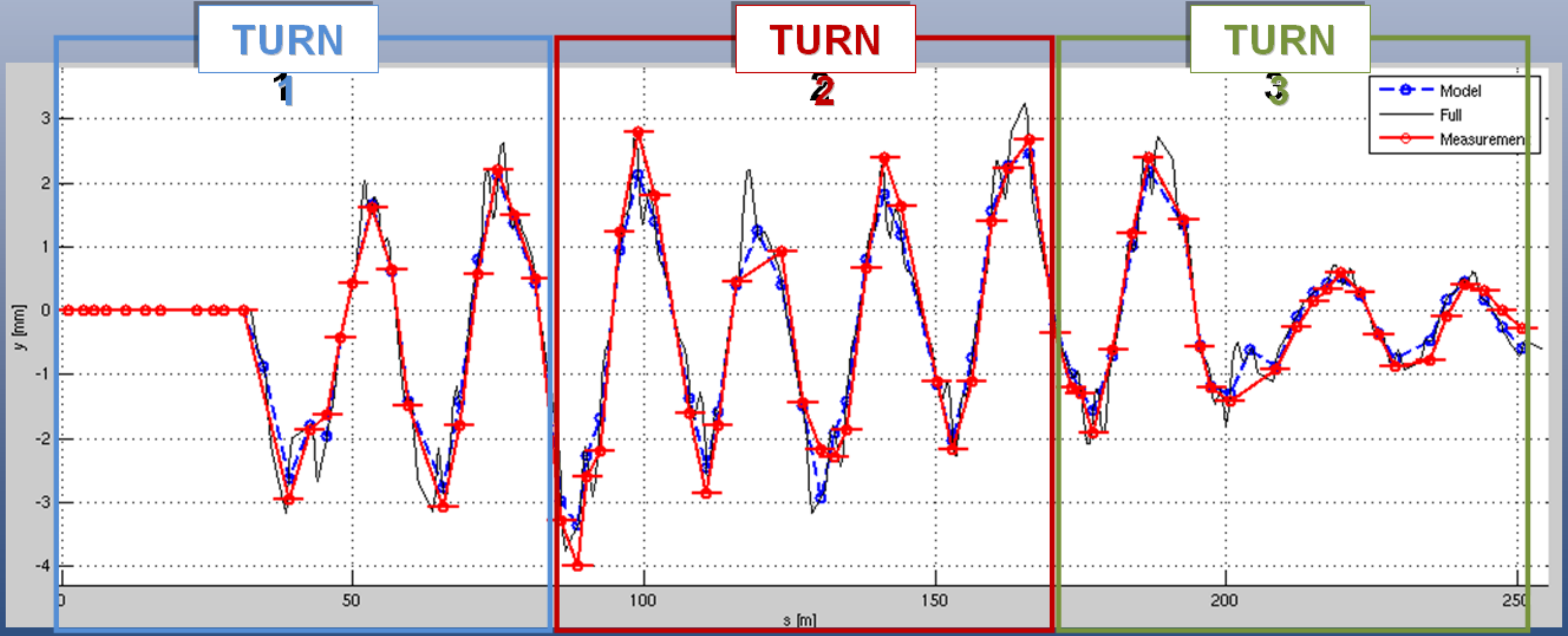
SUCCESSFUL DEMONSTRATION OF THE CR OPERATION!!



2008 milestones: the CR model improvement

To validate the MAD-X model of the combiner ring:

- ✓ High precision kick measurements compared to the model predictions:
  - Symmetric kick analysis to identify single quadrupole error
  - Multi-turn analysis to magnify the effect of the discrepancy



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  - ○ Dispersion
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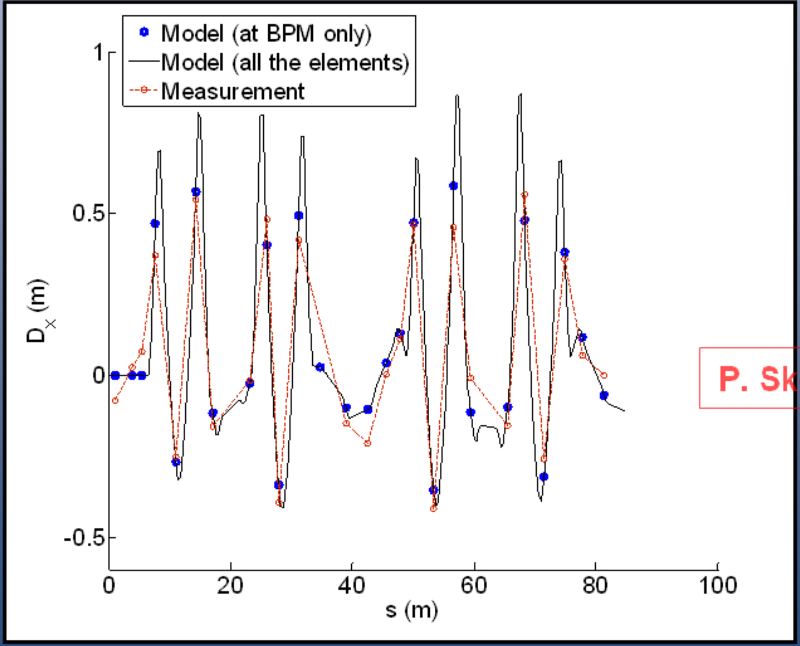
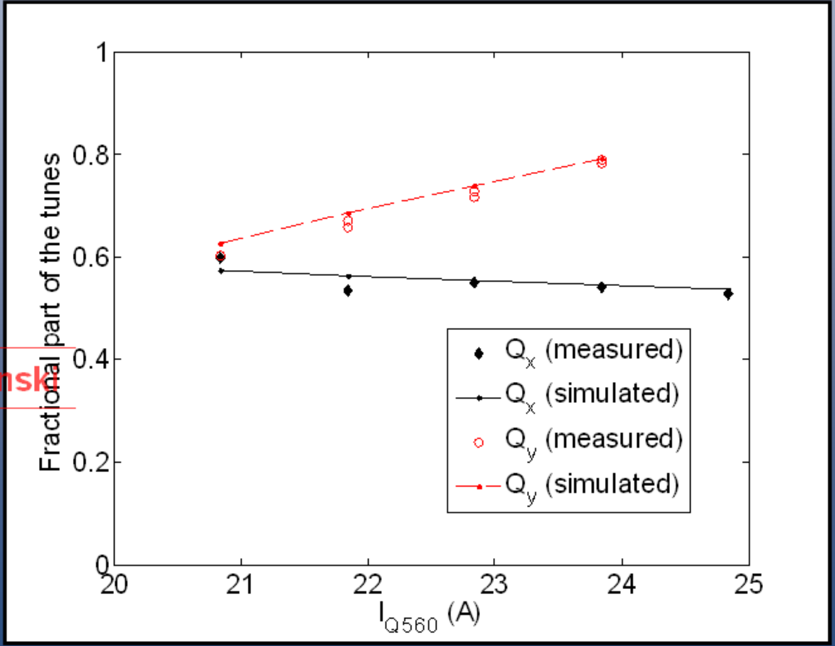


P. Skowronski



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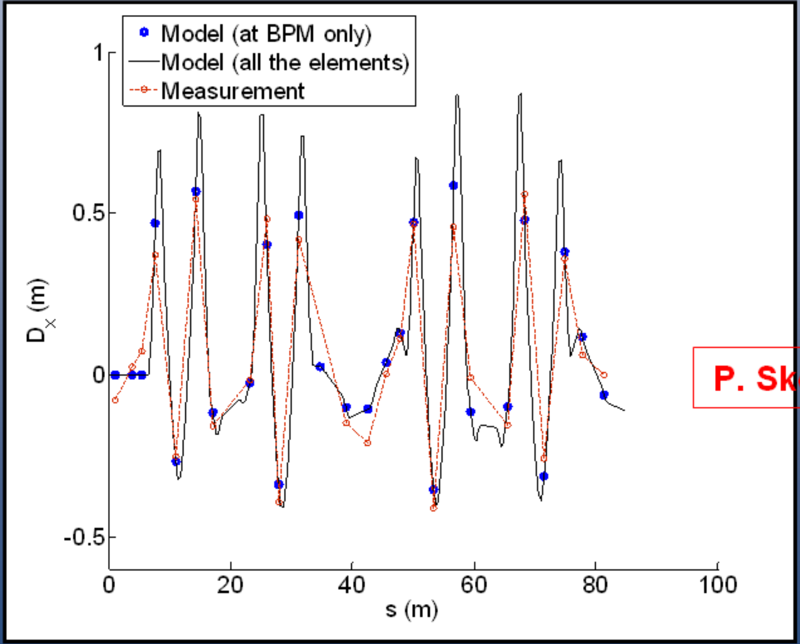

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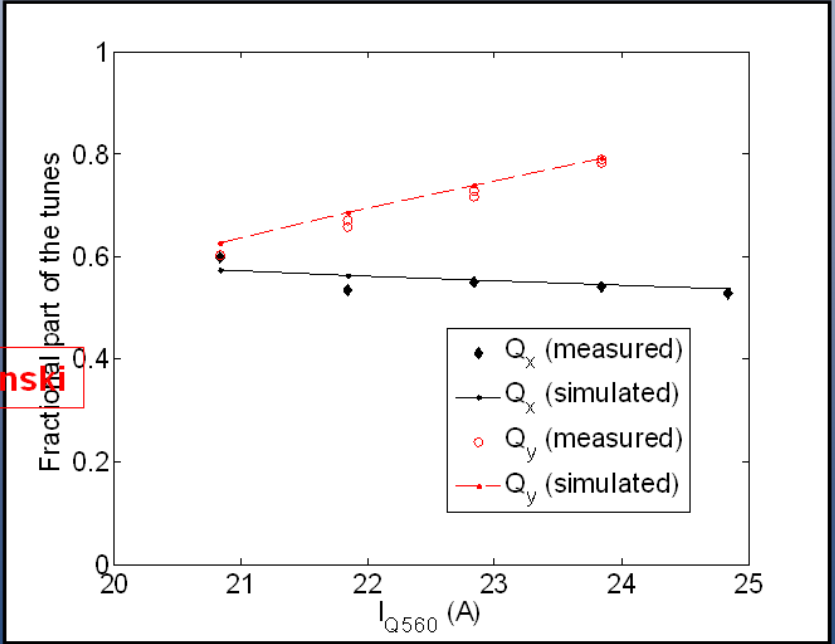

2008: new lines installed

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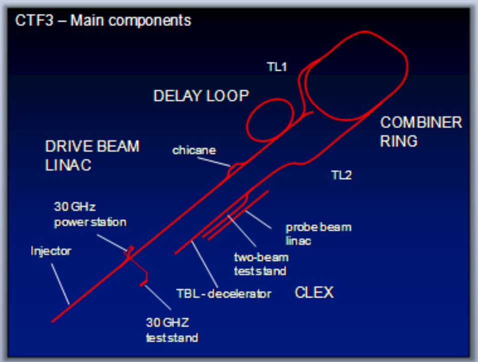

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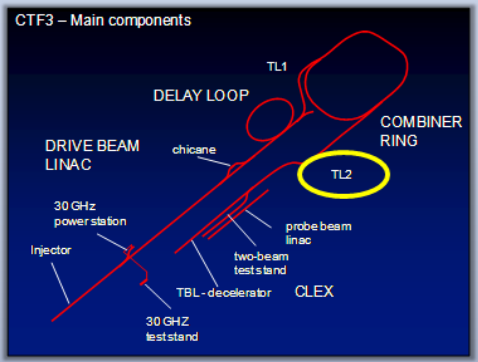
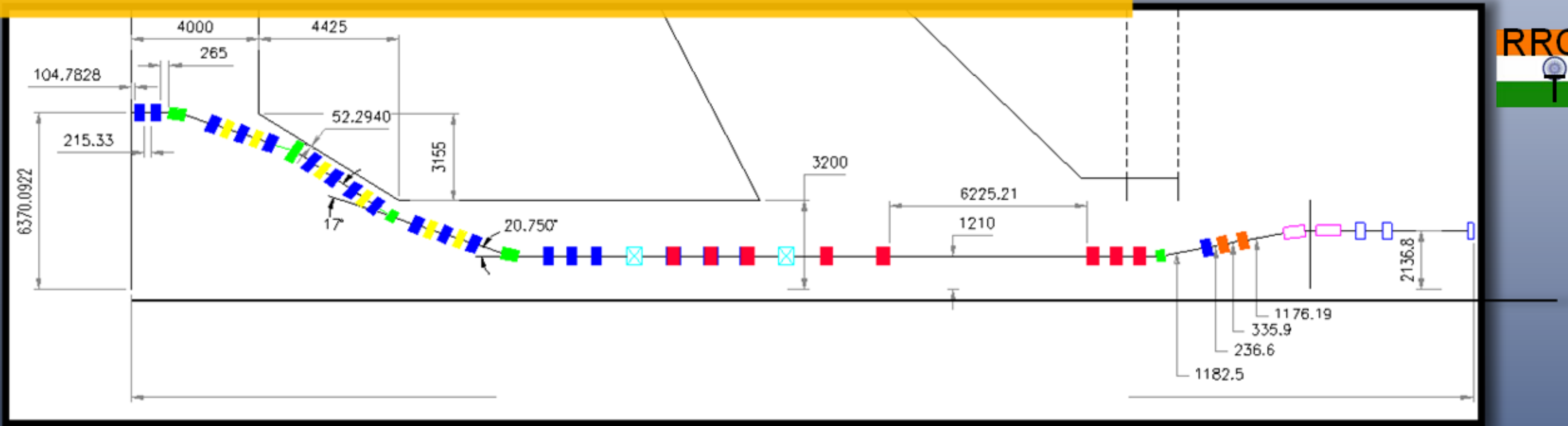
✓ TL2 → transfer line from CR to the CLEX area





RRCA

Module-3

- *Tunable R_{56} (from -0.35 to +0.35)*
- *Achromatic arc*
- *Final matching doublet*

Module-2

- *Straight section for tail clipper*
- *Vertical achromat*
- *Matching section*

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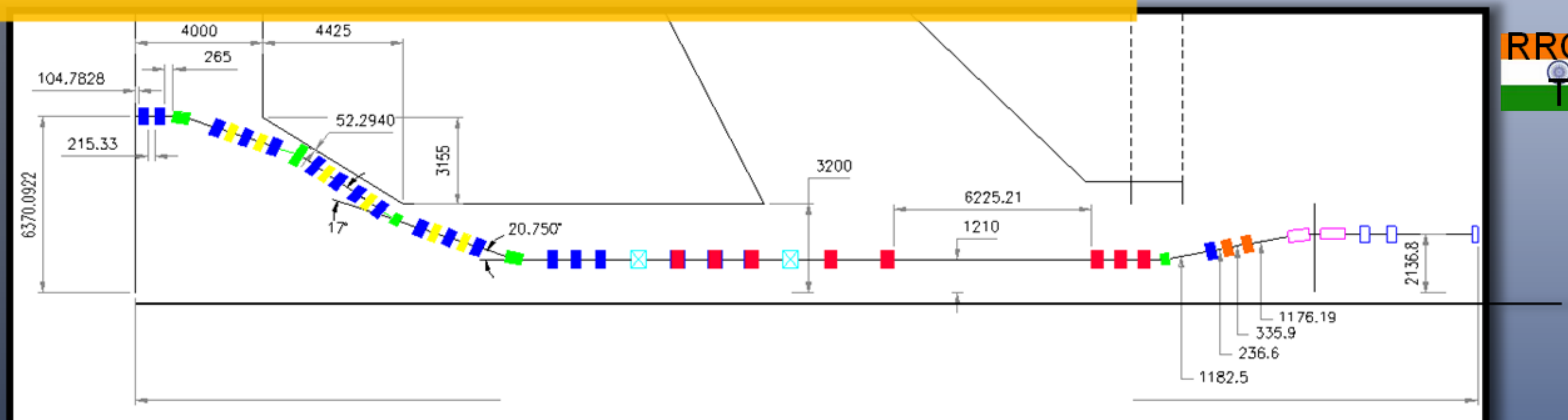

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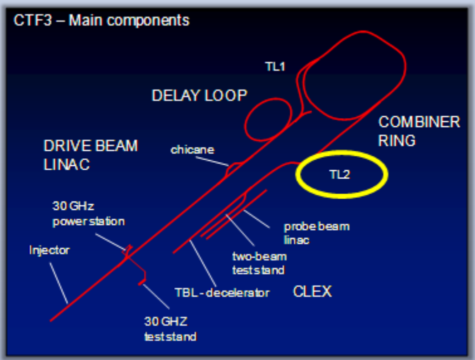

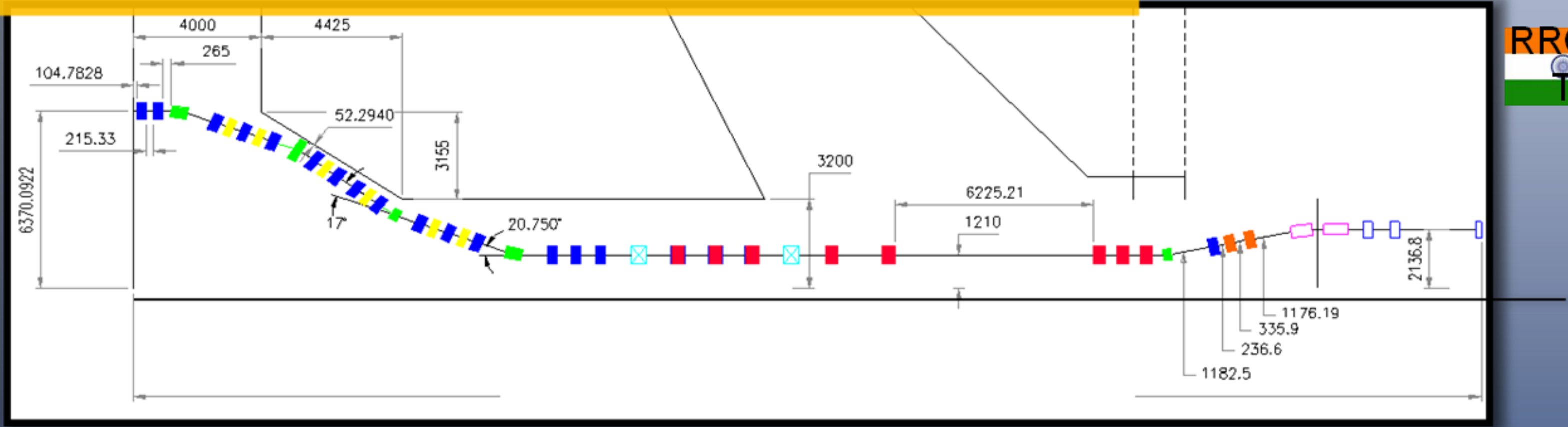

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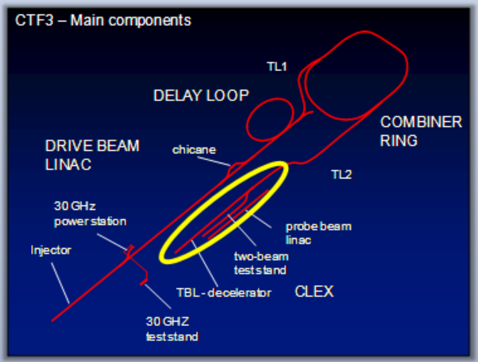

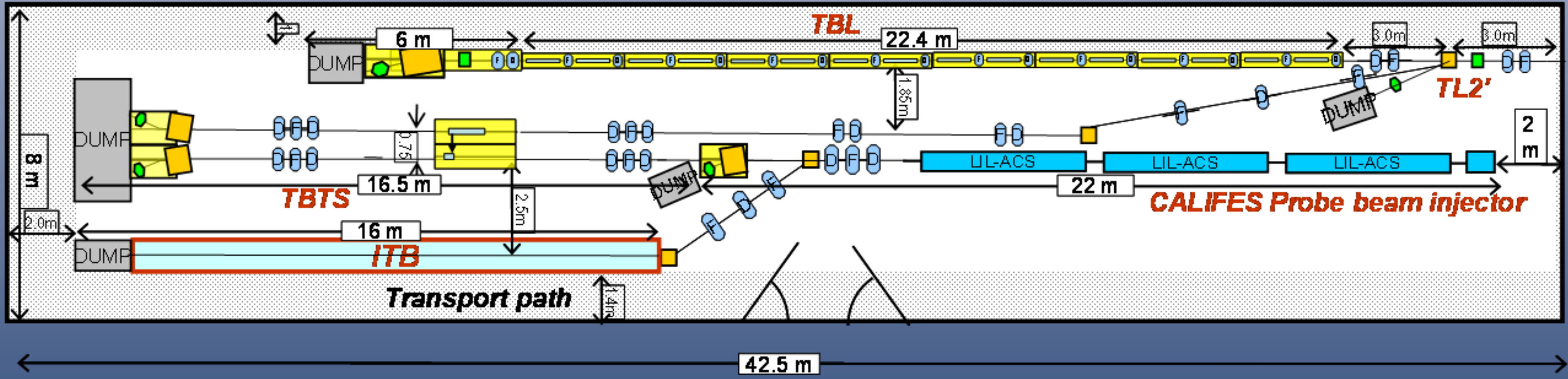

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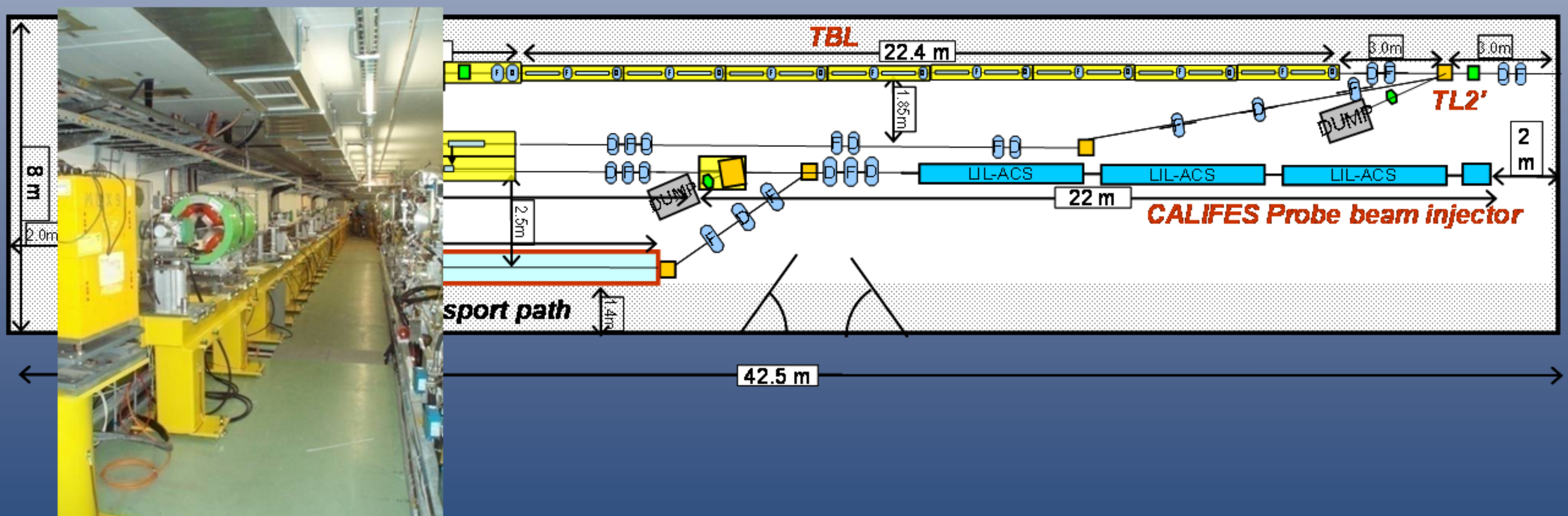

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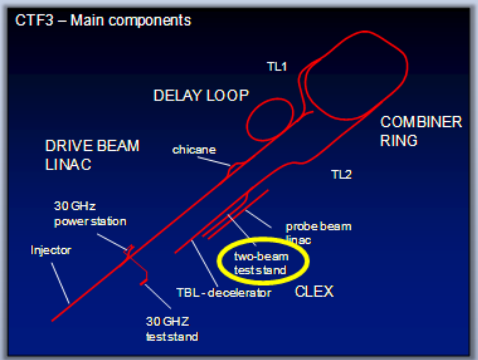

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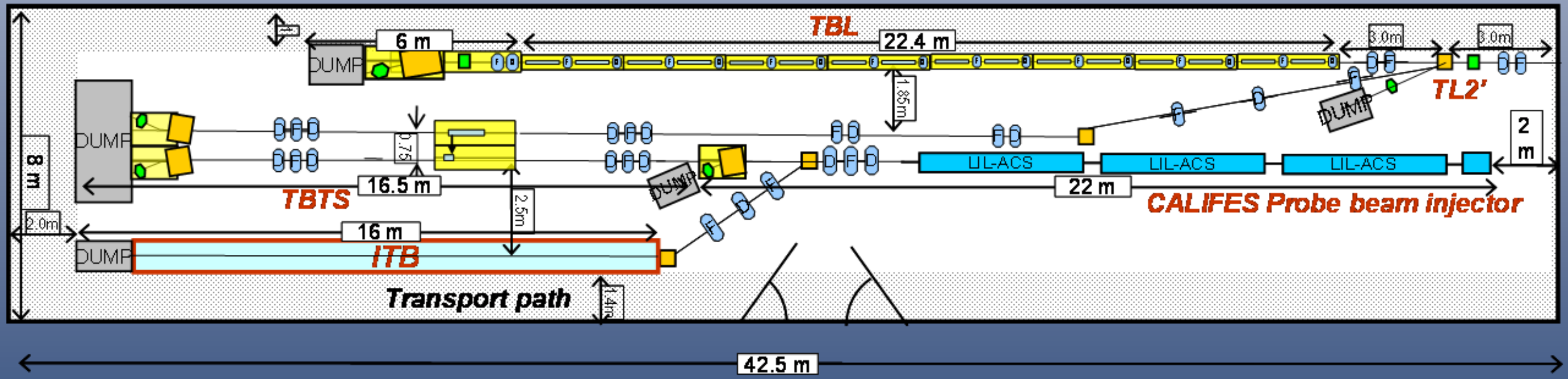

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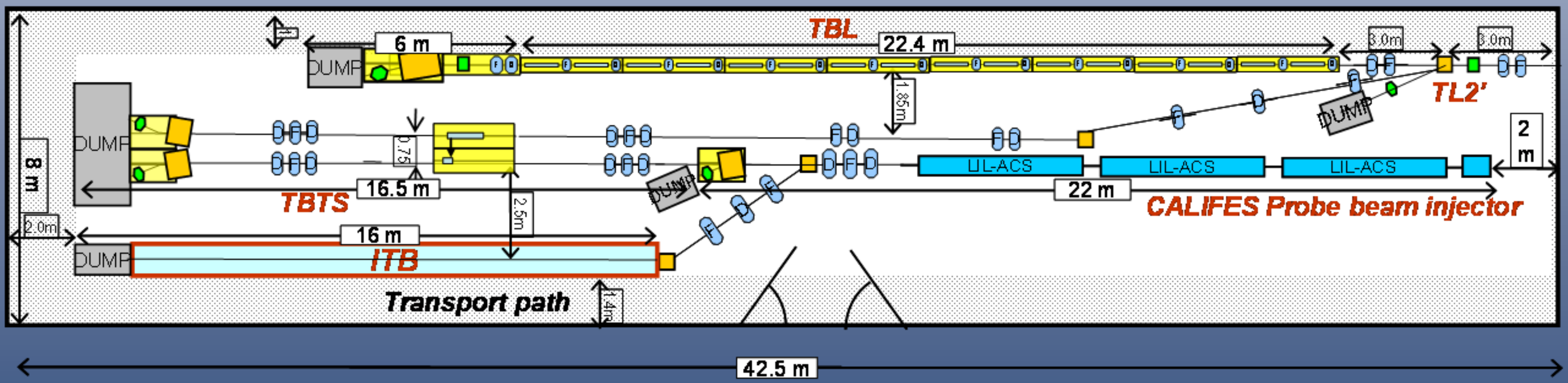
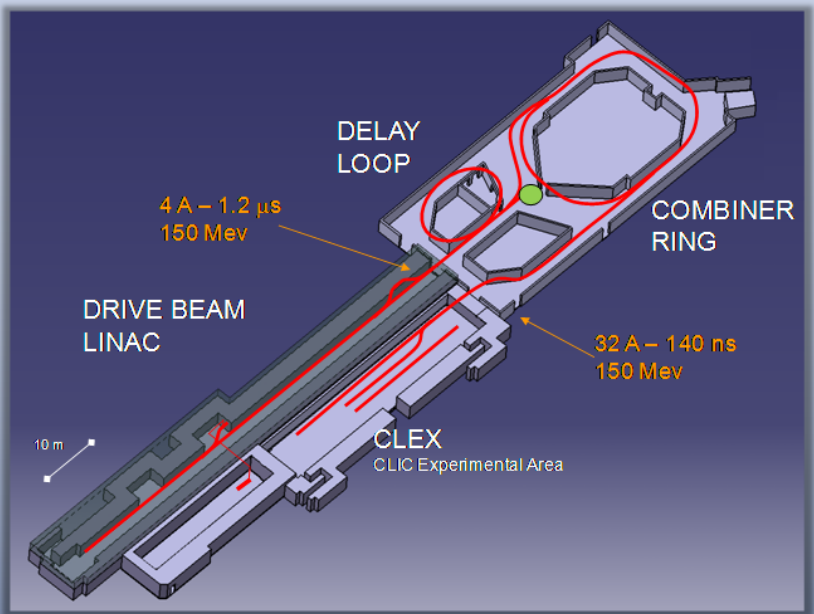


Transfer line 2 (TL2)



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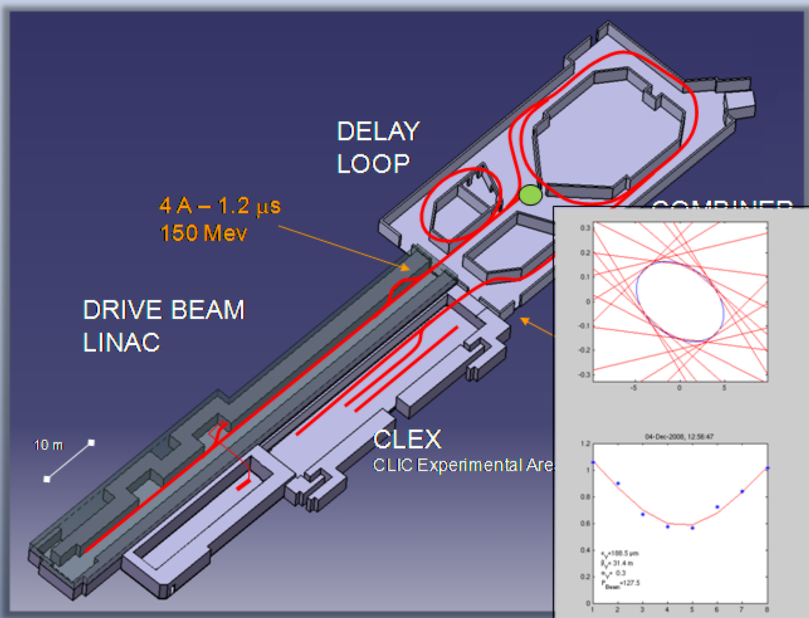

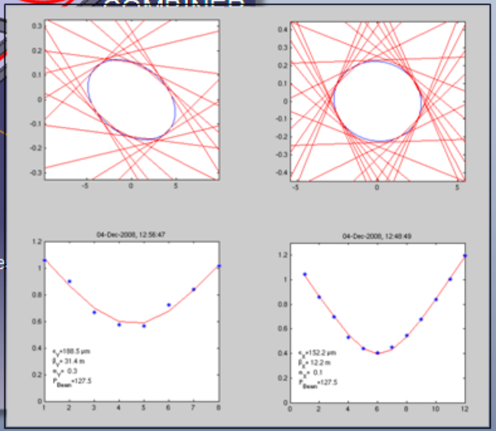

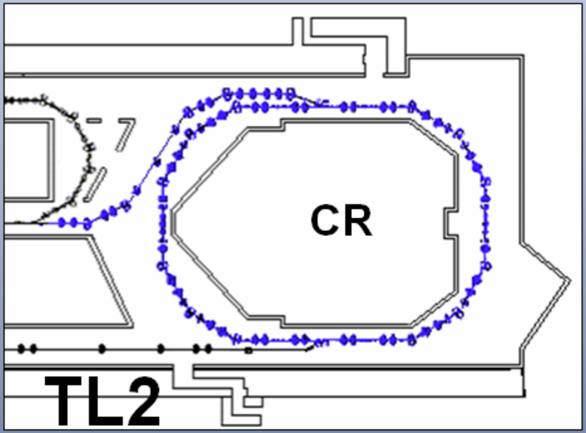

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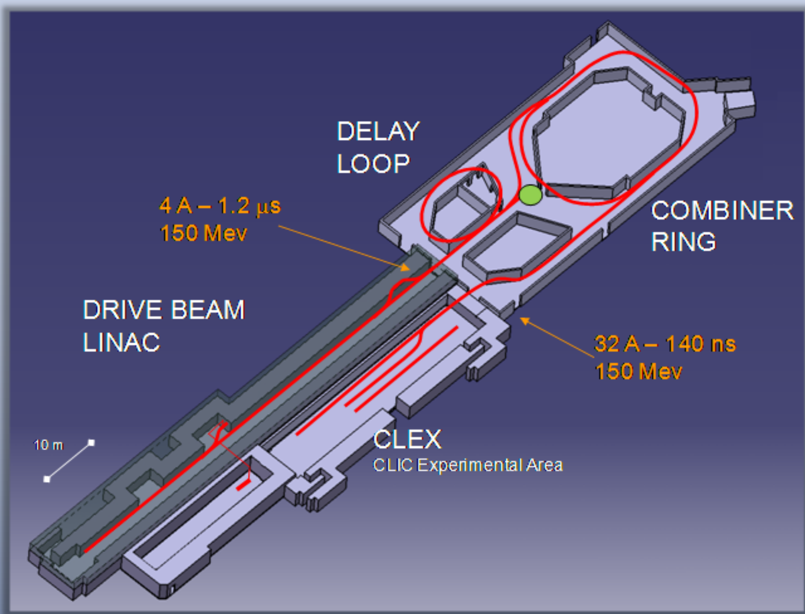
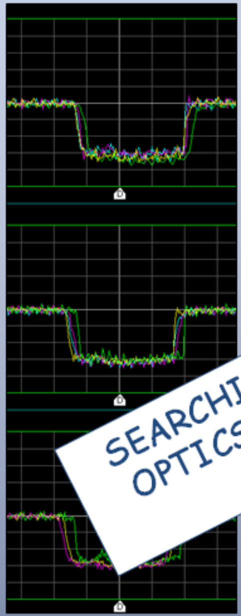
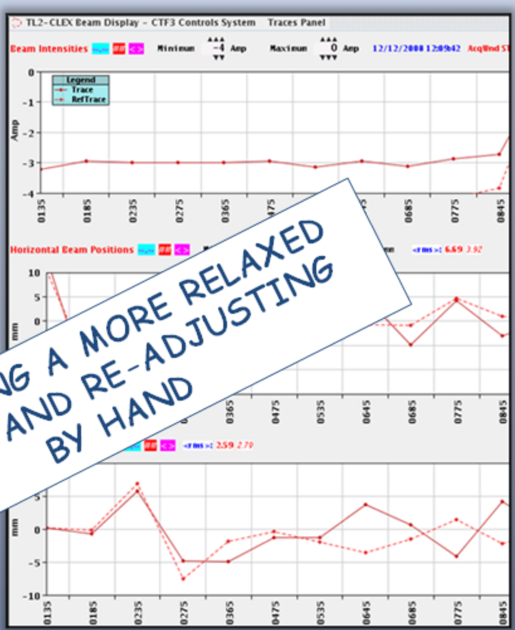
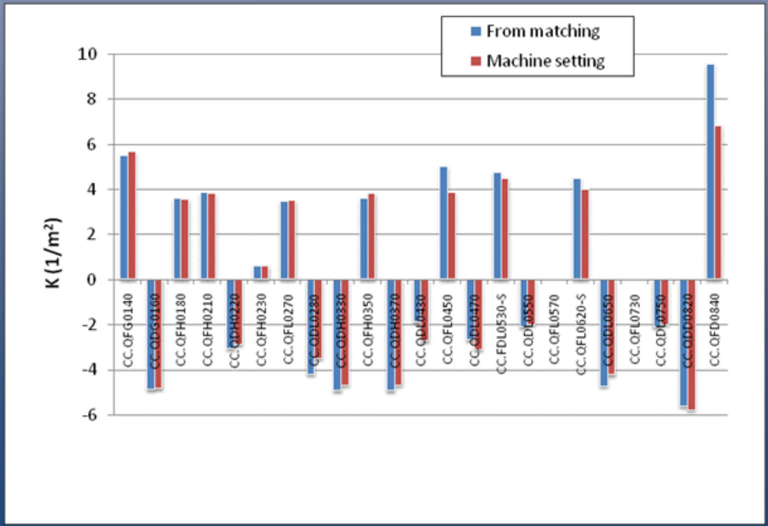


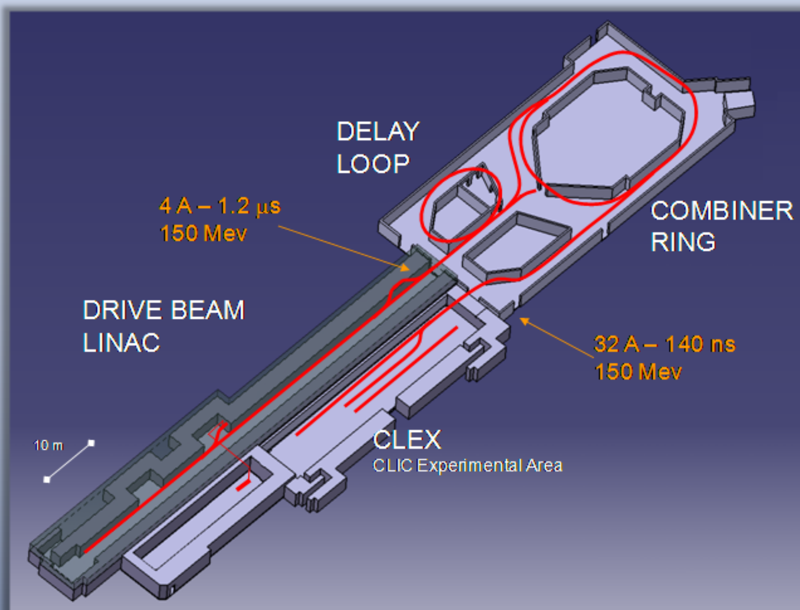


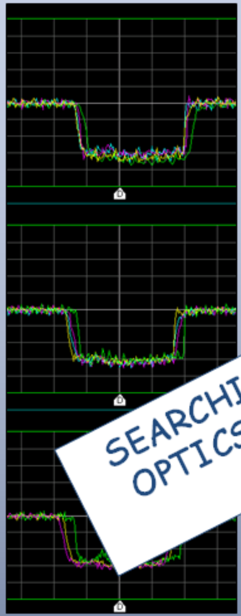


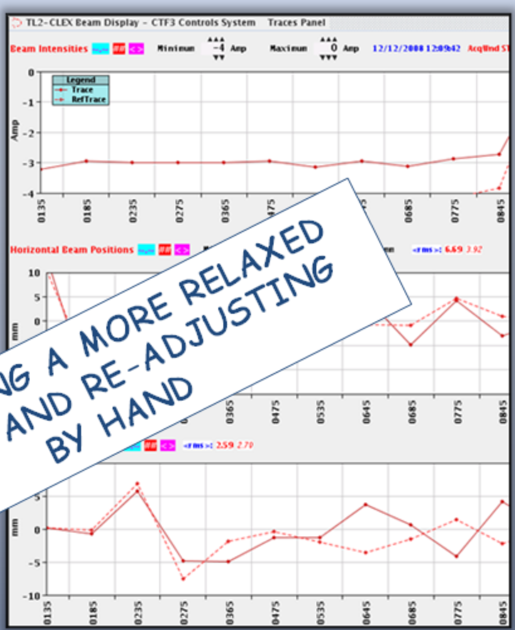
SEARCHING A MORE RELAXED OPTICS AND RE-ADJUSTING BY HAND



Transfer line 2 (TL2)







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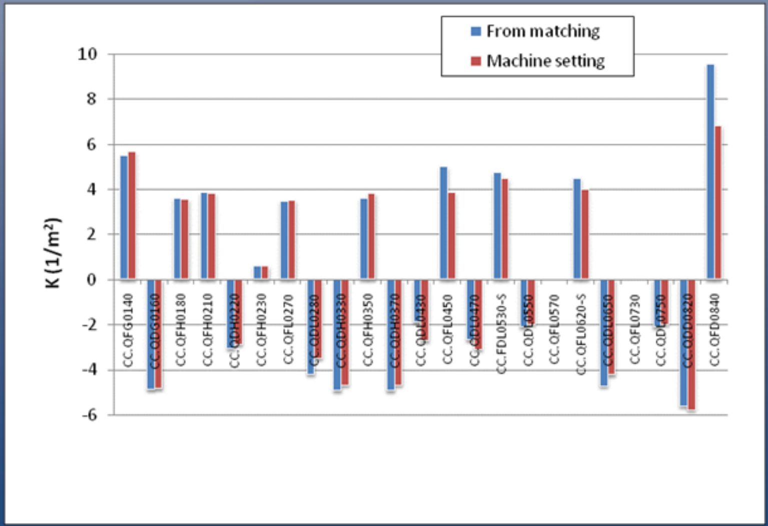

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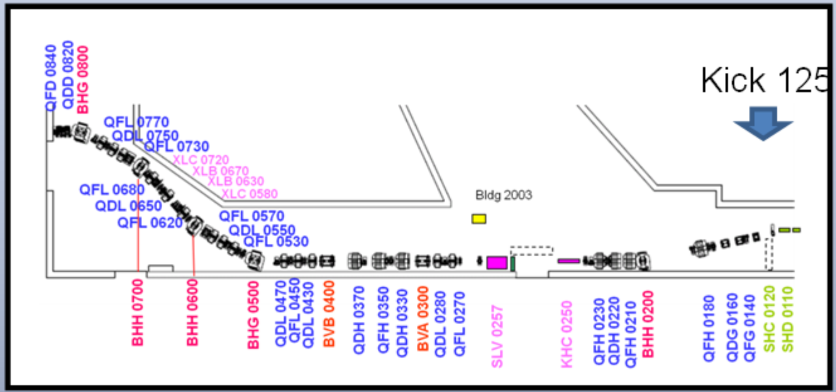

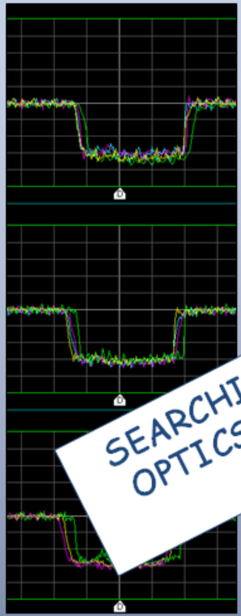

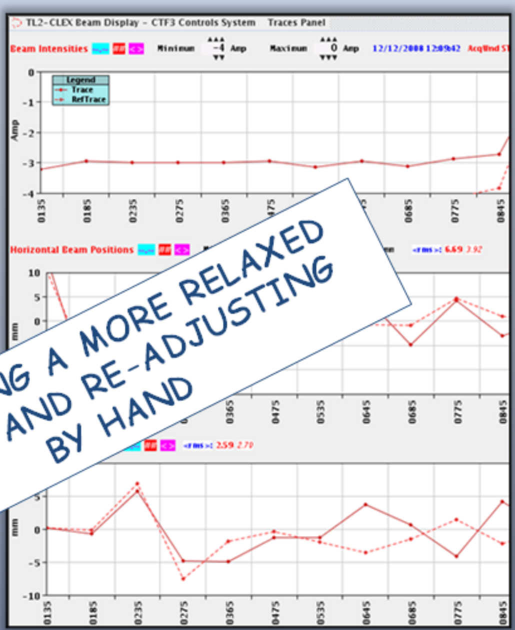

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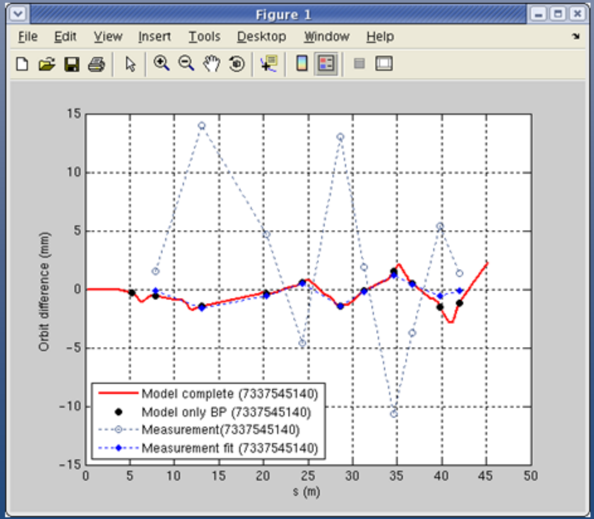

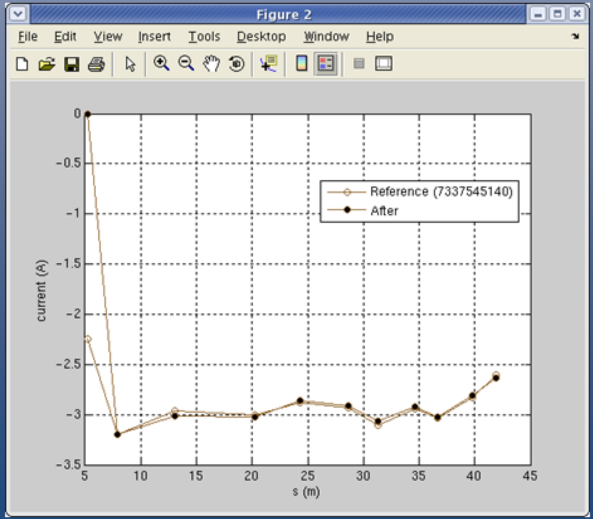

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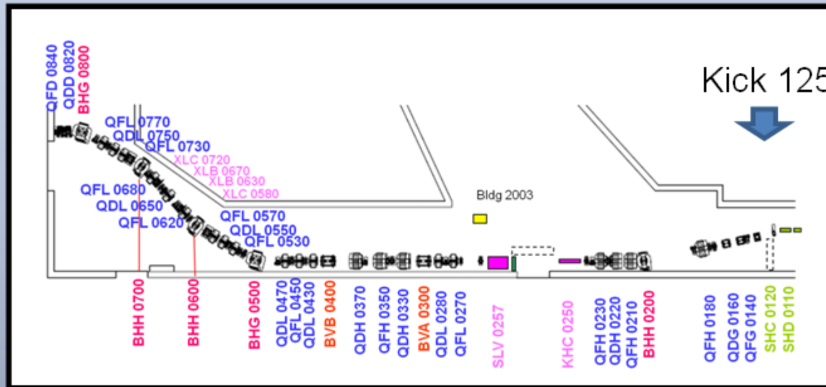

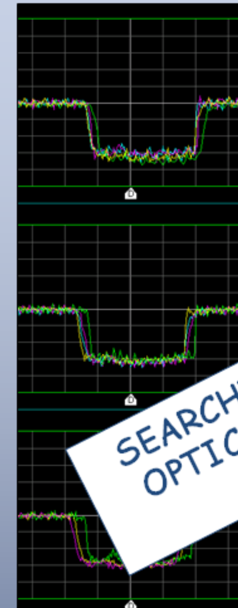

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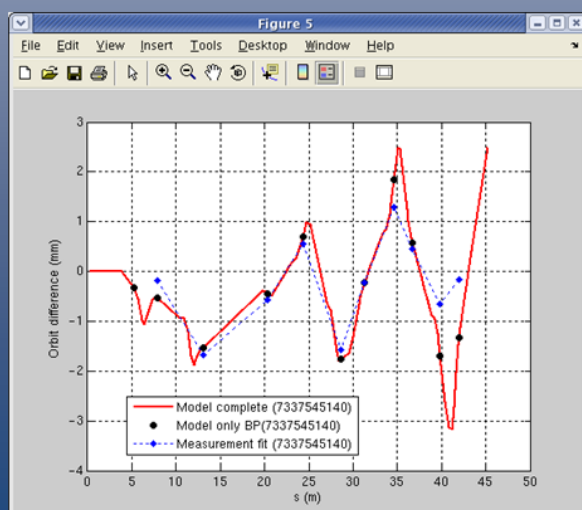

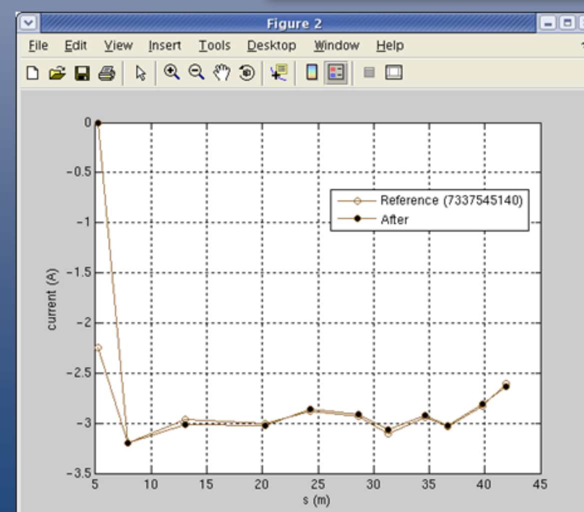

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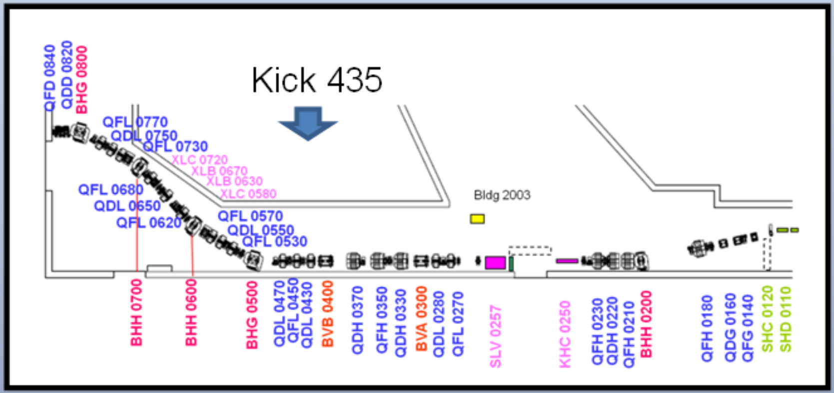

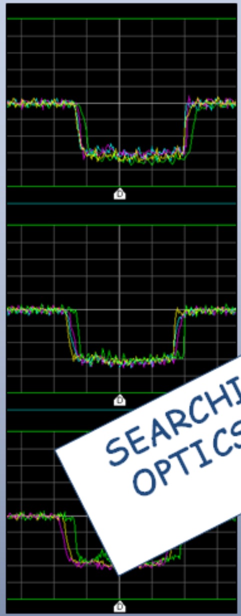

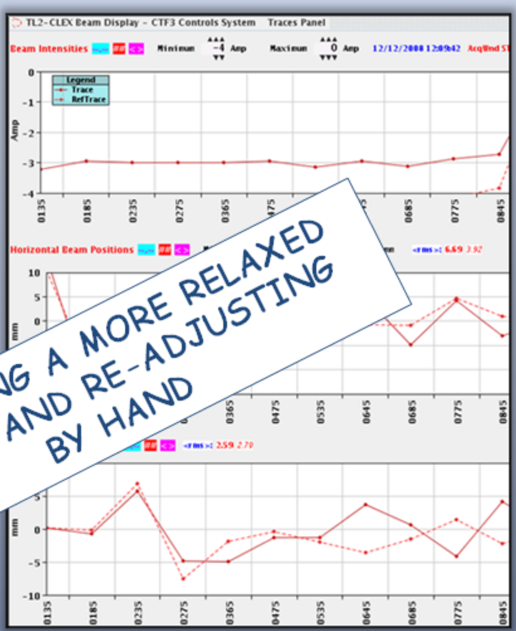

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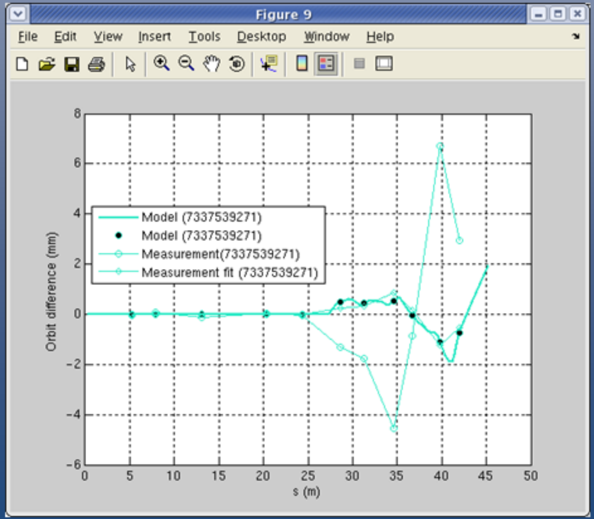

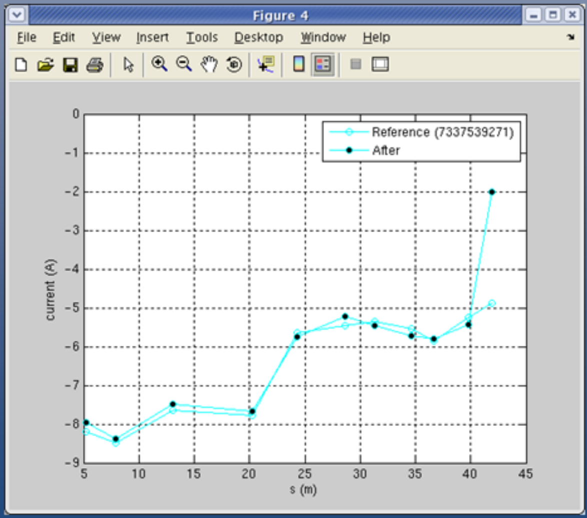

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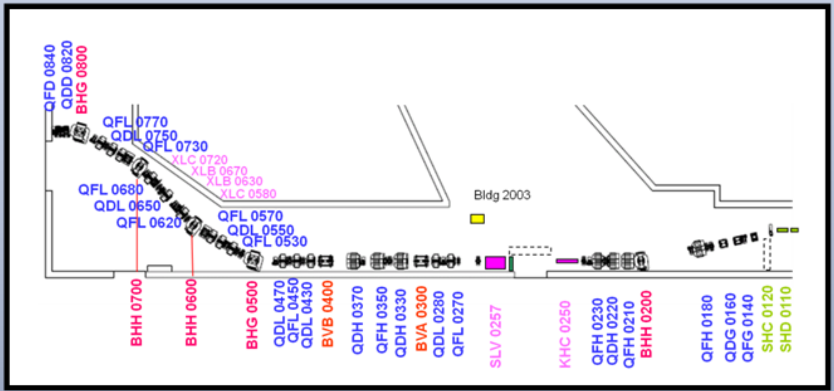

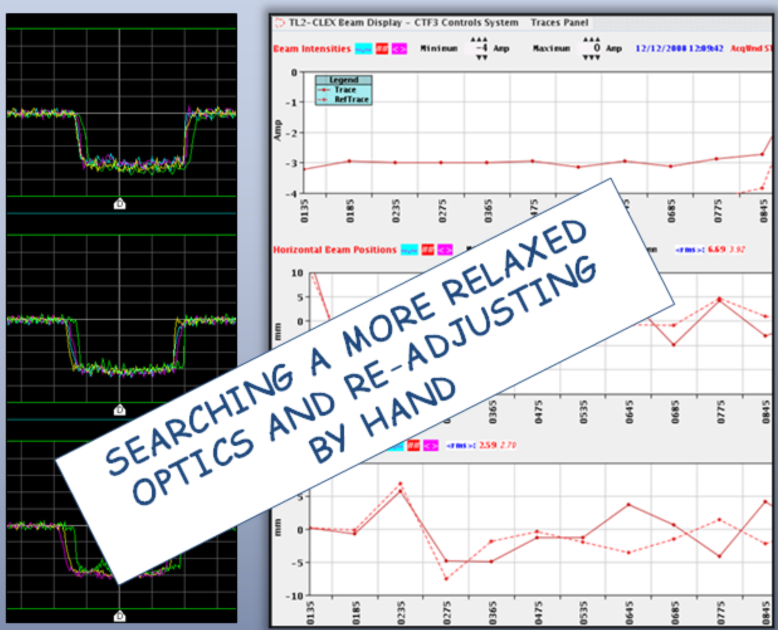

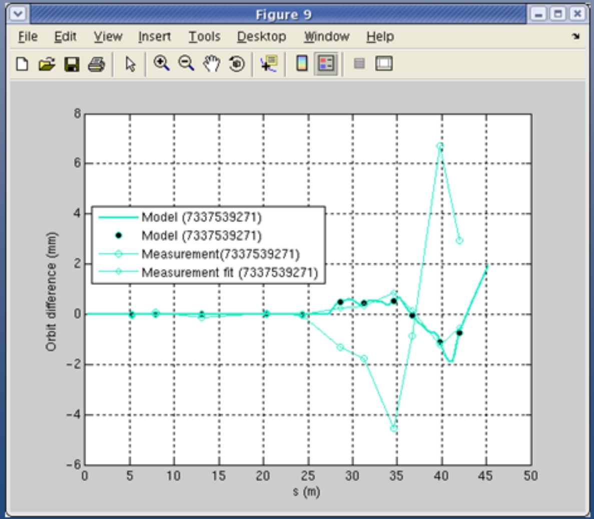

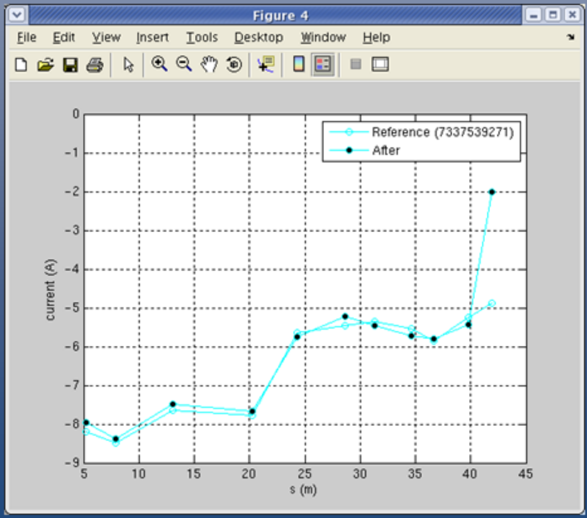

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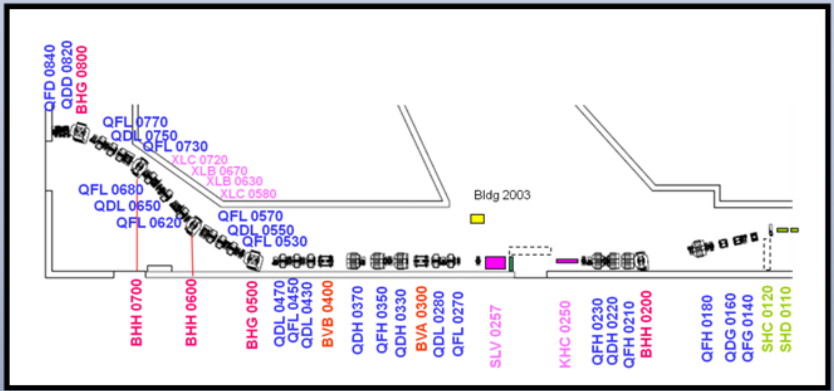

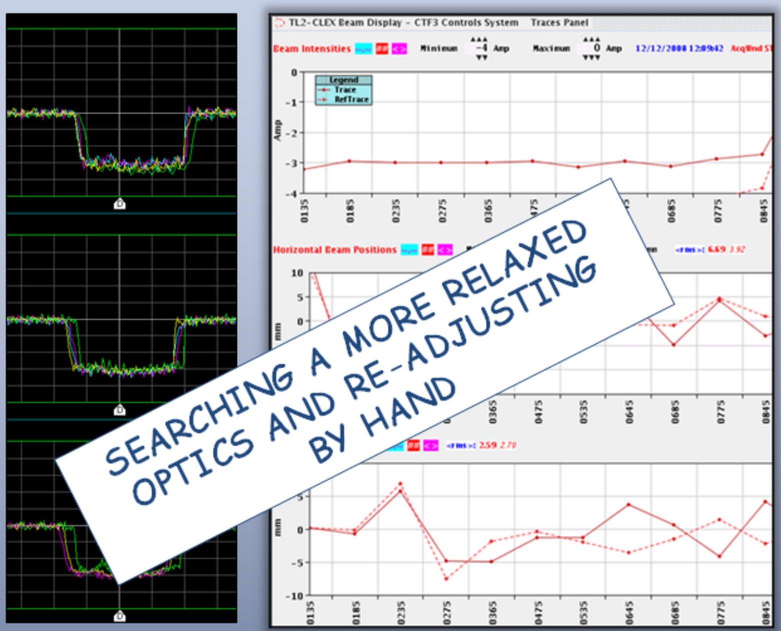

Steps of the commissioning:

- ✓ Beam transported to the end of the line with almost full transmission, BUT very difficult because no close MTV, new BPM electronics, bug in a quadrupole, …
- ✓ First kick measurements didn’t evidence huge model/machine discrepancies

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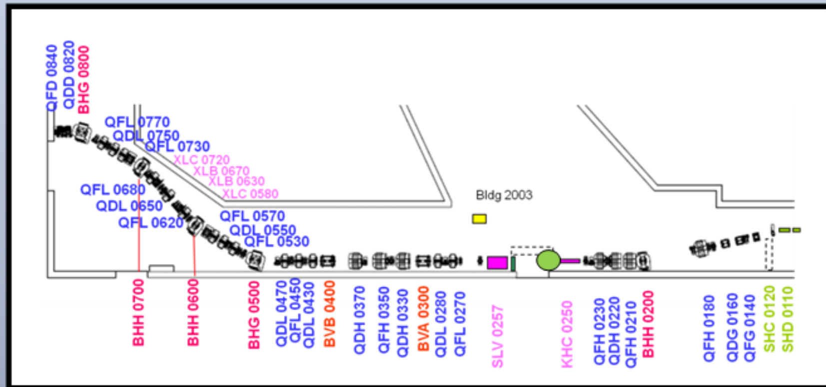

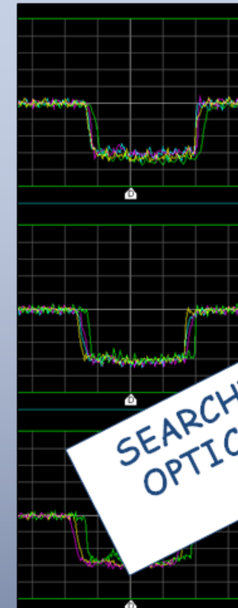

Steps of the commissioning:

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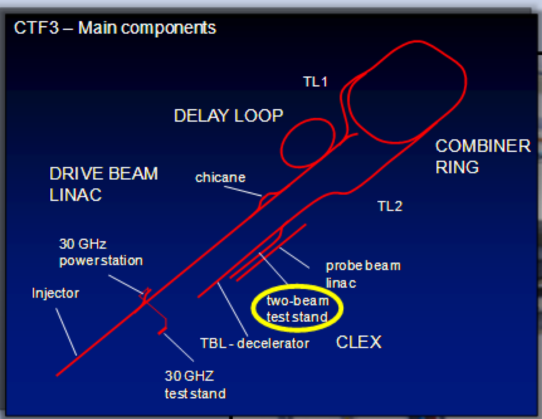
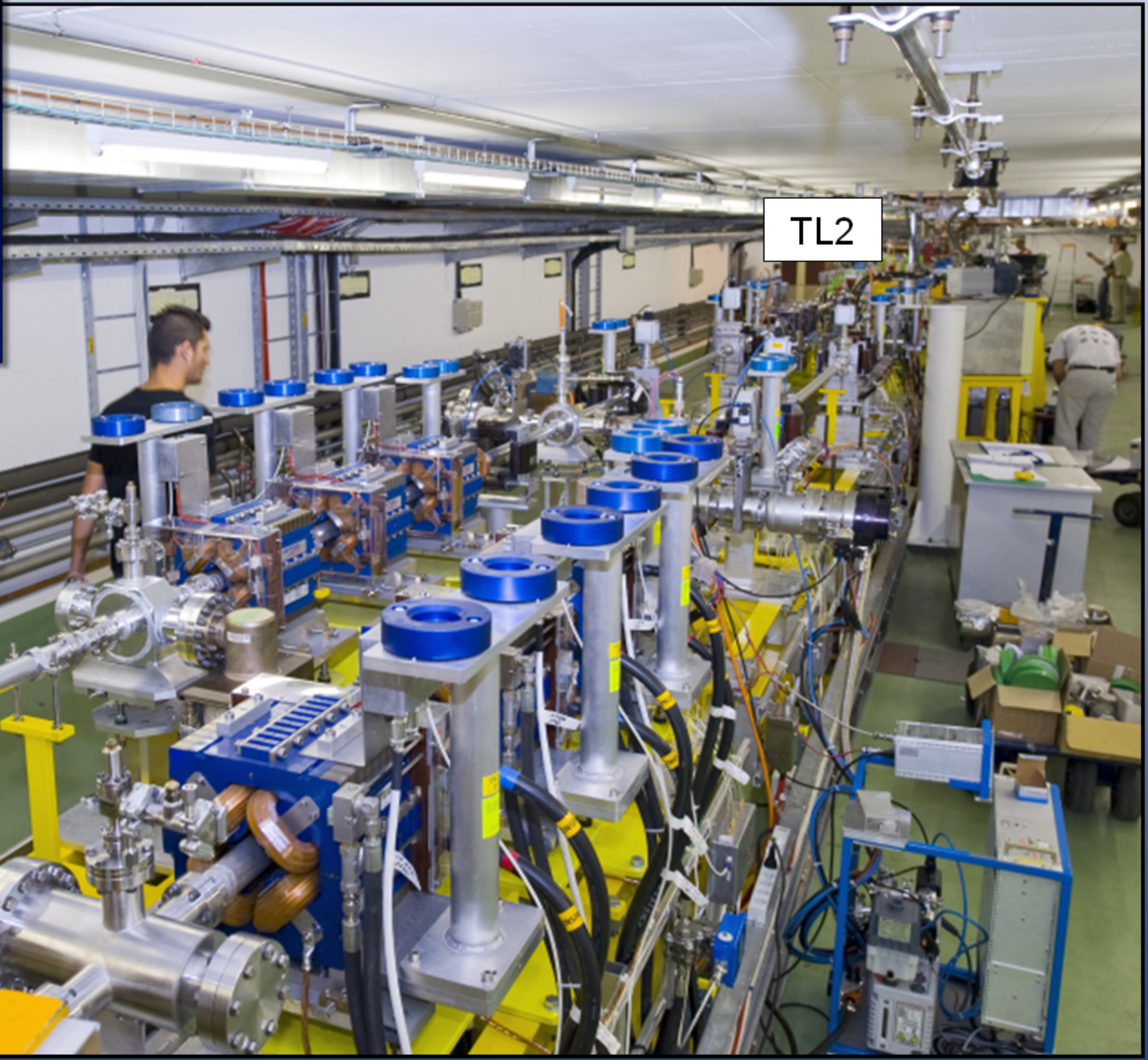
- ✓ During the 2008/2009 winter shut down new MTV installed

Two beam Test Stand (TBTS) line





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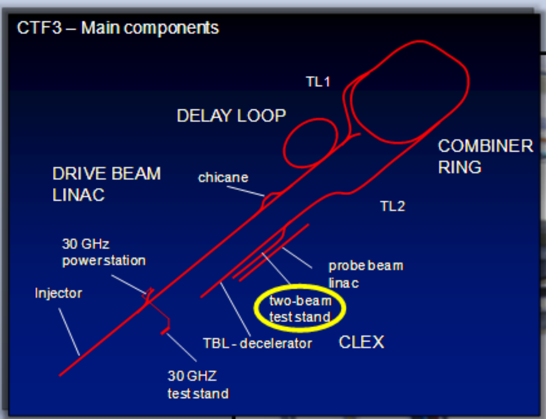

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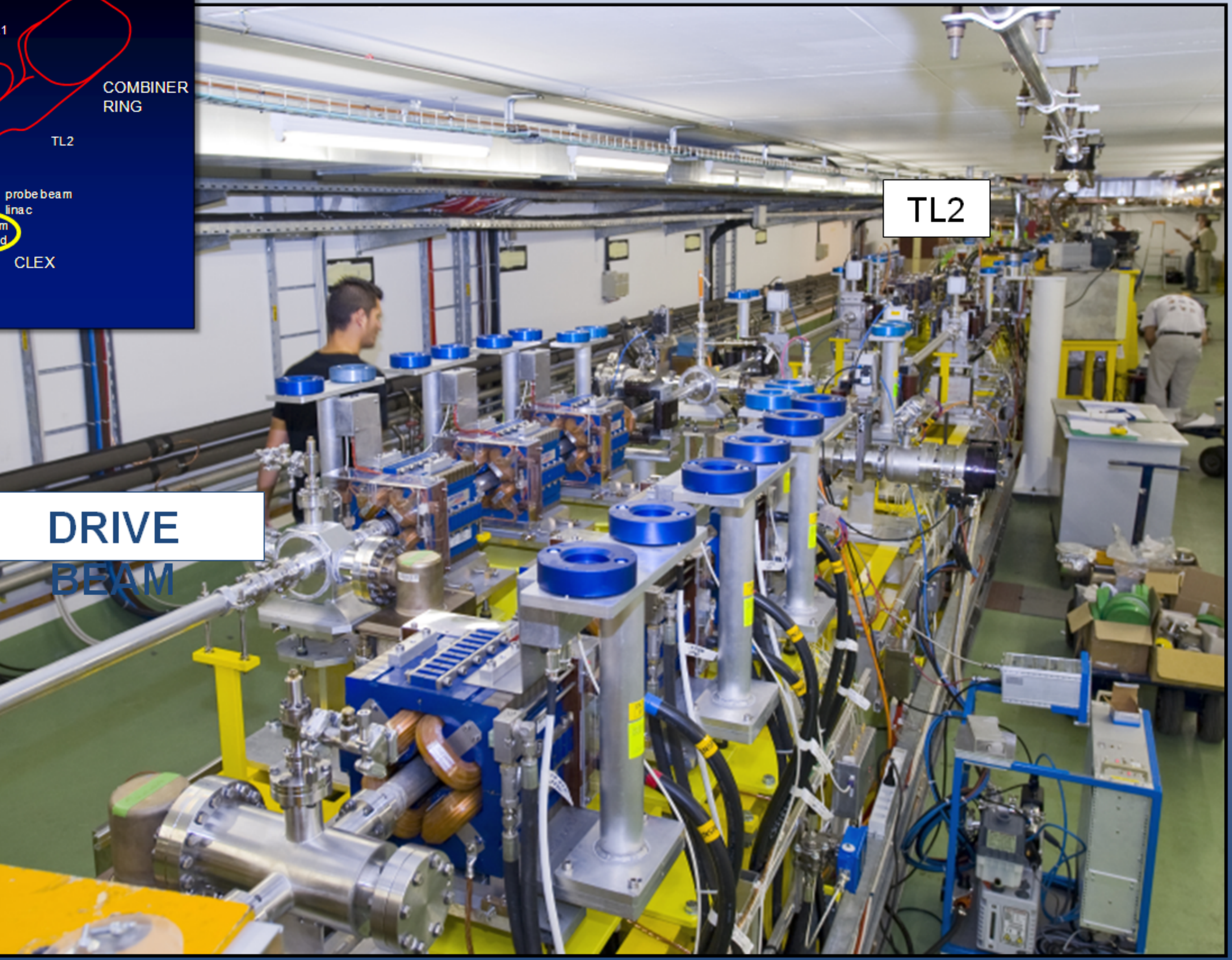

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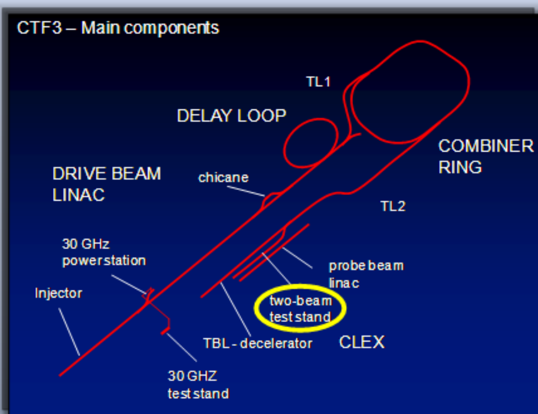

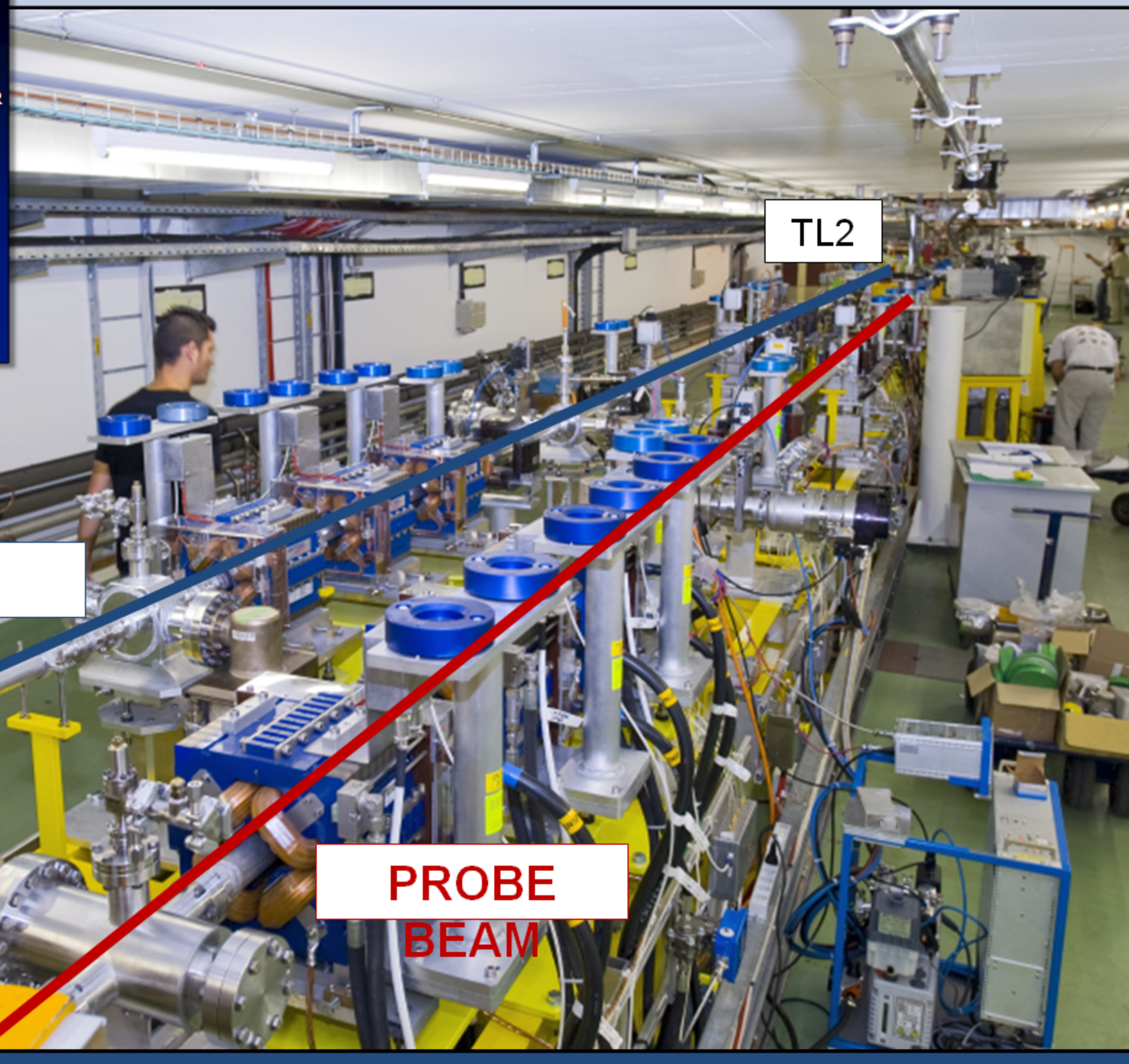

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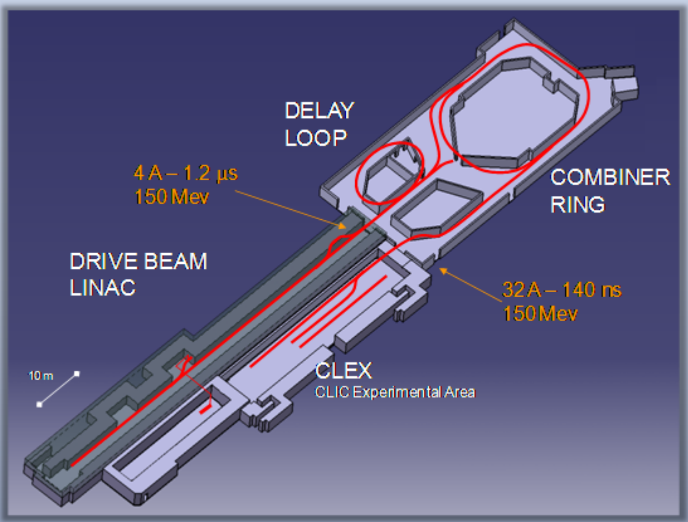
The recirculation mechanism



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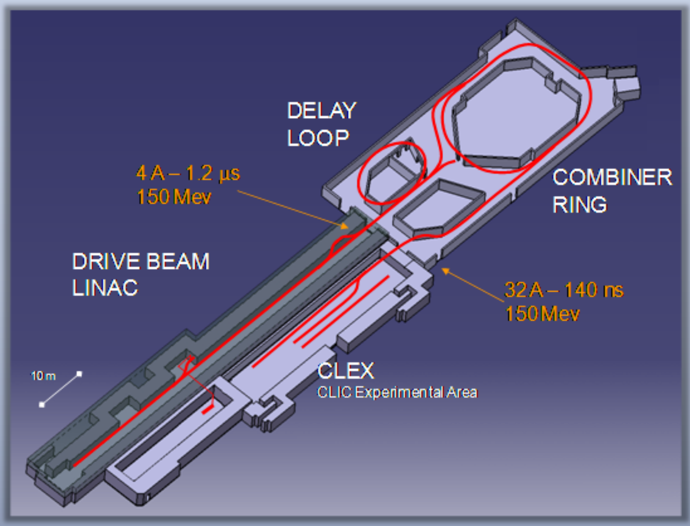

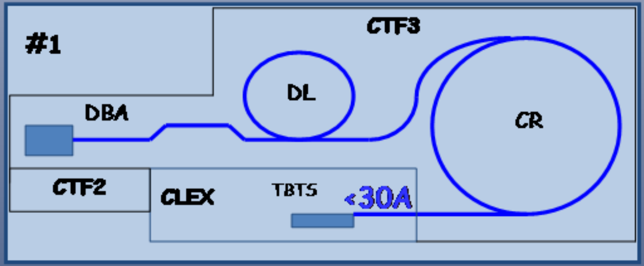

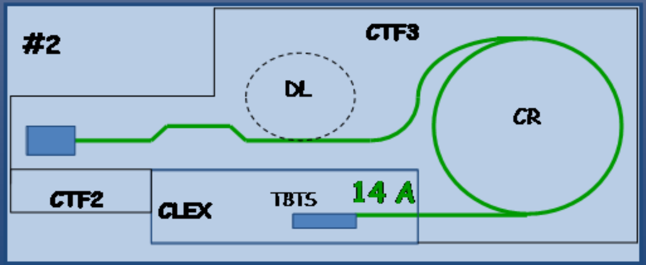

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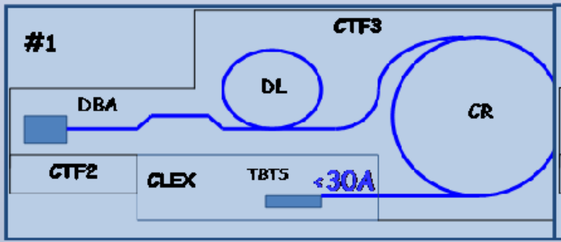

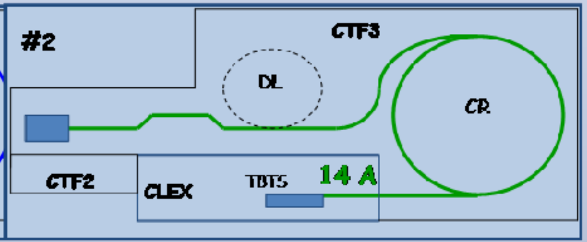

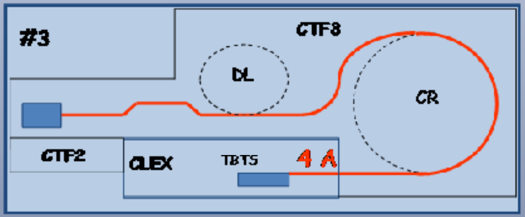

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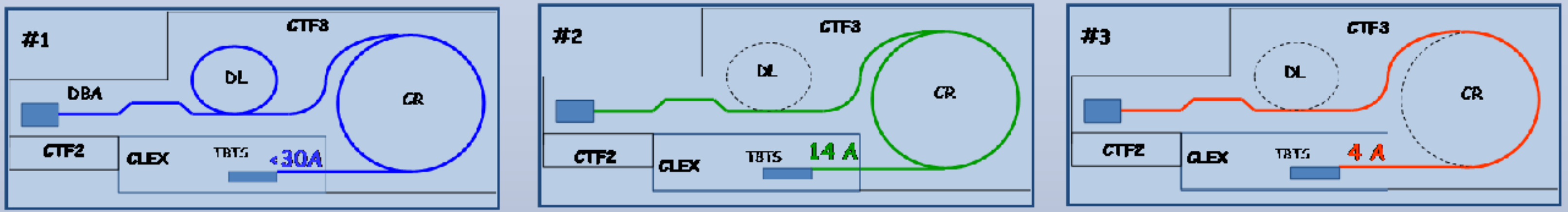
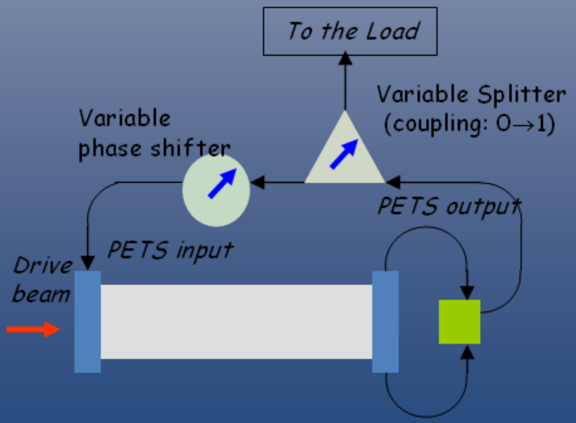


ONLY THE OPERATION MODE #1 WOULD ALLOW TO PRODUCE THE CLIC NOMINAL POWER (22 A TO GENERATE 136 MW)

RECIRCULATION→ A FRACTION OF THE POWER PRODUCED IS SENT BACK TO THE SAME STRUCTURE



2008 milestones: first beam through PETS

Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)

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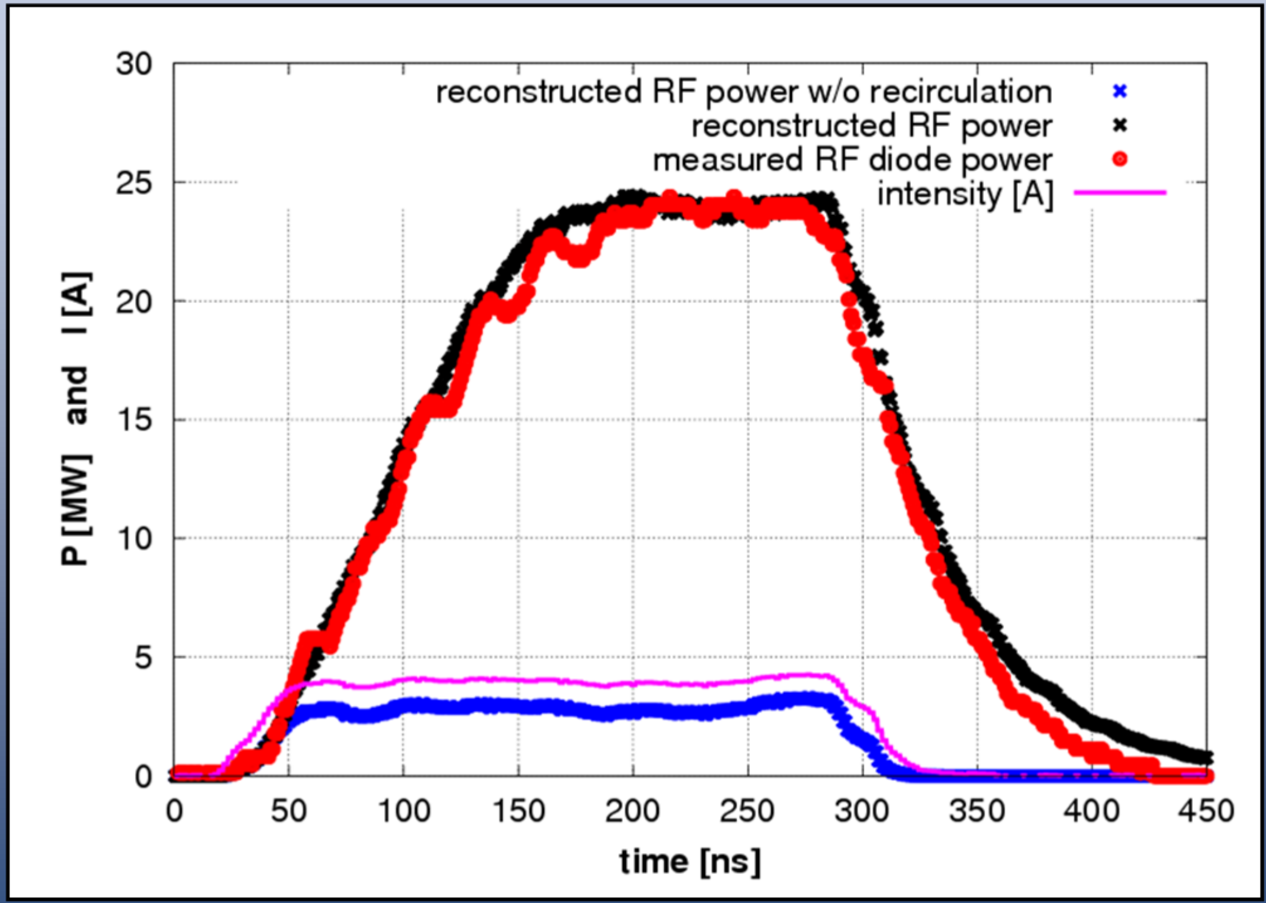
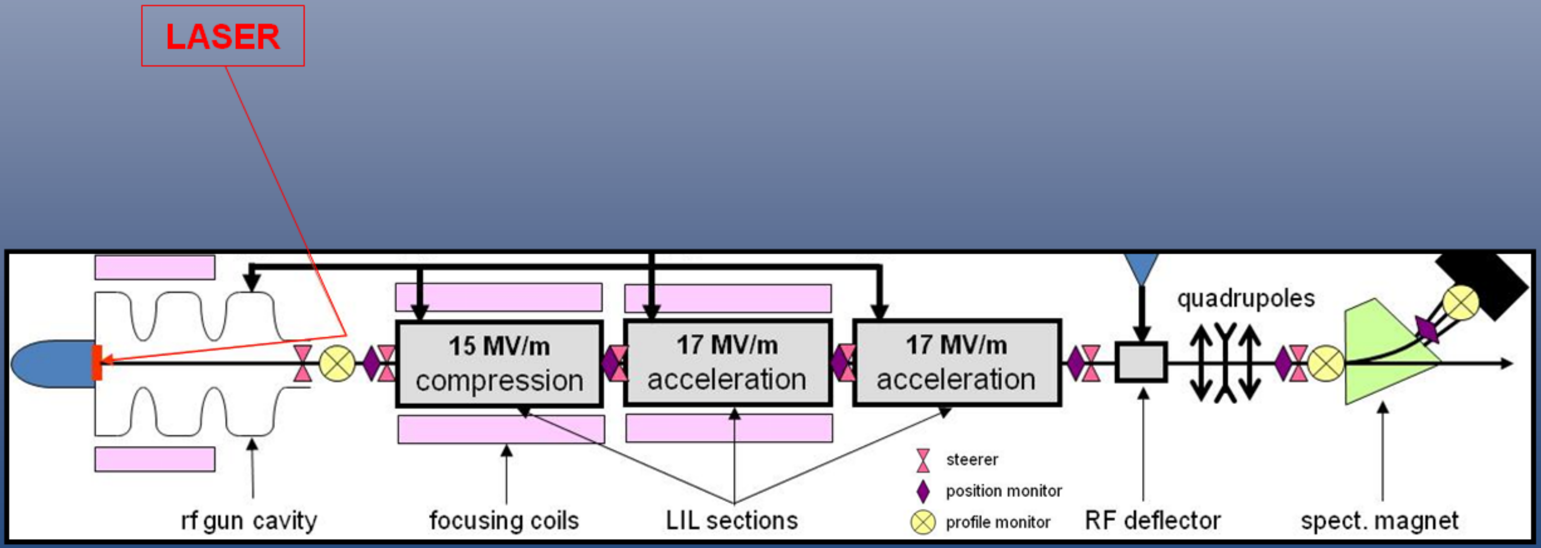


E. Adli. "Analysis of the first 12 GHz PETS tests with beam using a constant parameter recirculation model". CERN-CTF3 Note 096.

CALIFES


CTF3 – Main components
TL1
DELAY LOOP
COMBINER RING
DRIVE BEAM LINAC
chicane
TL2
30 GHz power station
probe beam linac
Injector
two-beam test stand
TBL - decelerator
CLEX
30 GHZ test stand


LASER
15 MV/m compression
17 MV/m acceleration
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steerer
position monitor
profile monitor
rf gun cavity
focusing coils
LIL sections
RF deflector
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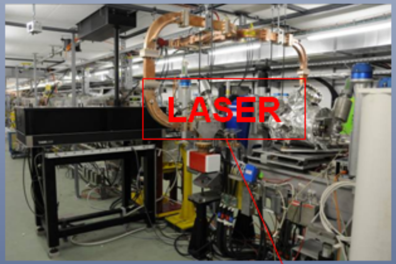

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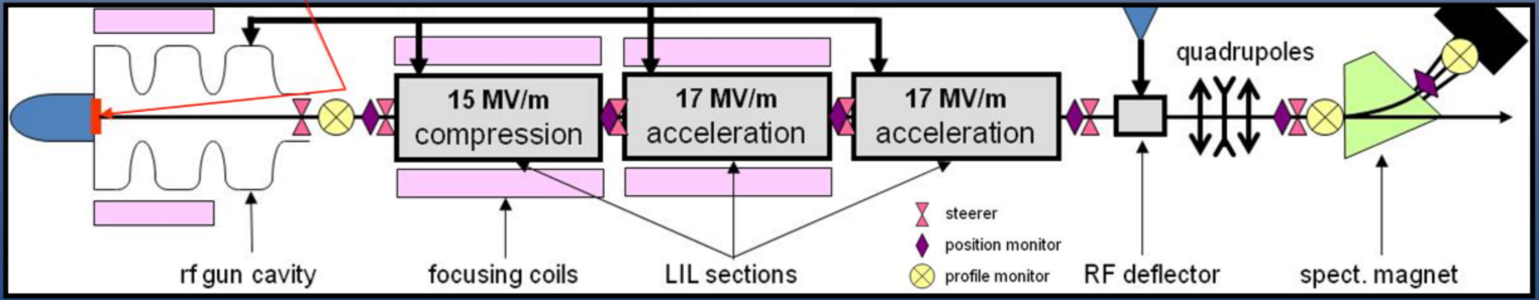

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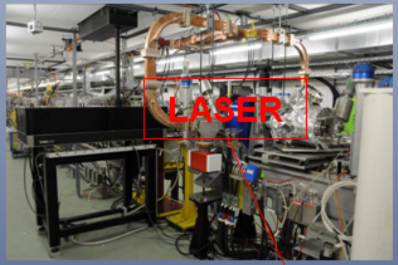
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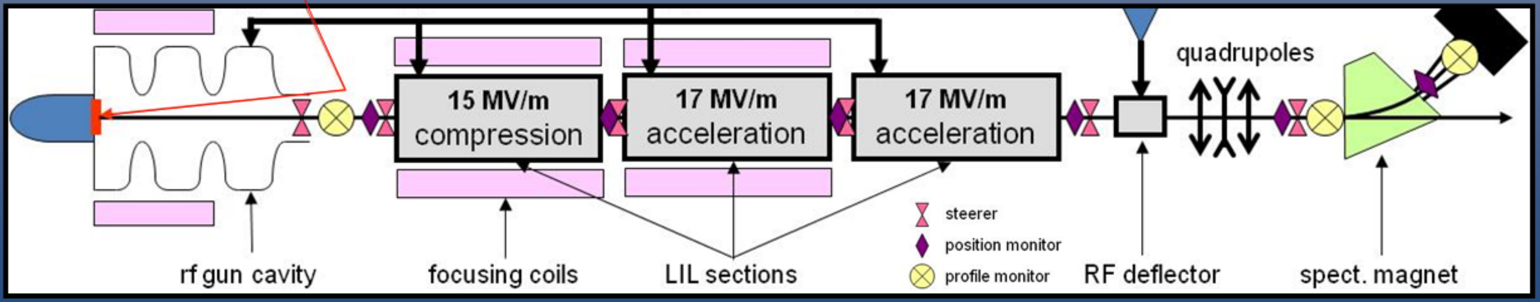
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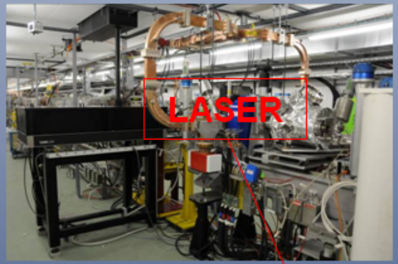
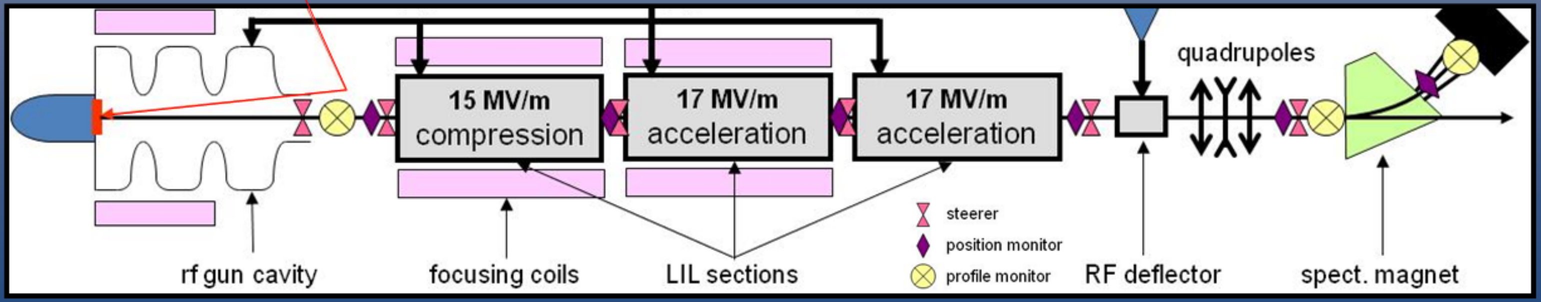
CALIFES

Steps of the commissioning:

- ✓ Time: one week in December 2008 + April 2009





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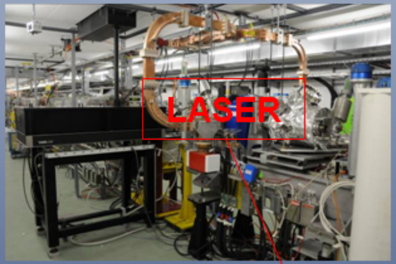

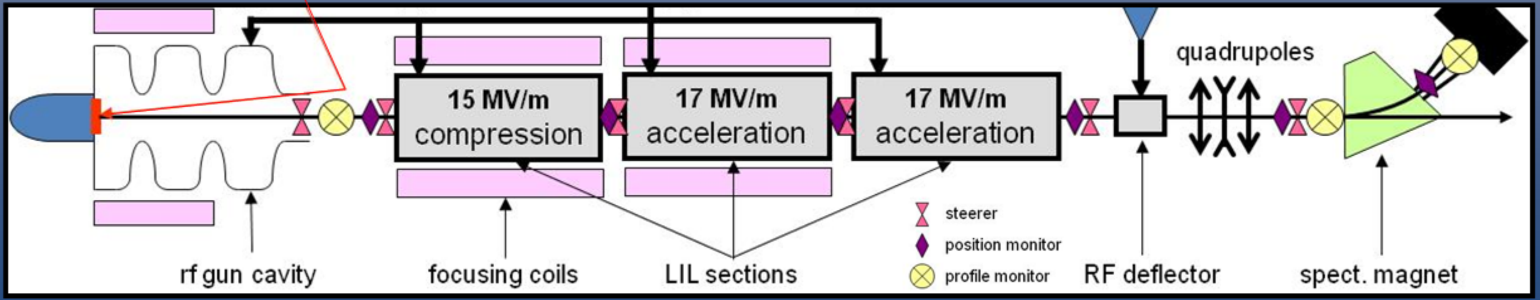

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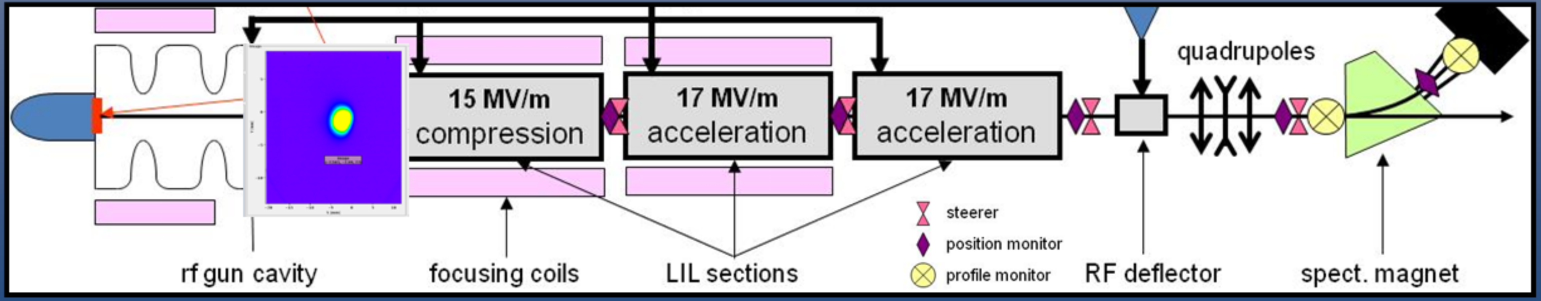

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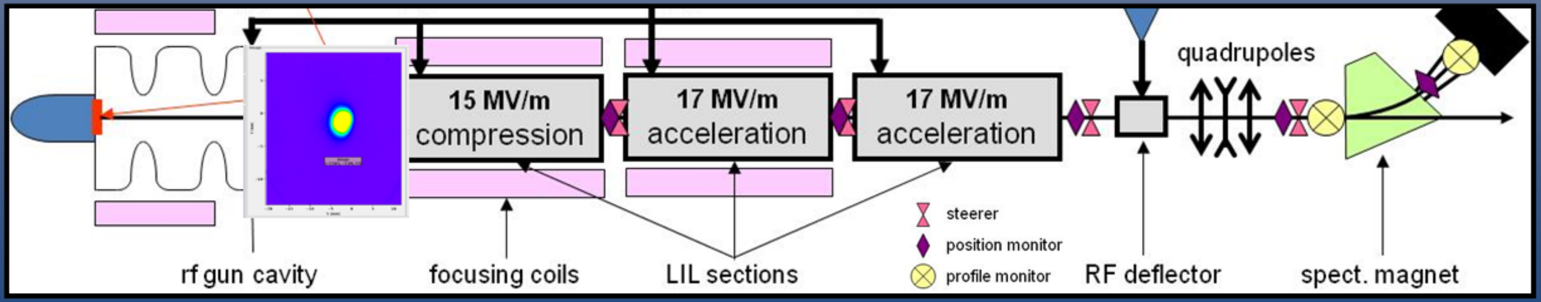

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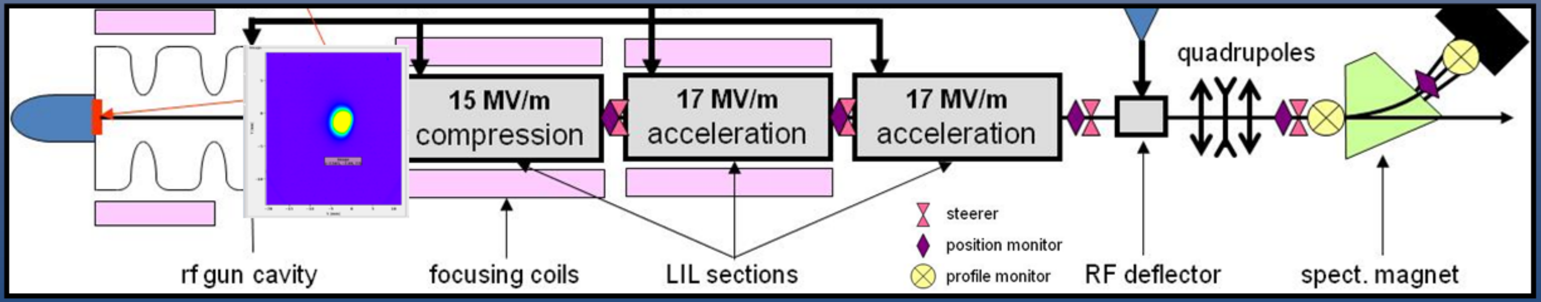

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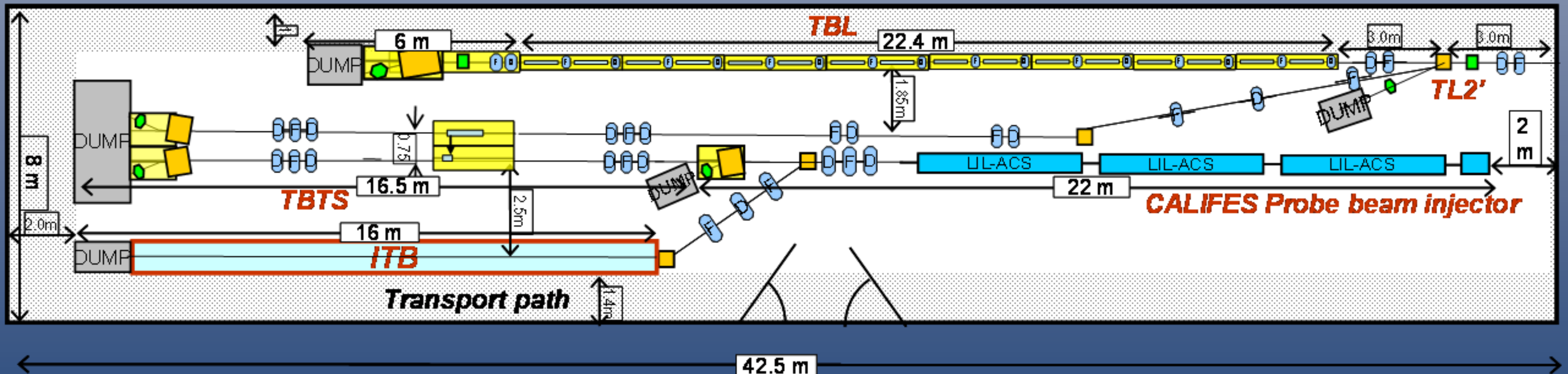

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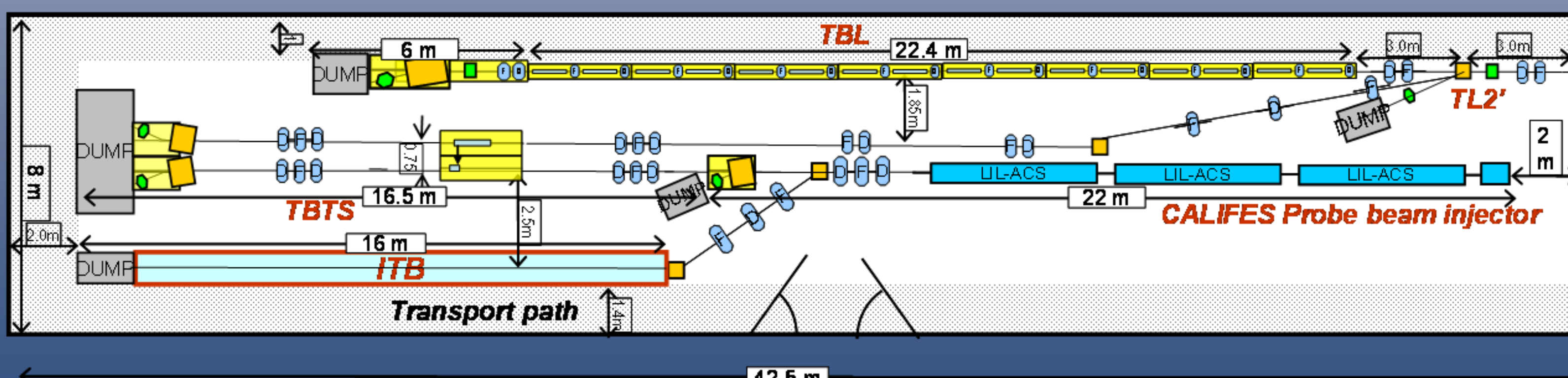
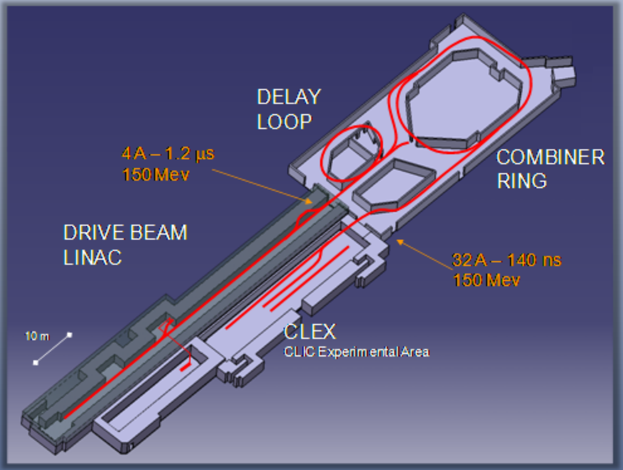


Drive beam generation



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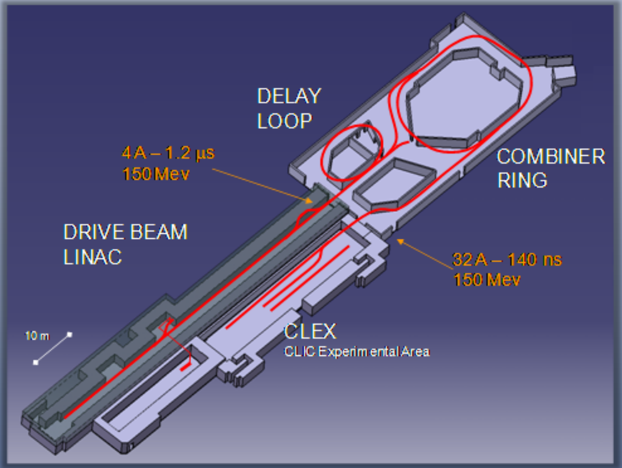

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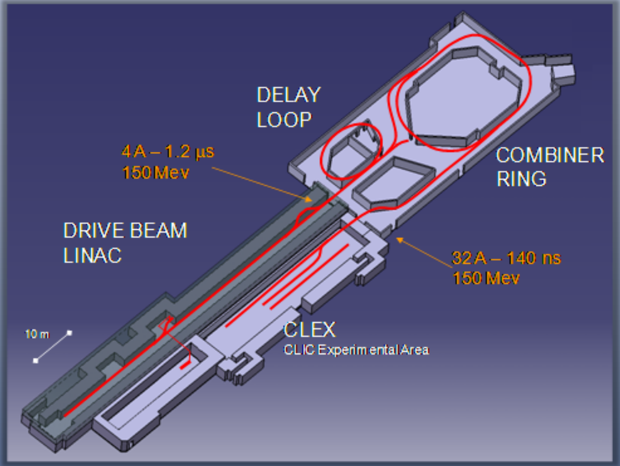

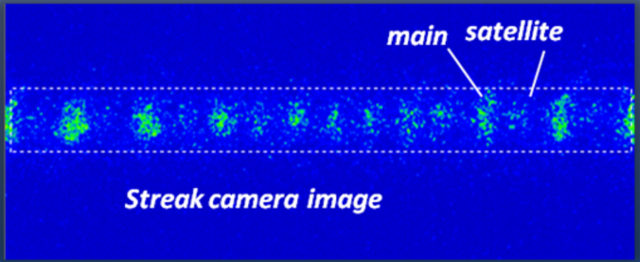

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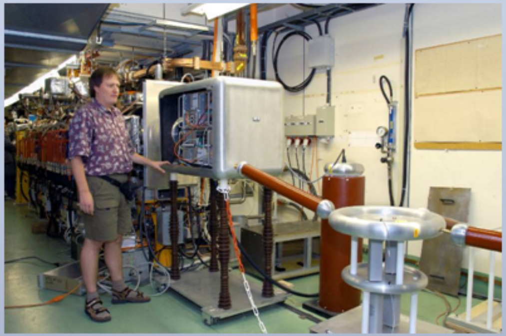

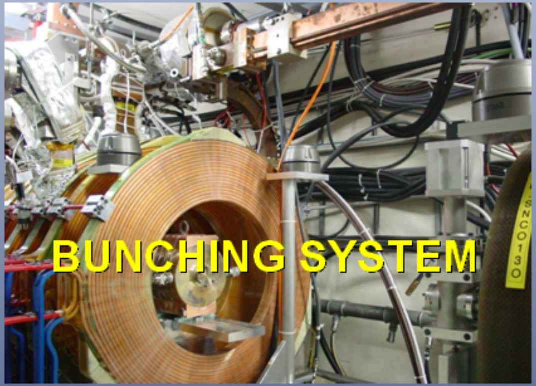

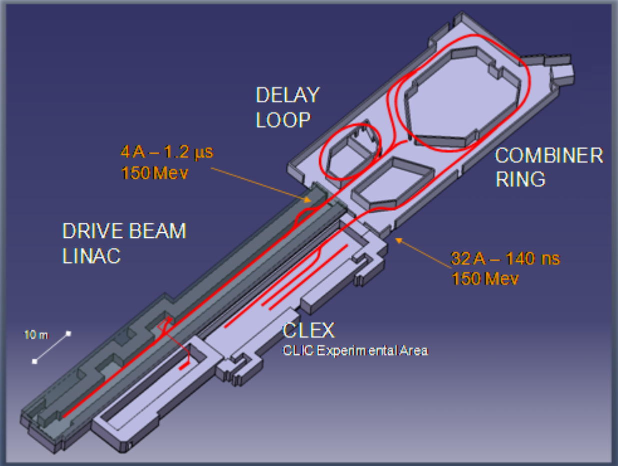

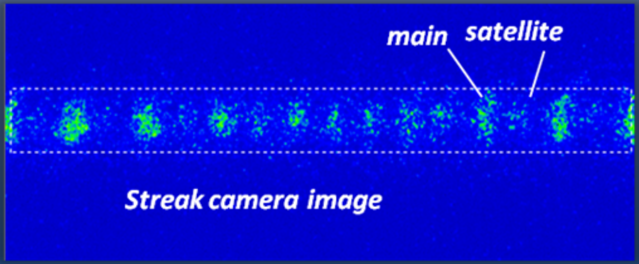

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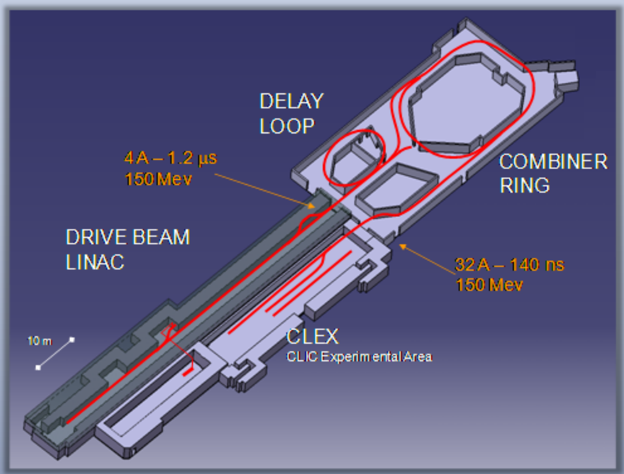

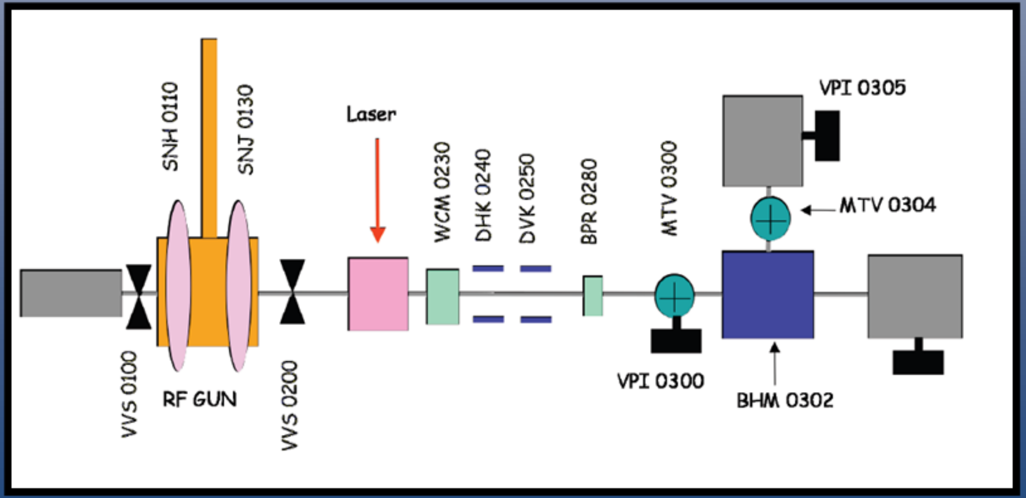

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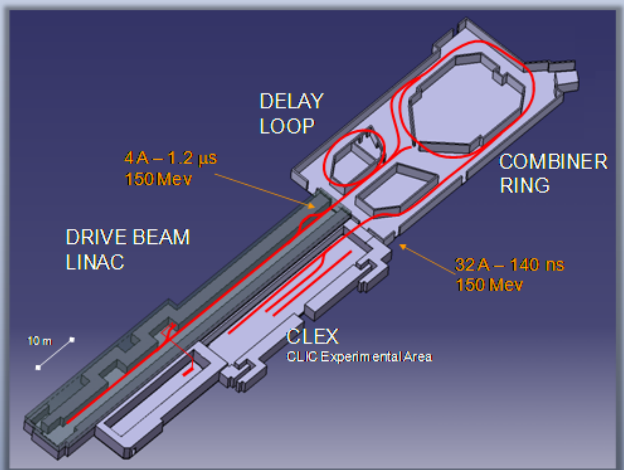

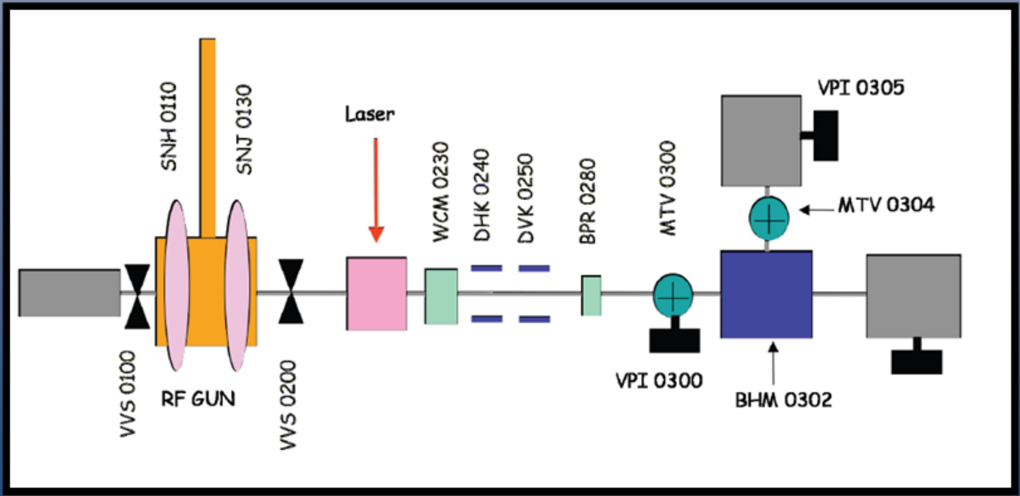

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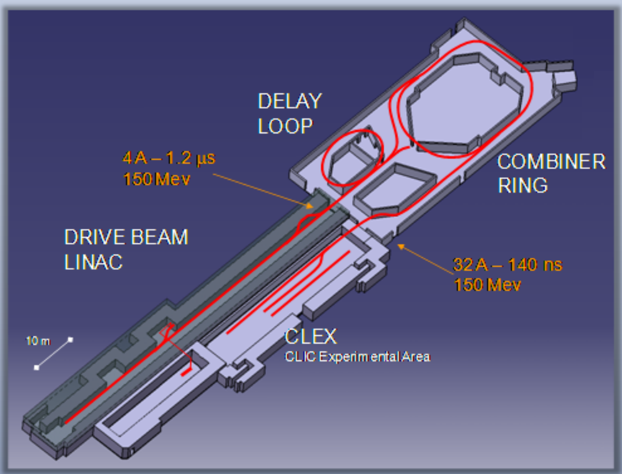

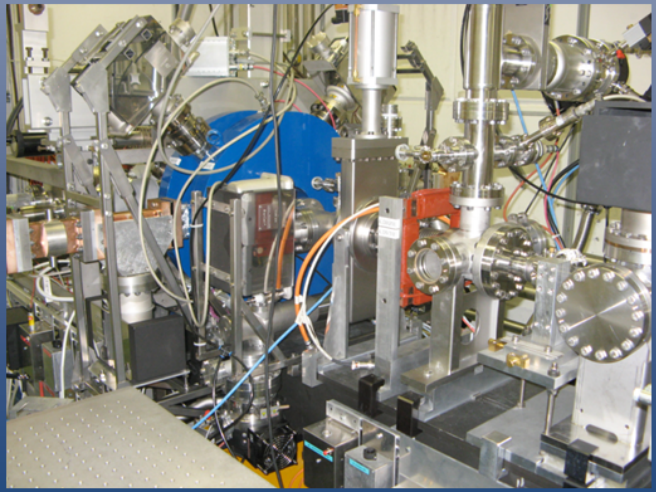

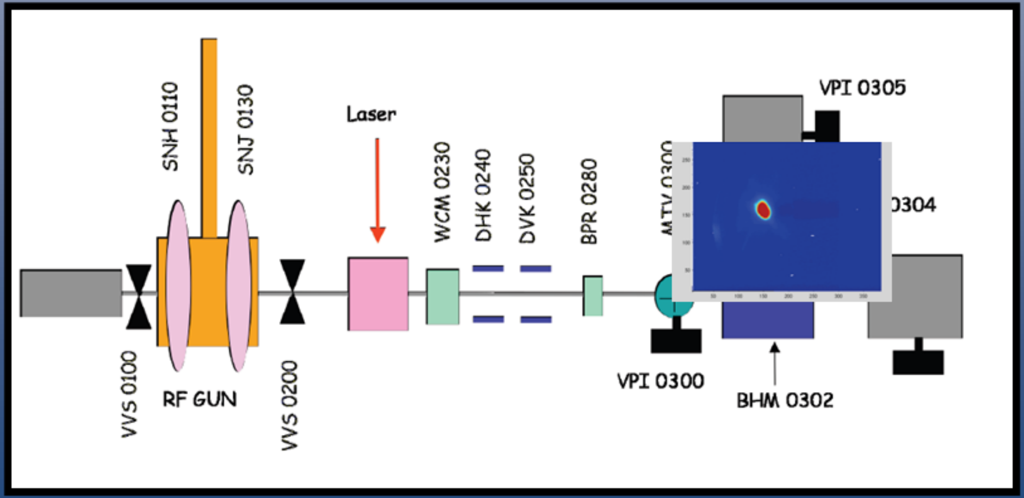

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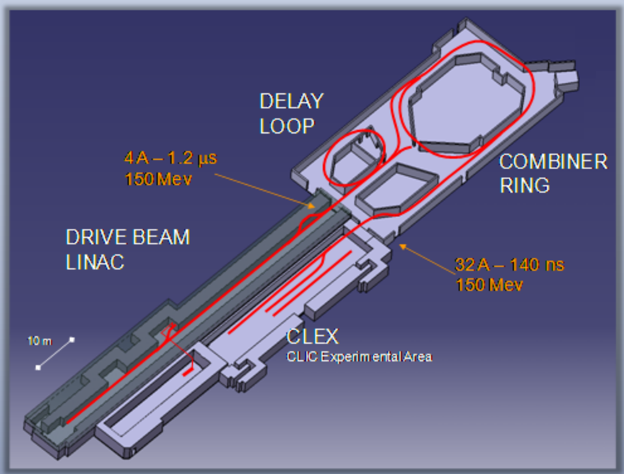
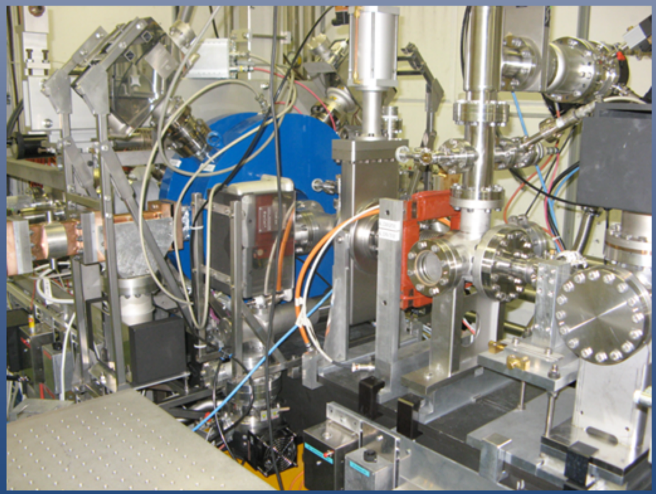
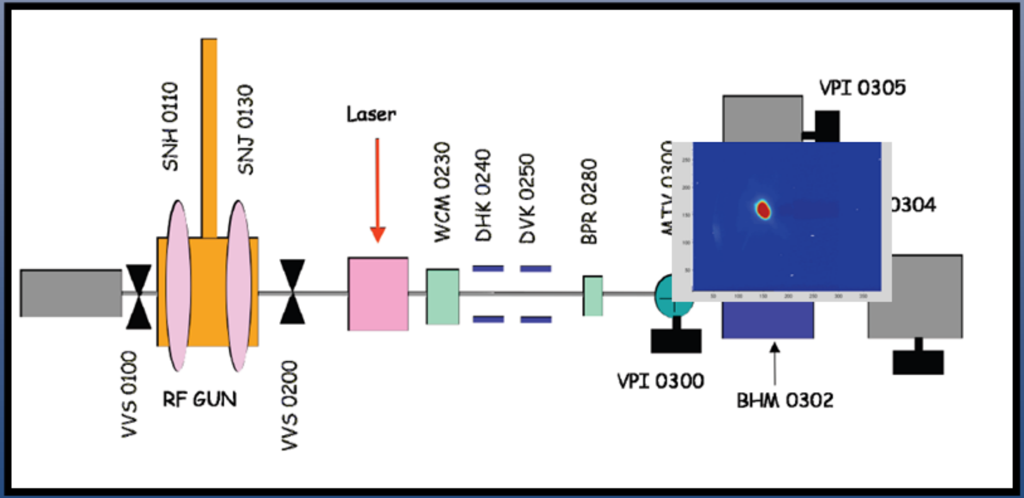
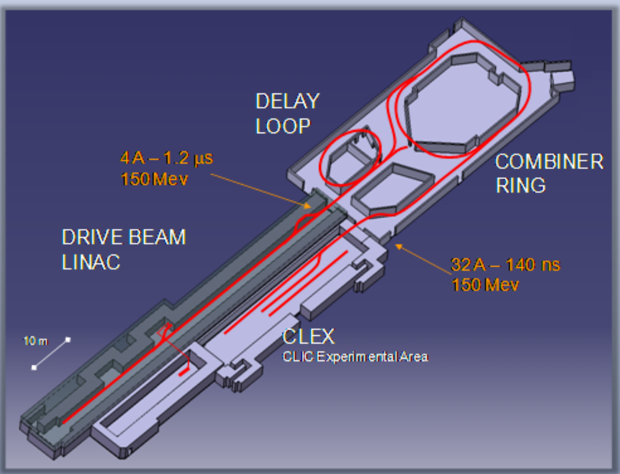




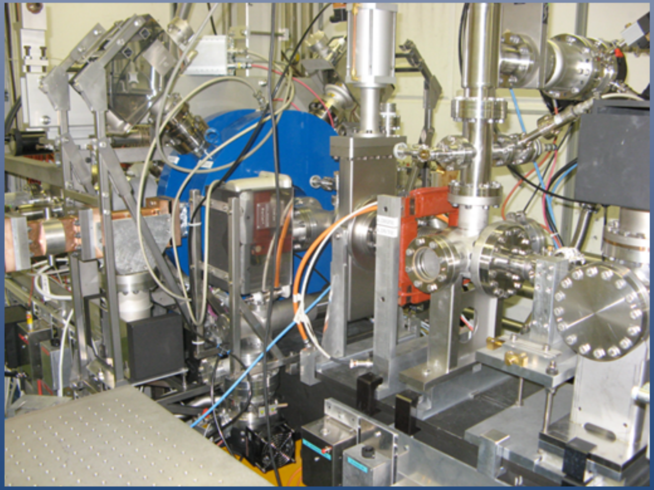


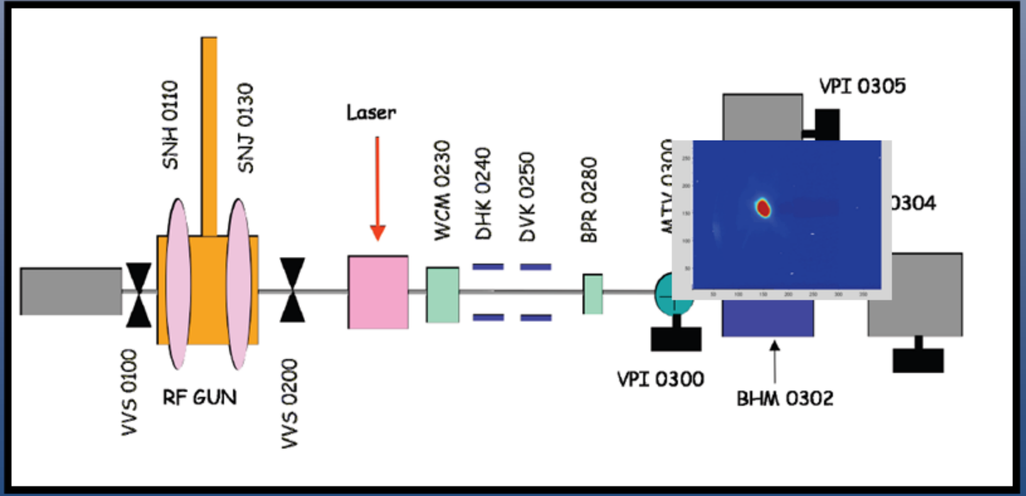
Drive beam generation

	Design	Measured
RF frequency (GHz)	2.9985	2.9985
Beam energy (MeV)	5-6	5.3
Number of bunches	1908	>1908
Charge per bunch (nC)	2.3	2.3
Normalized emittance (π mm . mrad)	< 25	< 25
Quantum Efficiency (Cs_2Te)	3%	3%< QE < 4%



MO6RFP063 and M. Petrarca CERN/EN Seminar (April 2009).





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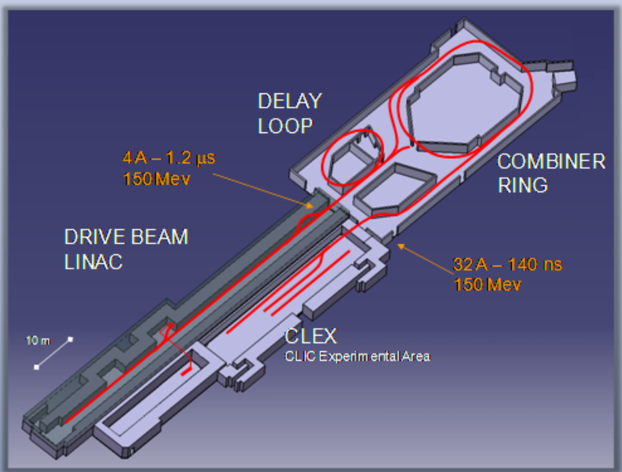

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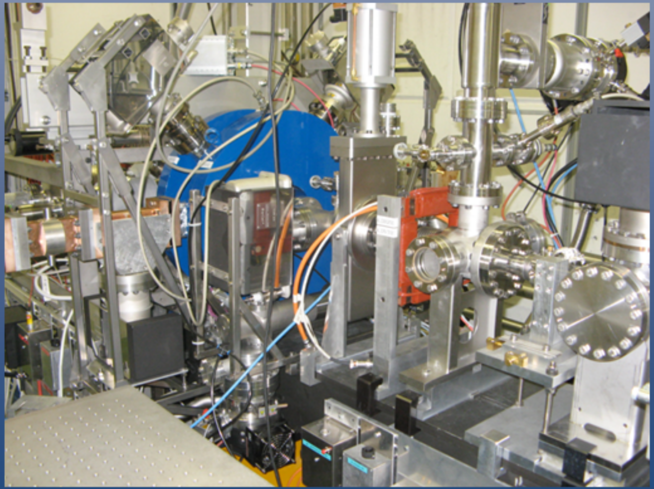
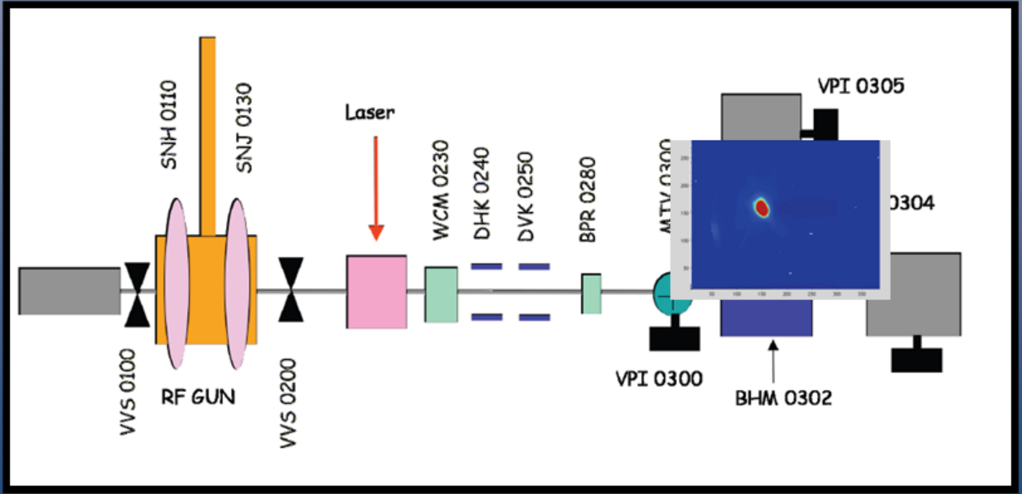
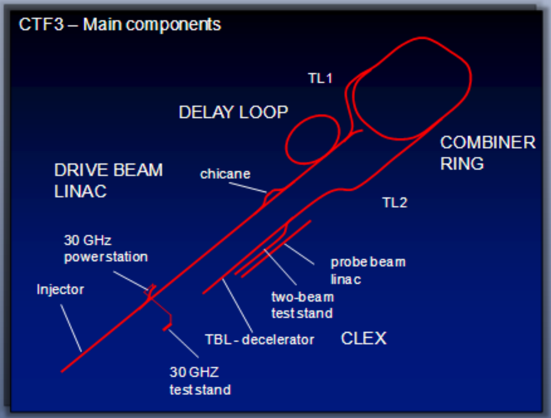




Other ongoing experiments



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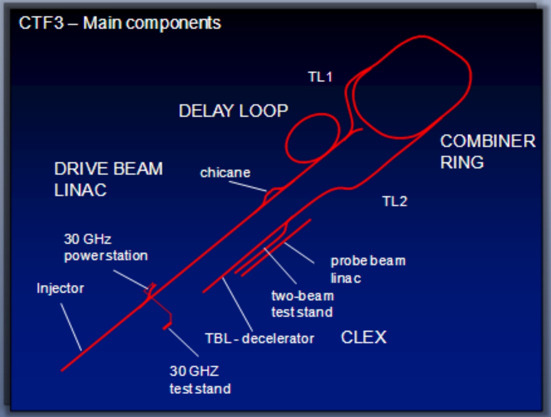

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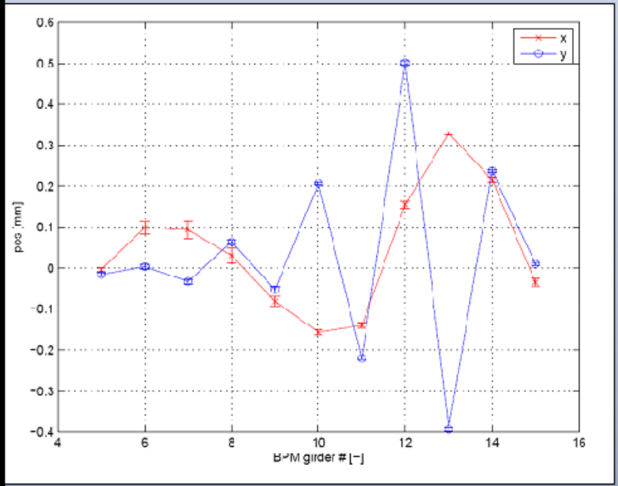

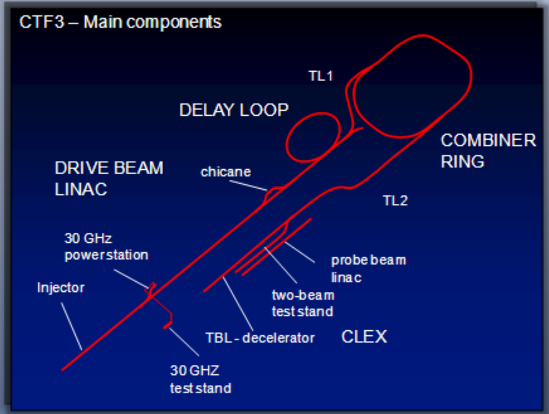

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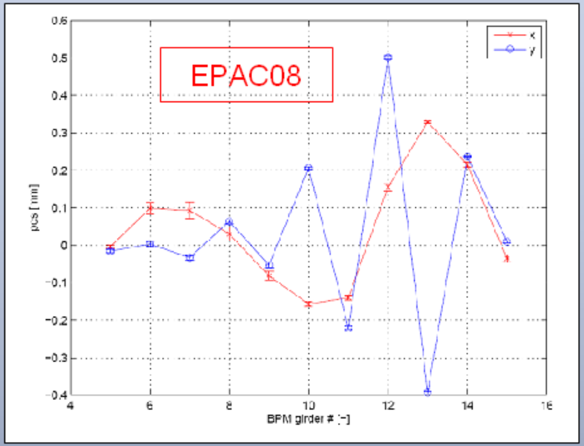

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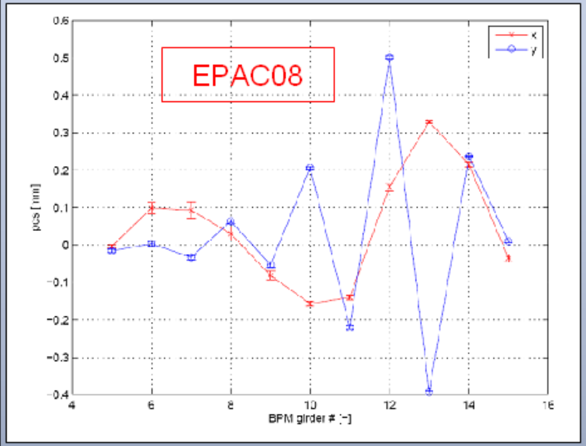

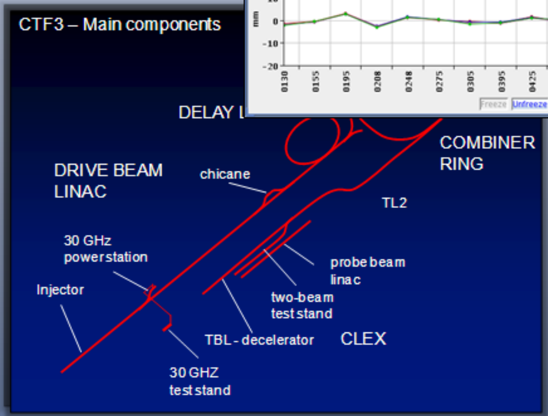

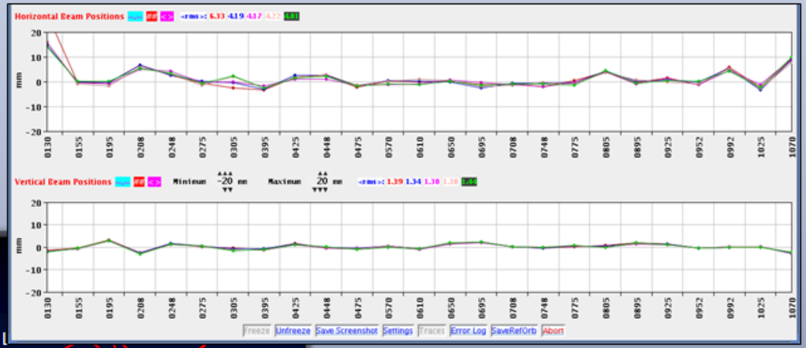

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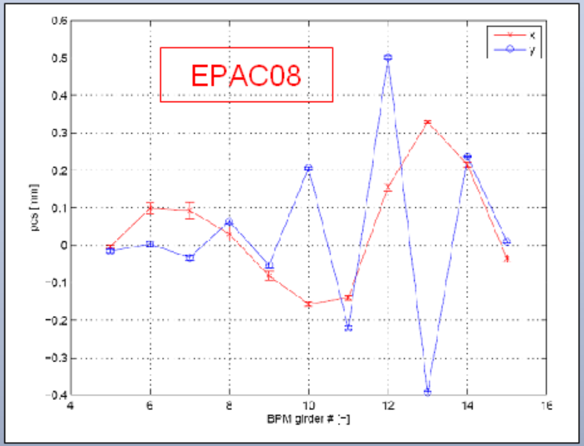

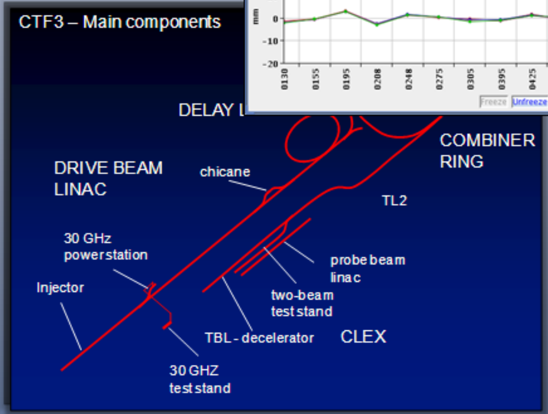

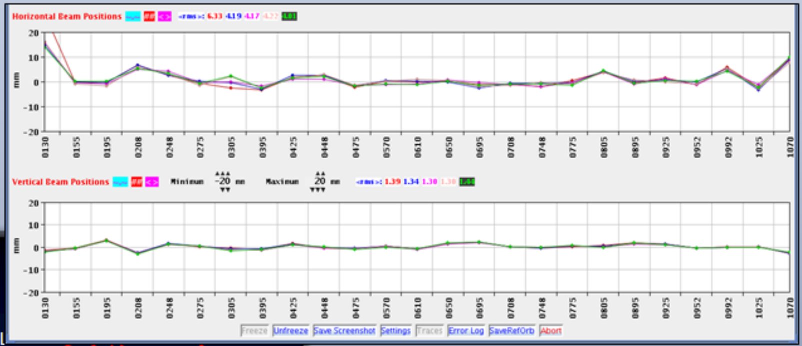

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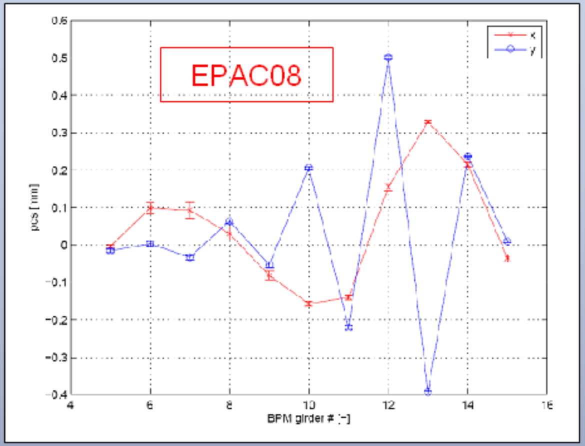

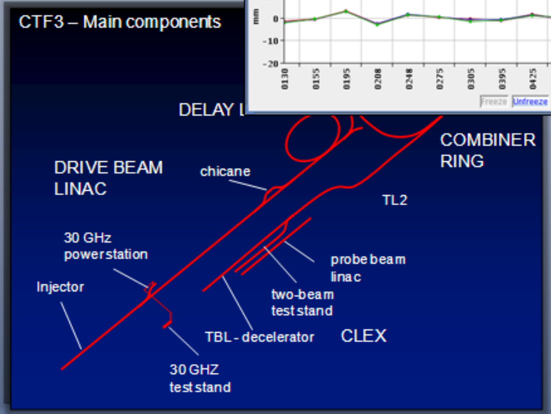

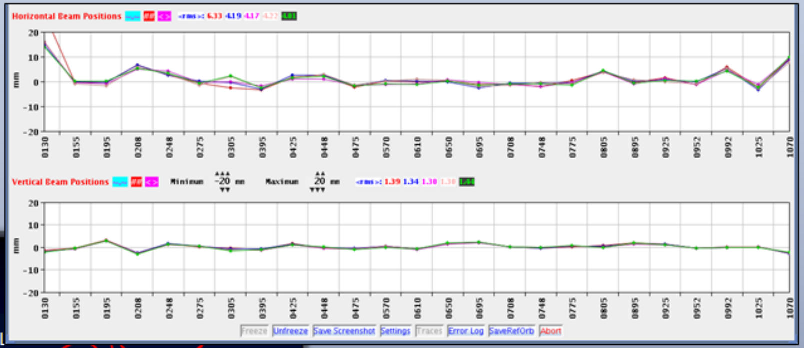

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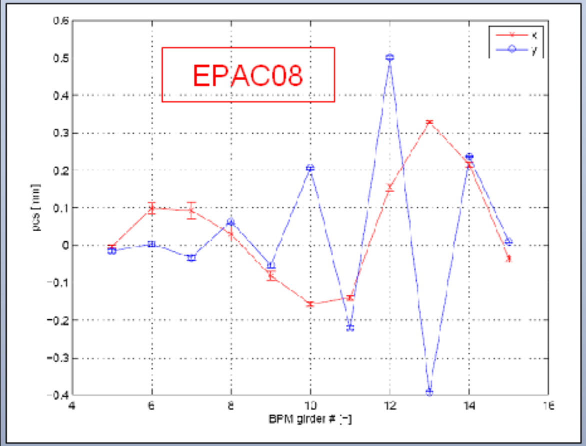

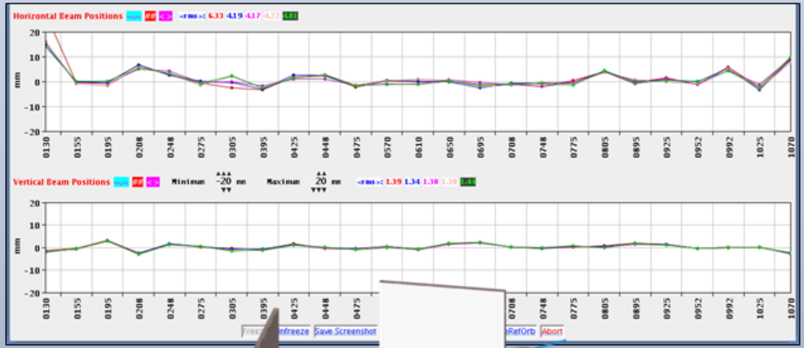

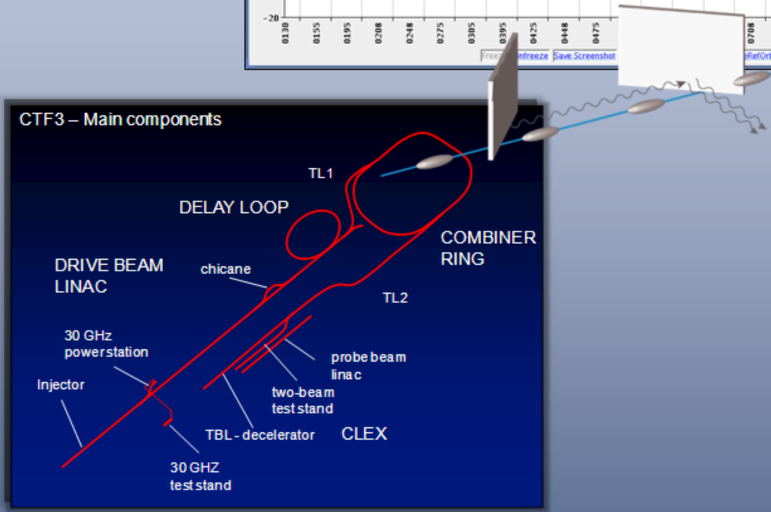

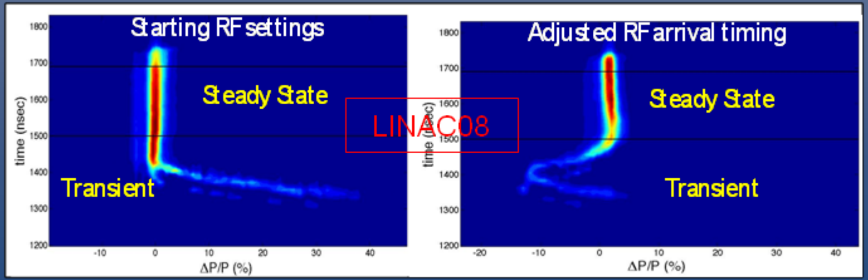

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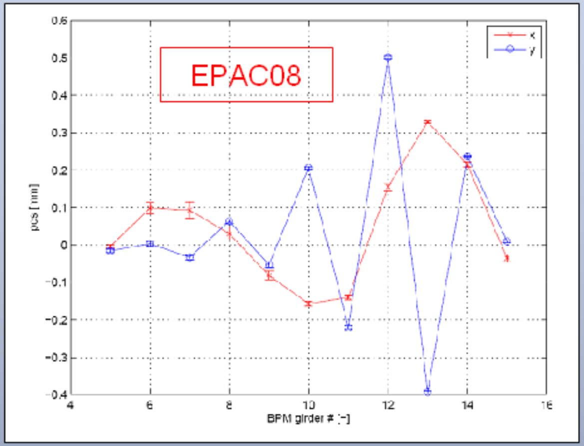

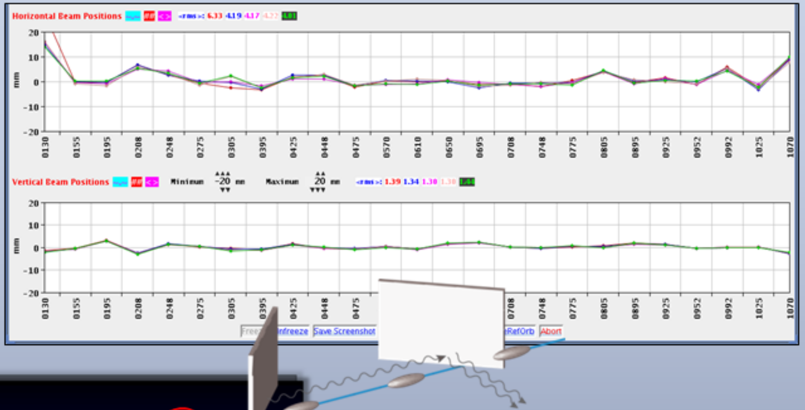

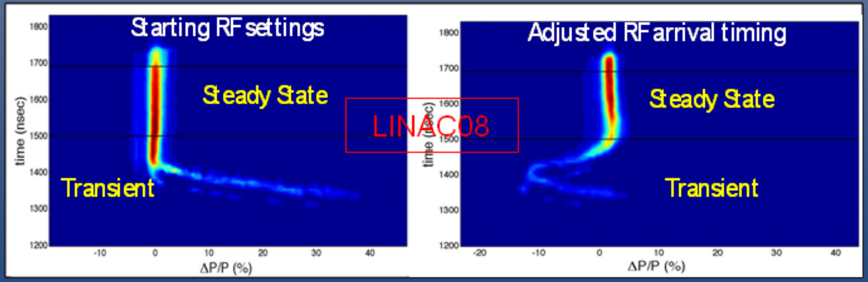

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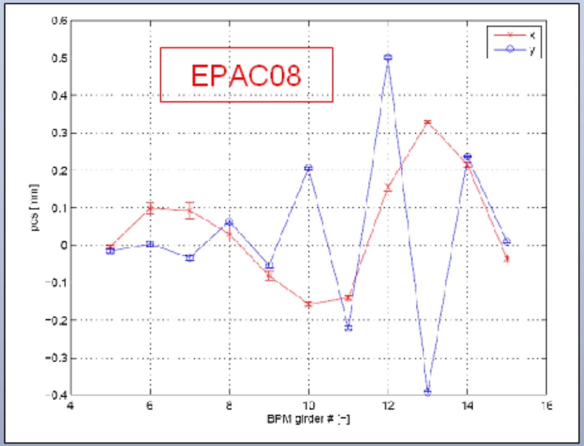

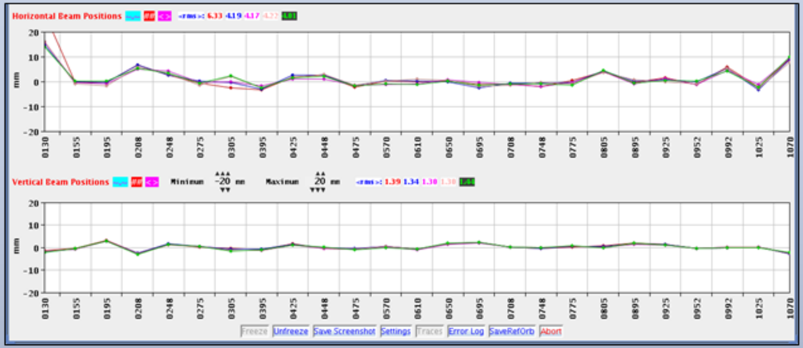

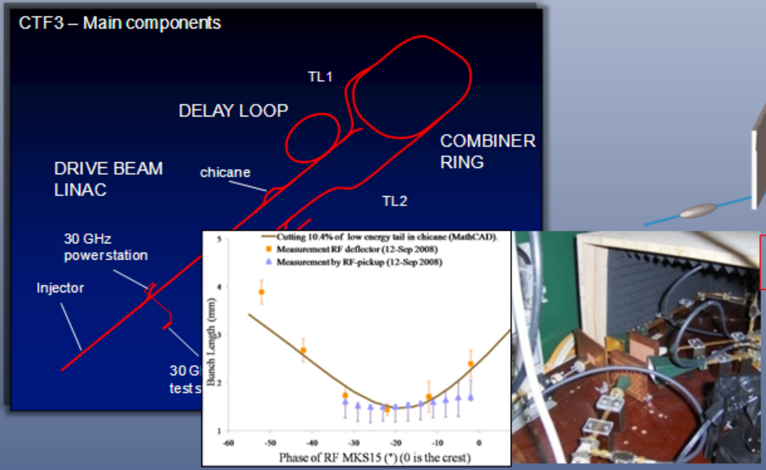

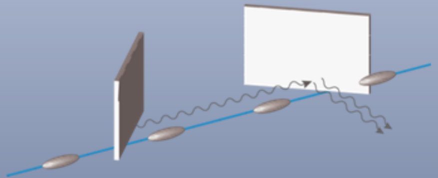

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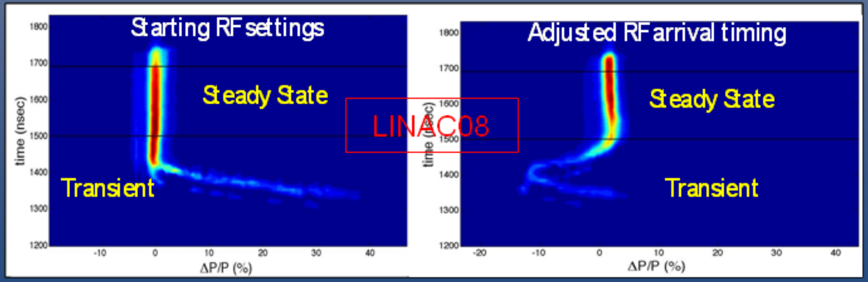

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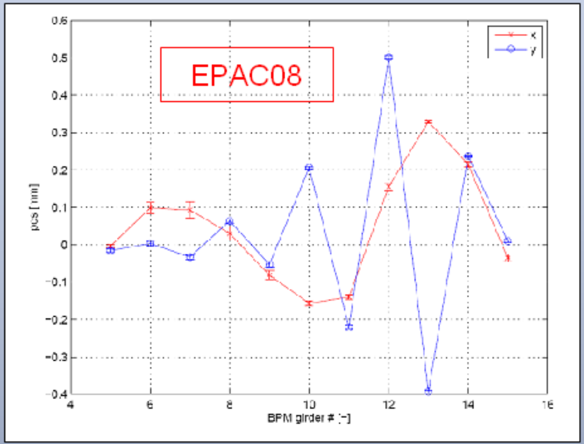

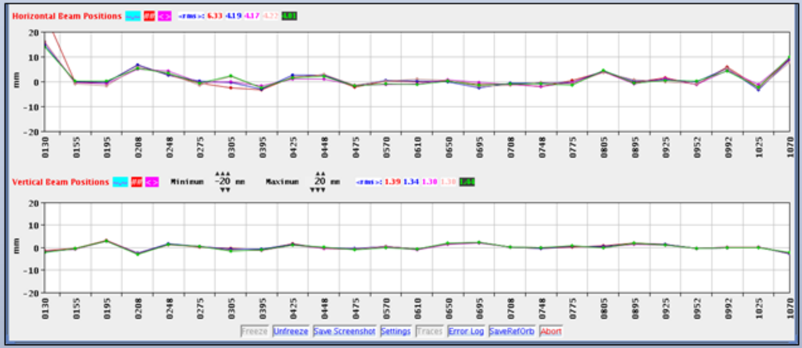

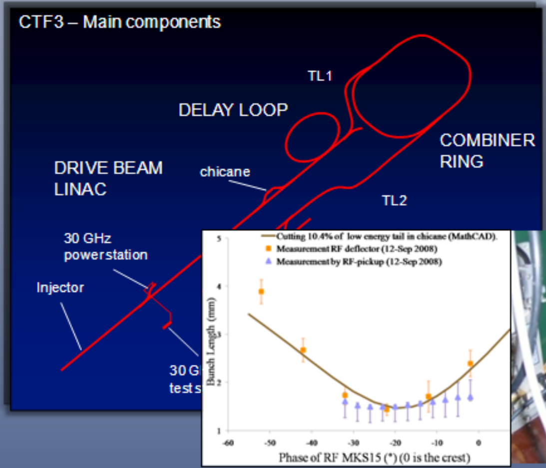

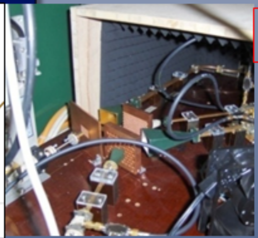

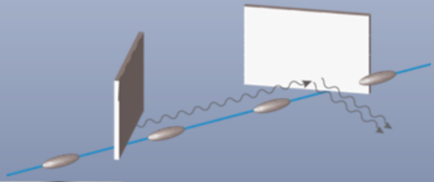

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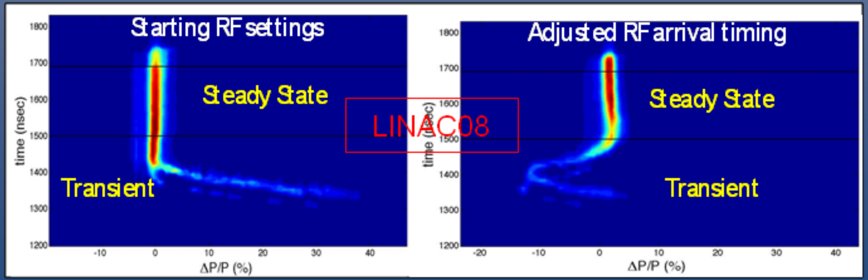

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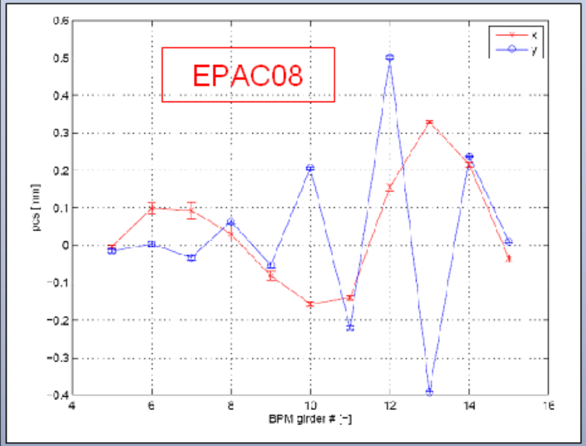
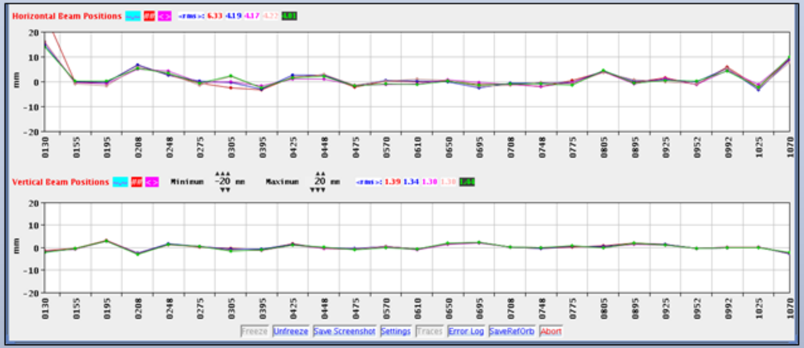
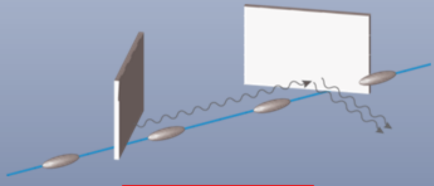
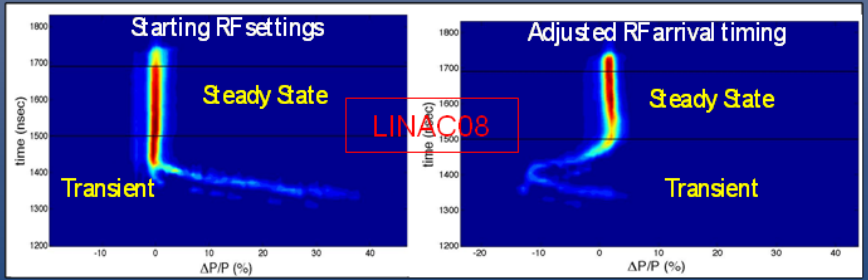
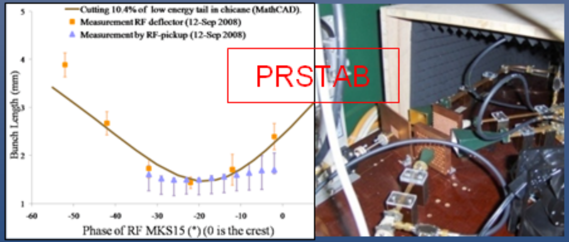






TH5RFPO6
6



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Conclusions

SEVERAL OF THE CTF3 GOALS HAVE BEEN ALREADY DEMOSTRATED IN THE PAST YEARS:

- ✓ *Fully loading operation mode works (consistent with theory predictions)*
- ✓ *Factor 2 demonstrated in delay loop*

2008 MILESTONES:

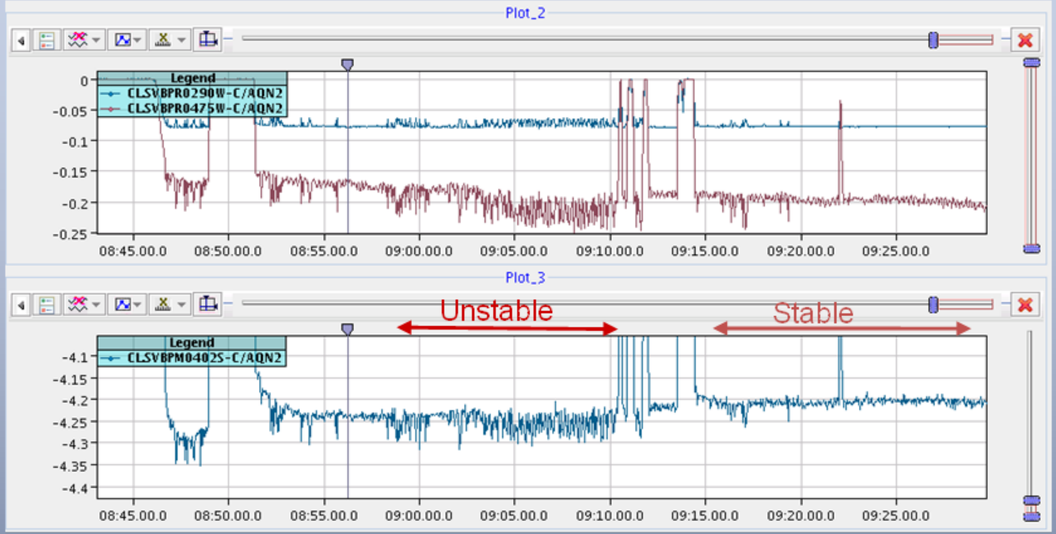
- ✓ *Factor 4 recombination achieved (after cure of the vertical instability)*
- ✓ *New lines installed and commissioning already started*
- ✓ *First beam through PETS in the CLEX area*
- ✓ *Recirculation mechanism worked as expected*

FUTURE SHORT TERM PROGRAMS:

- ✓ *Put in operation DL and CR together*
- ✓ *Test of the two beam acceleration scheme in CLEX (acceleration and stability studies)*

Spare slides

Gun instability



CTF3 Linac is fully loaded ⇒ The energy transferred to the beam depends on the beam current

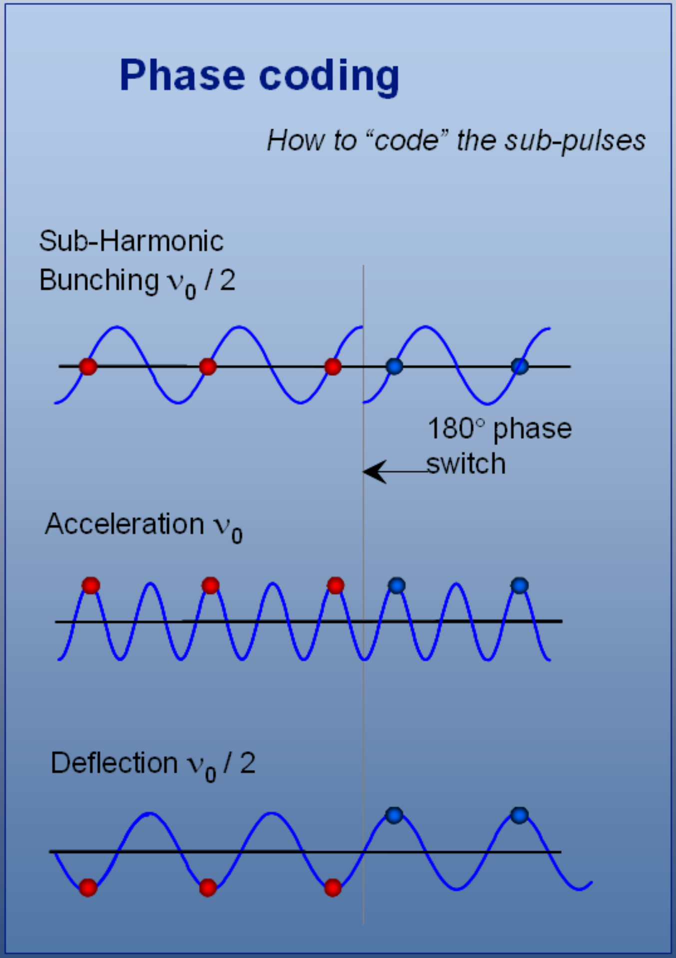
Gun instability (HV fluctuations) ⇒

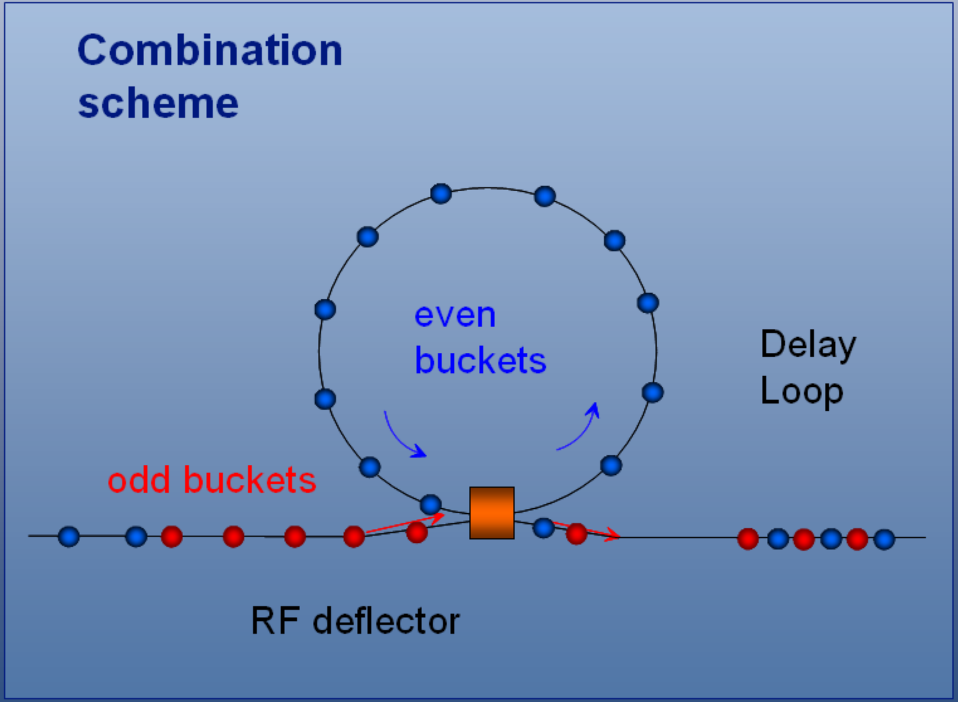
- The current is different shot to shot
- The energy gain is different shot to shot
- Position jitter in dispersive regions
- Set up and measurements VERY difficult

Problem solved since September 2008

Gap creation and x2 multiplication

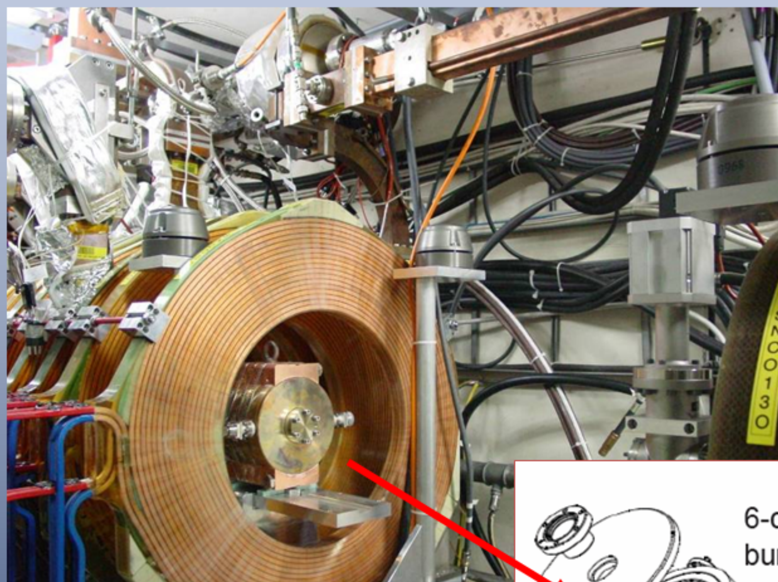
$$L_{delay} = n\ \lambda_0 = c\ T_{sub\text{-}pulse}$$



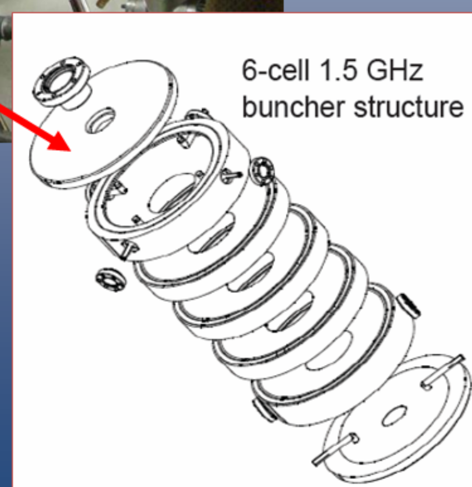


Phase coding and satellites

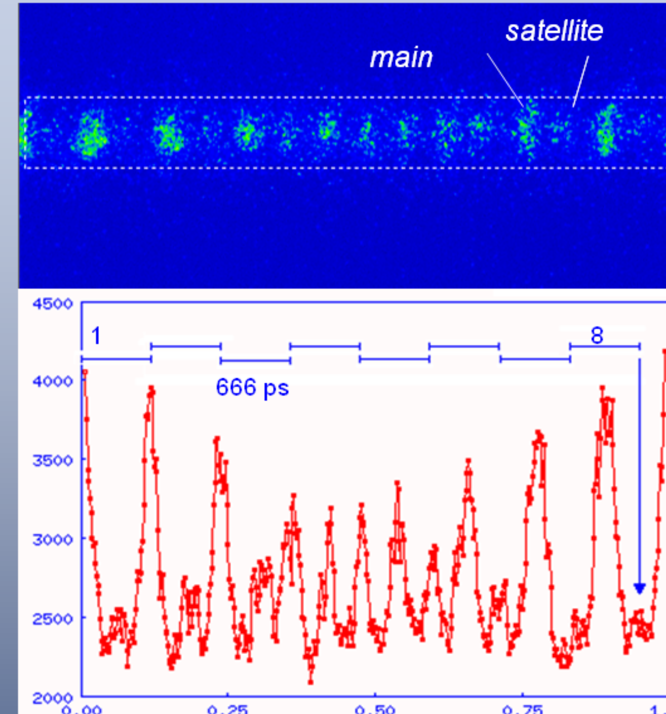
Fast phase switch from
SHB system (CTF3)



3 TW Sub-harmonic bunchers,
each fed by a wide-band TWT

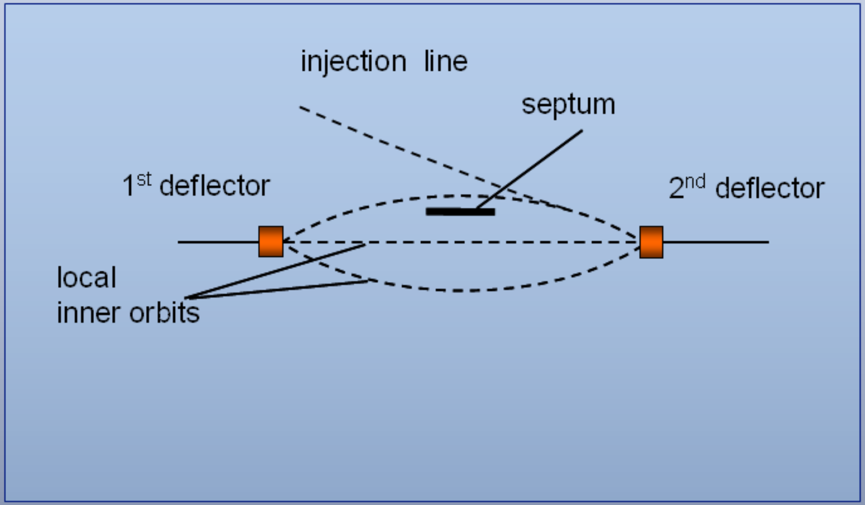


Streak camera image

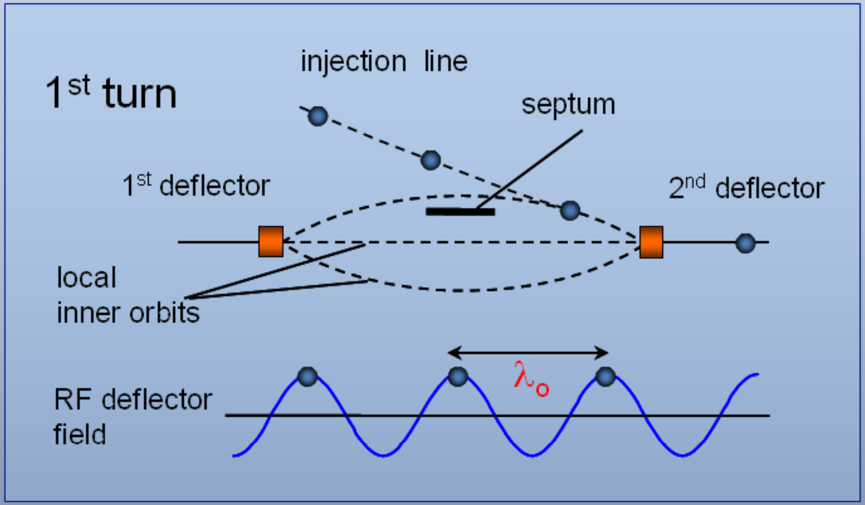


8.5 · 666 ps = 5.7 ns

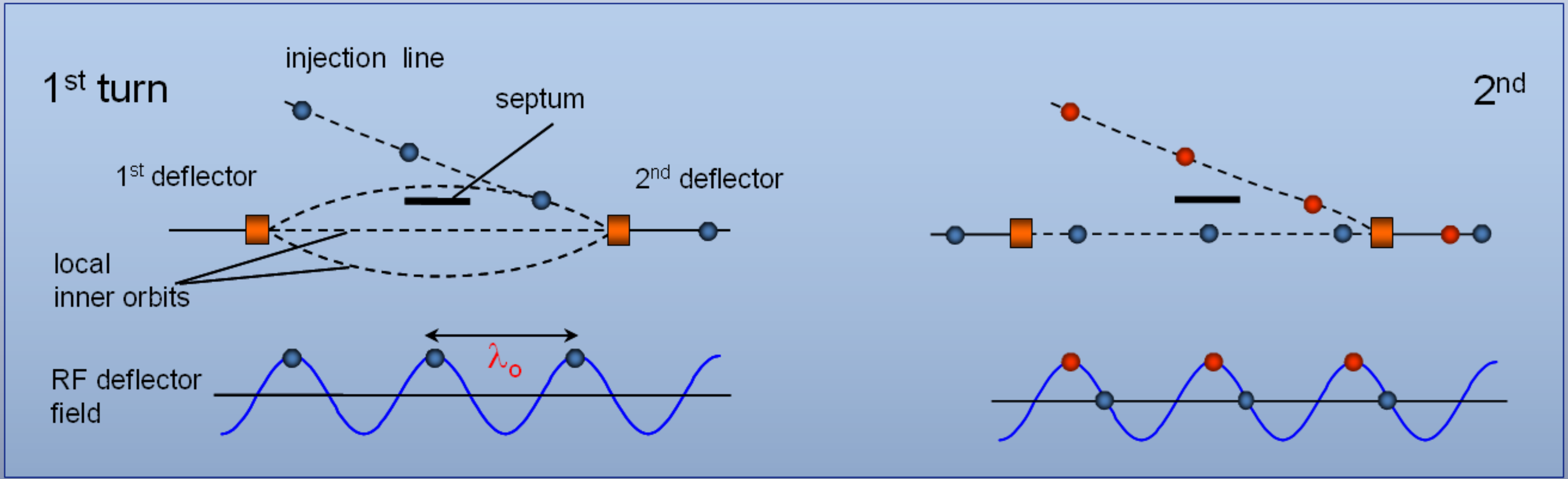
Combiner ring multiplication



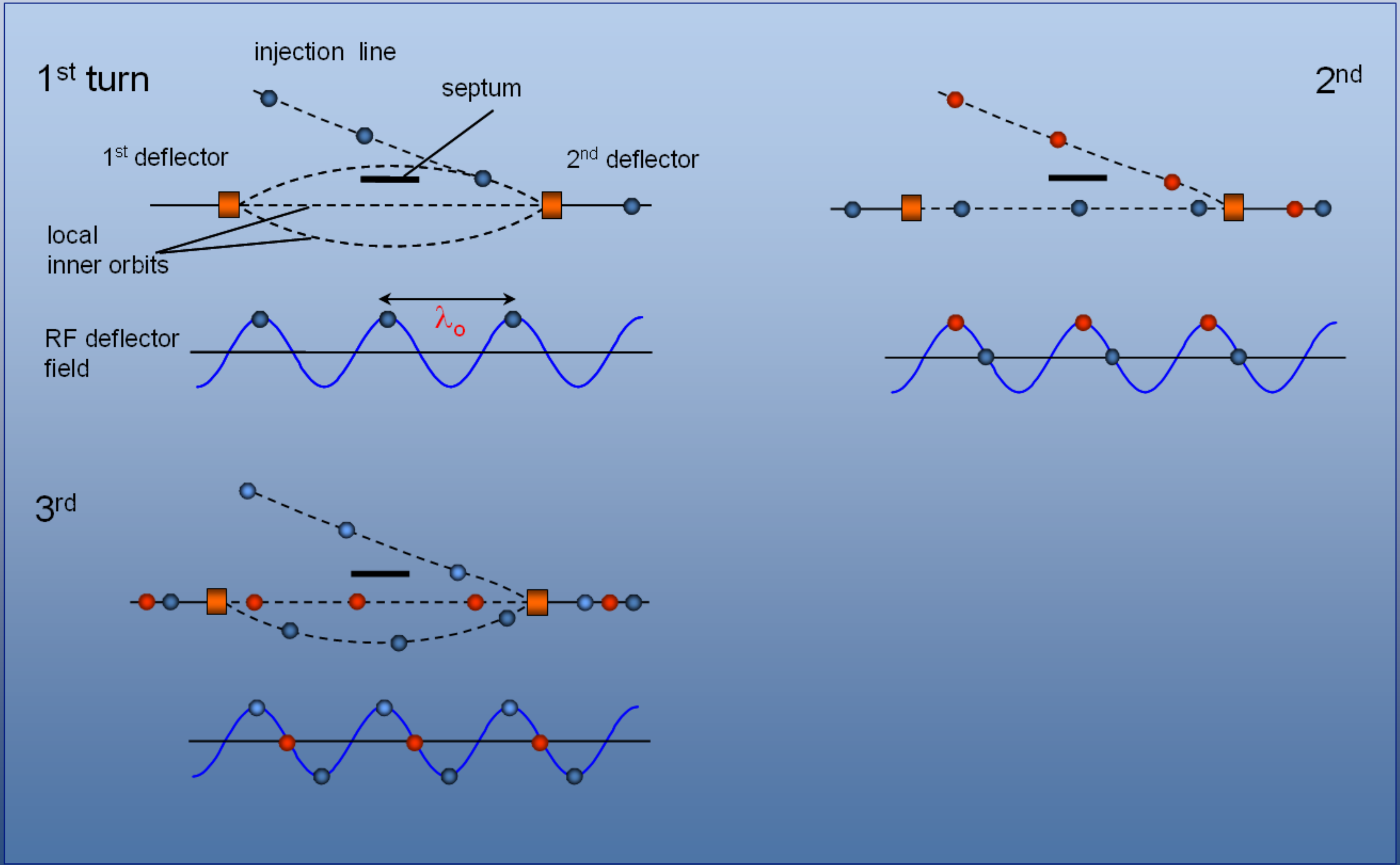
Combiner ring multiplication



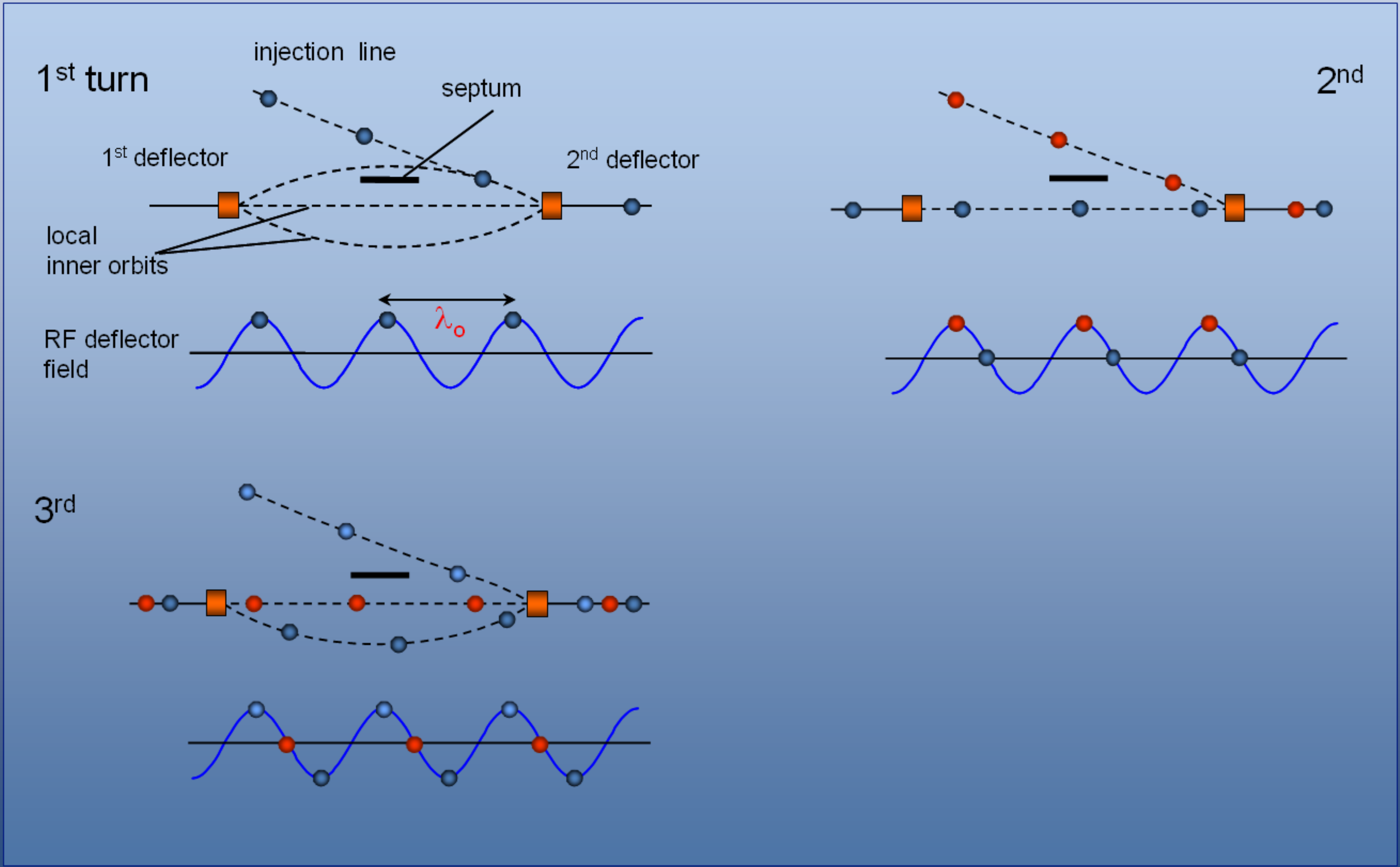
Combiner ring multiplication



Combiner ring multiplication



Combiner ring multiplication



PETS

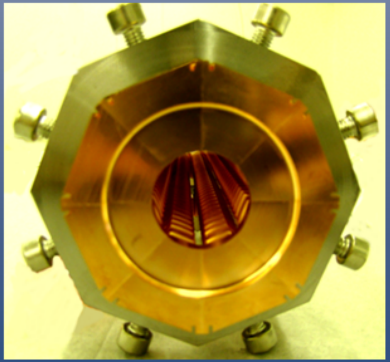
Special development for CLIC

• Travelling wave structures	136 MW RF @ 240 ns per PETS
• Small R/Q : 2.2 kΩ/m	(2 accelerating structures)
(accelerating structure: 15-18 kΩ/m)	0.21 m active length
• 100 A beam current	total number : 35’703 per linac

8 Sectors
damped
on-off possibility

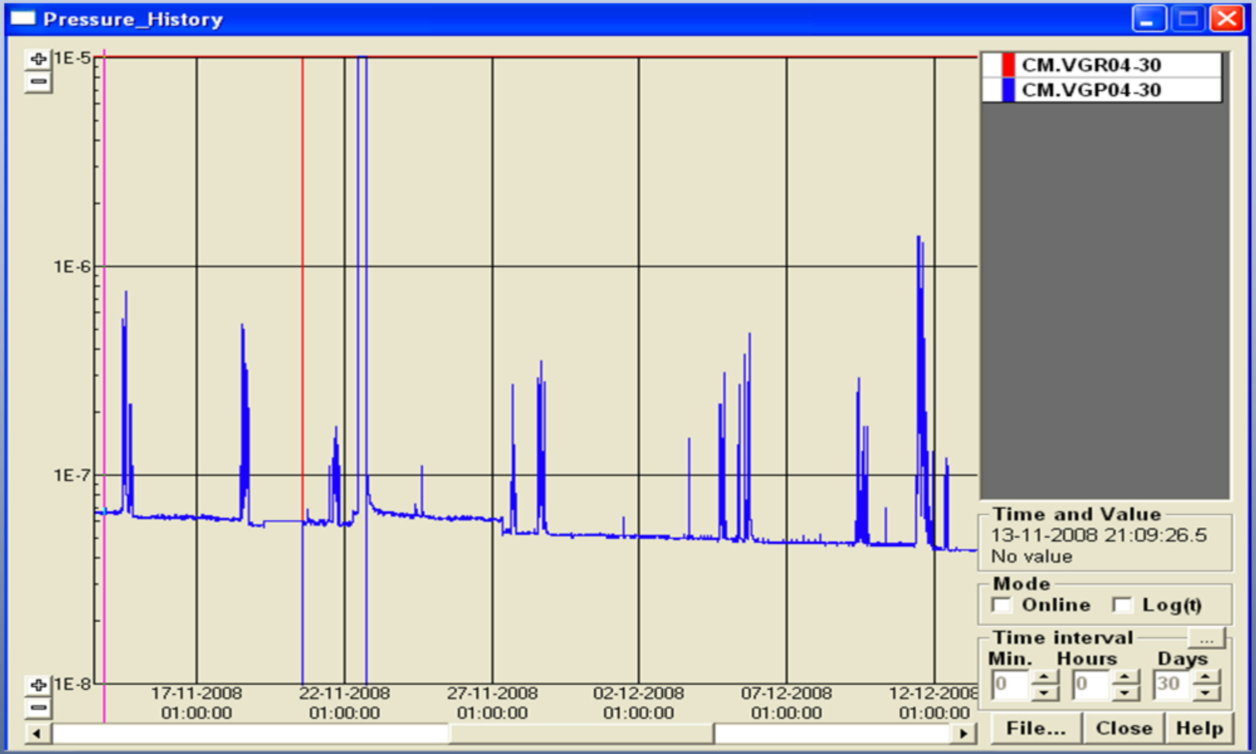
Status:
Advanced design,
RF power testing at SLAC planned July 08
with beam in CTF3 in autumn 2008

ref: Igor Syratchev



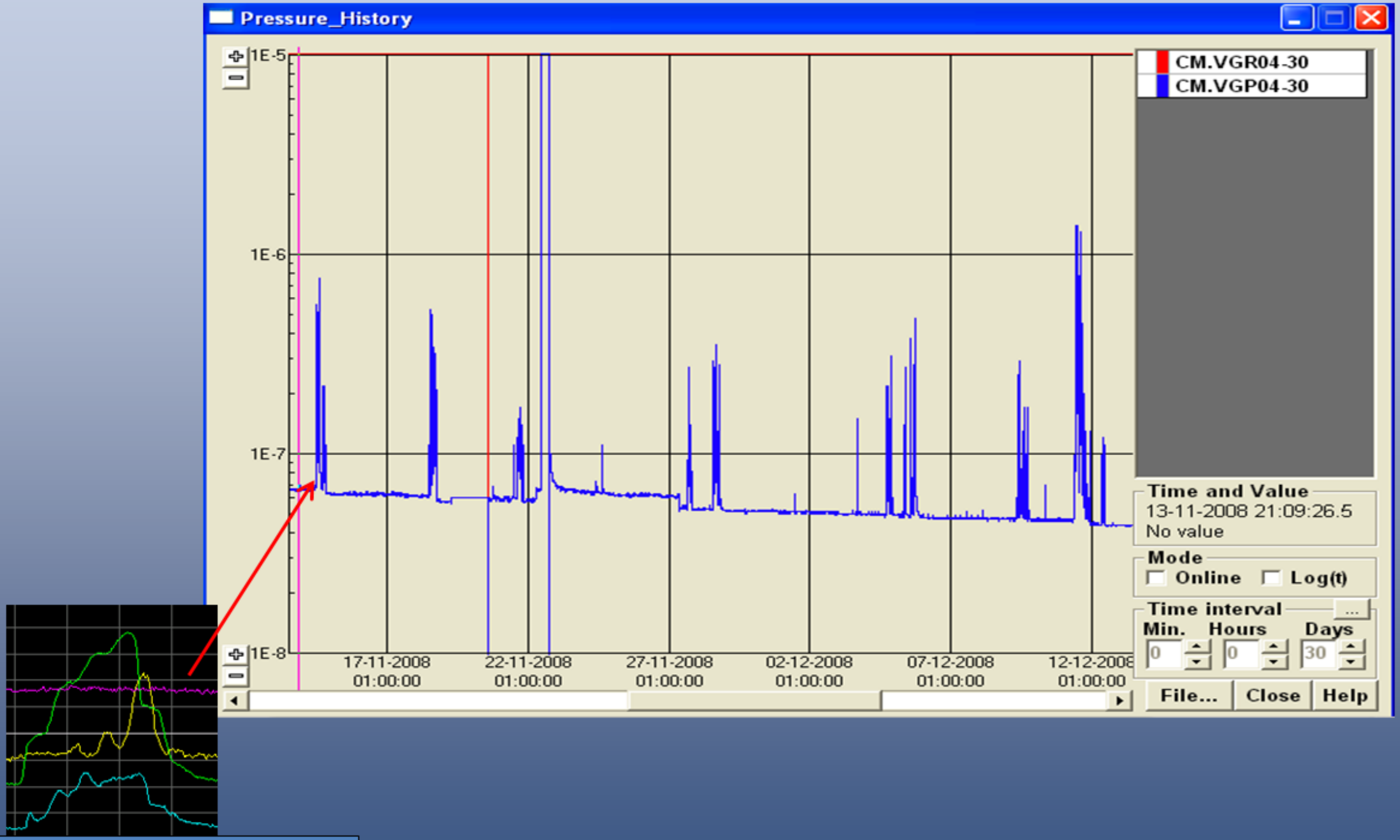
2008 milestones: first beam through PETS

Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)



2008 milestones: first beam through PETS

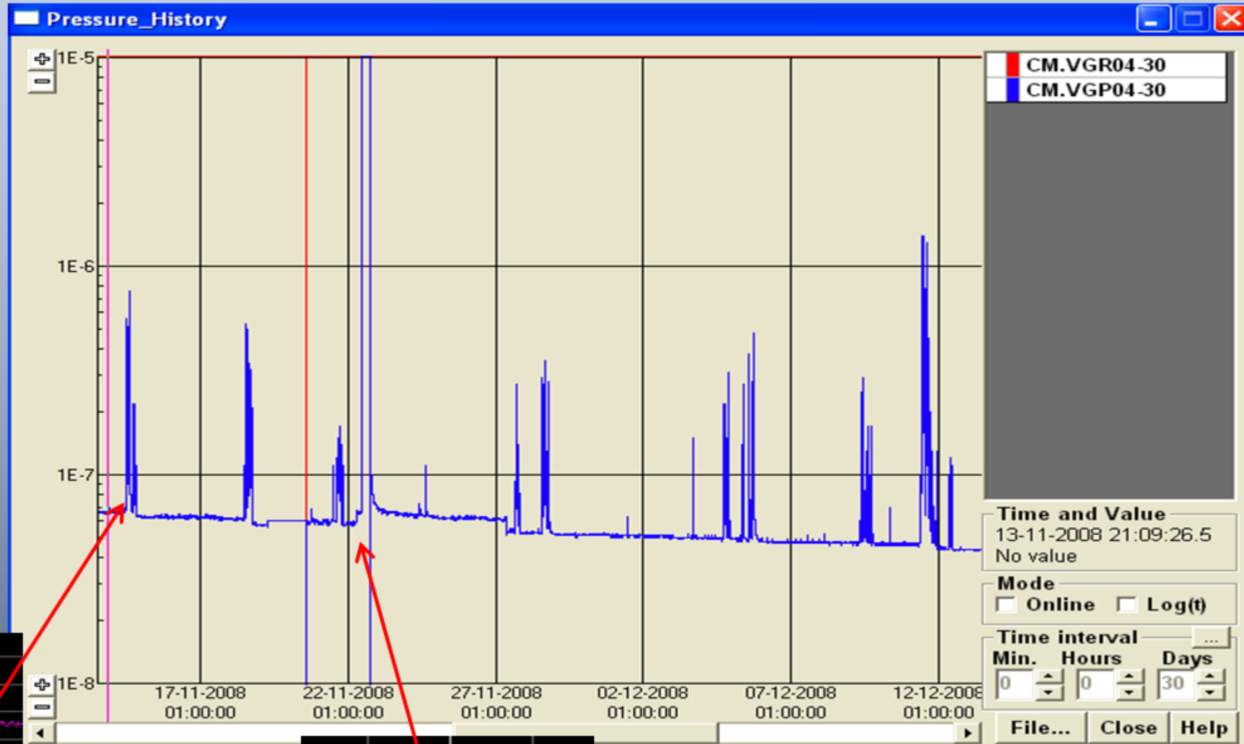
Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)

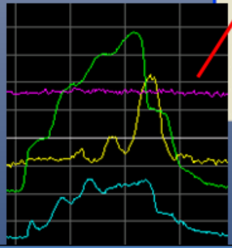


14/11: First beam
2A w/ recirculation (by chance: positive build-up!)

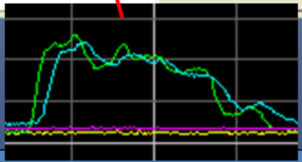
2008 milestones: first beam through PETS

Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)





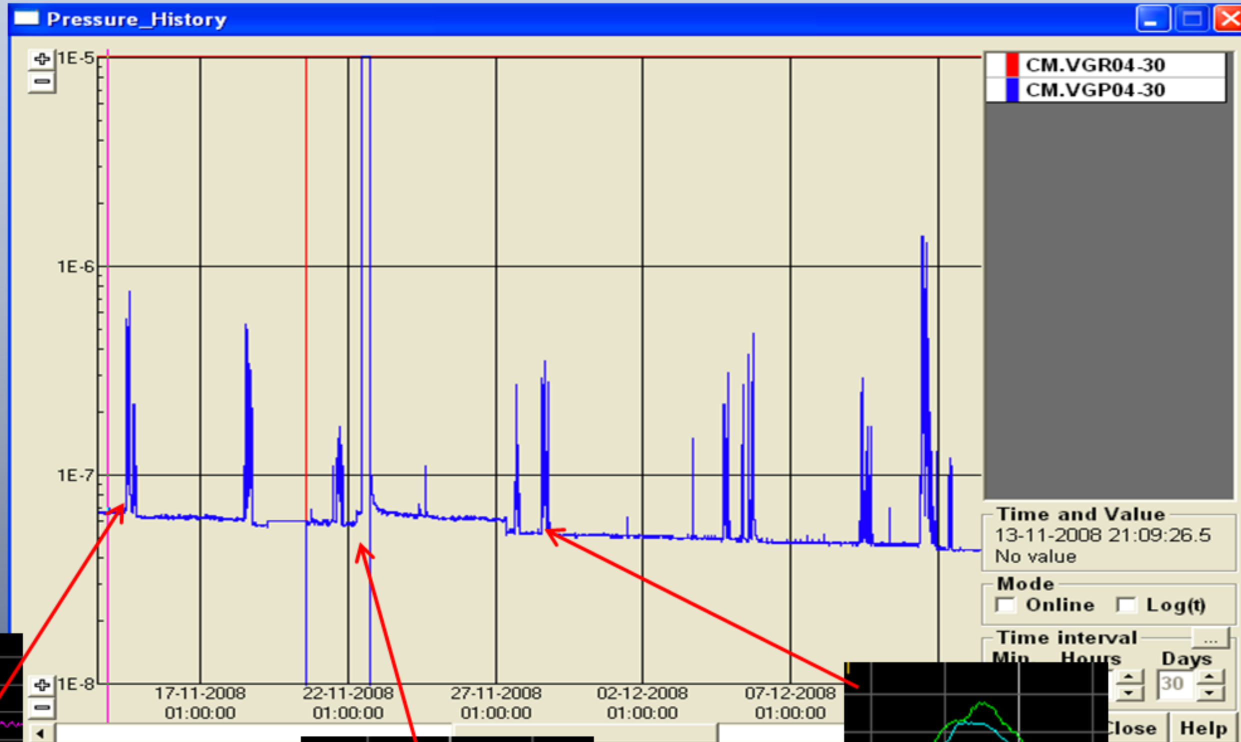
14/11: First beam
2A w/ recirculation (by chance: positive build-up!)

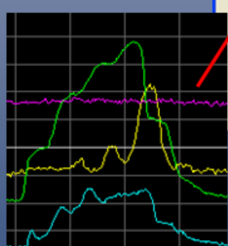


21/11: Manually forces splitter to extreme position: no recirculation (to verify beam generated RF power)

2008 milestones: first beam through PETS

Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)





14/11: First beam
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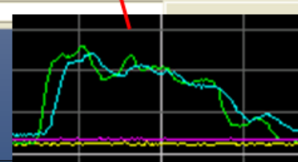

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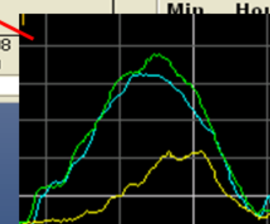
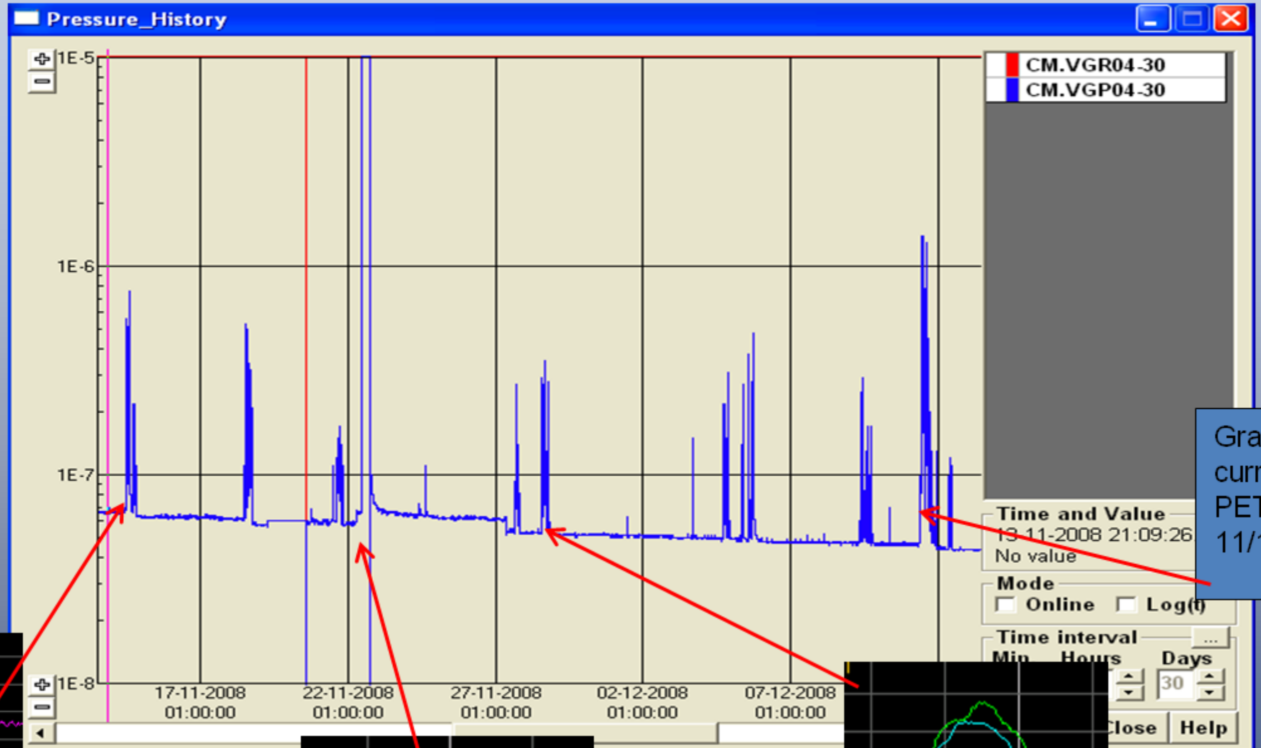


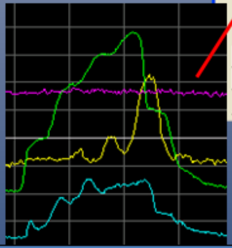
28/11 : Adjusted phase-shifter : back to constructive recirculation mode

2008 milestones: first beam through PETS

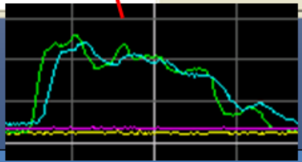
Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)



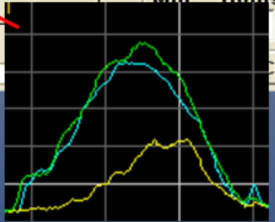
Gradually increasing current arriving at PETS, up to ~ 5A, 11/12



14/11: First beam
2A w/ recirculation (by chance: positive build-up!)

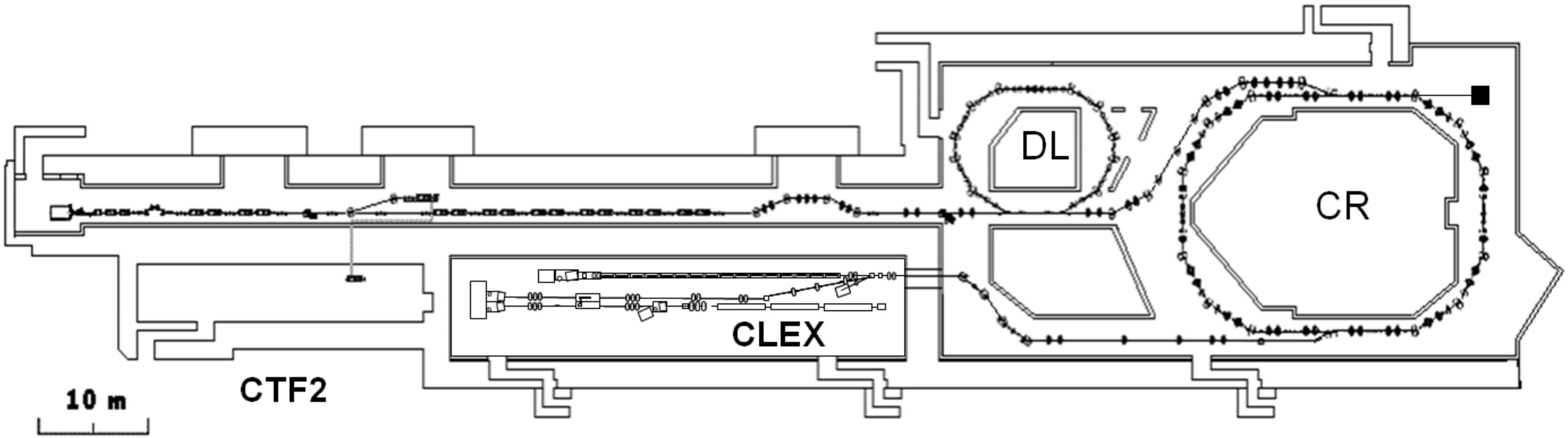


21/11: Manually forces splitter to extreme position: no recirculation (to verify beam generated RF power)

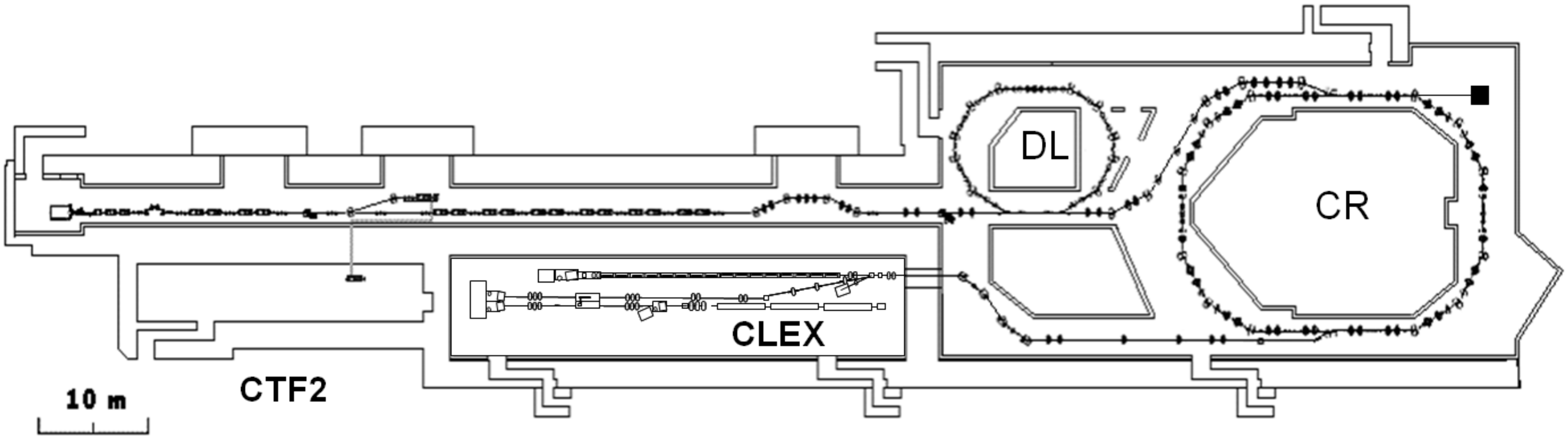


28/11 : Adjusted phase-shifter : back to constructive recirculation mode

Drive beam complex commissioning

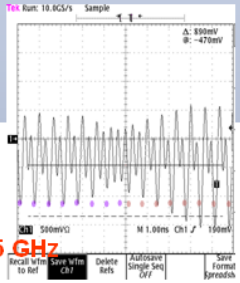


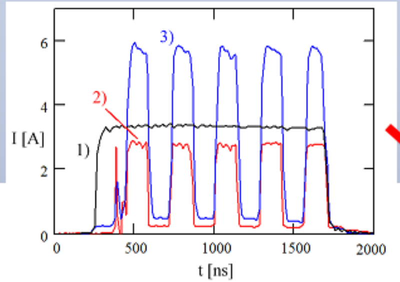
Drive beam complex commissioning



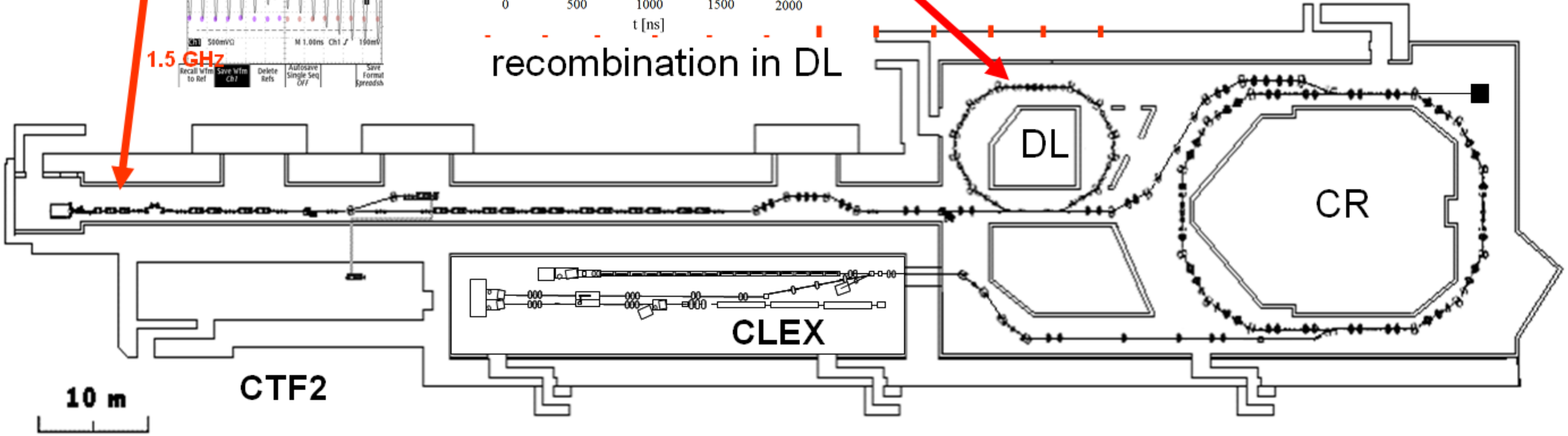
Drive beam complex commissioning

Phase coding



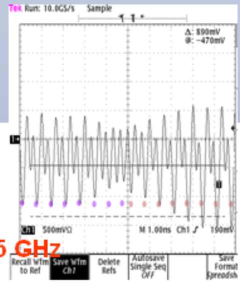


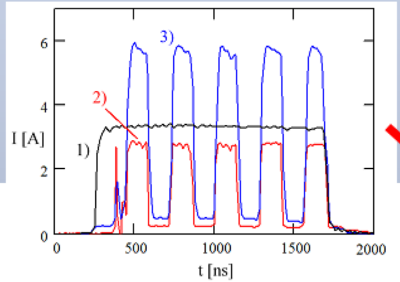
recombination in DL



Drive beam complex commissioning

Phase coding





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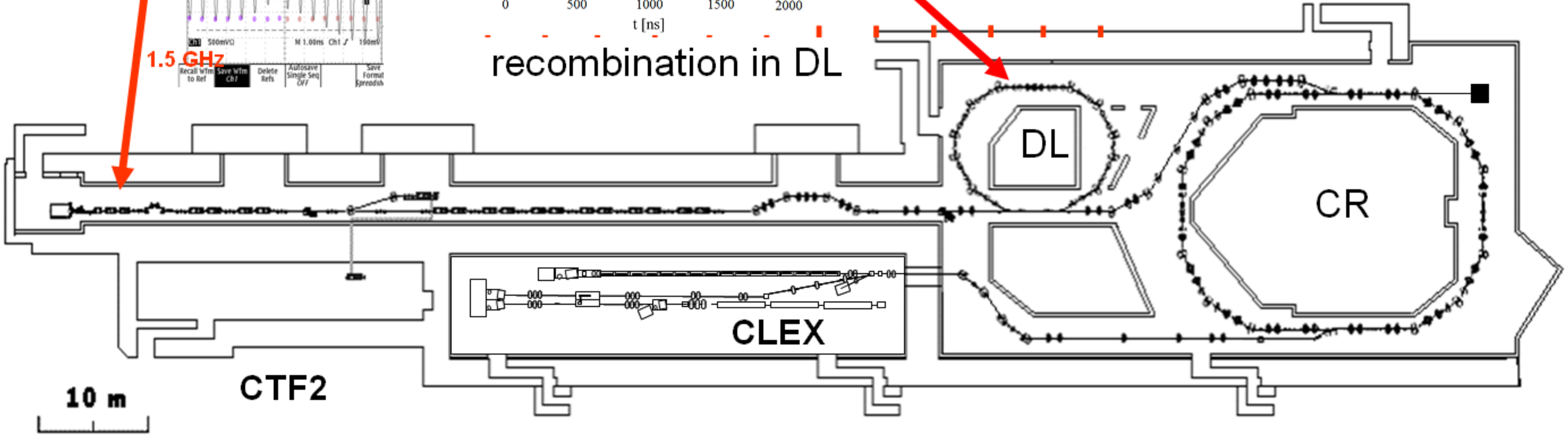
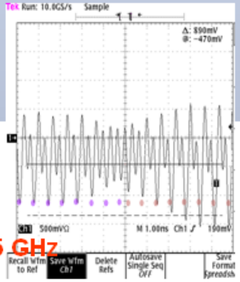
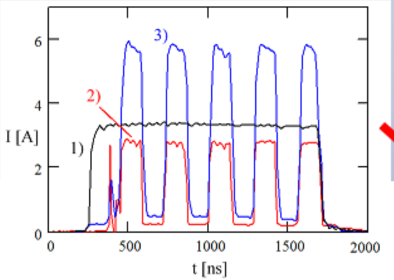


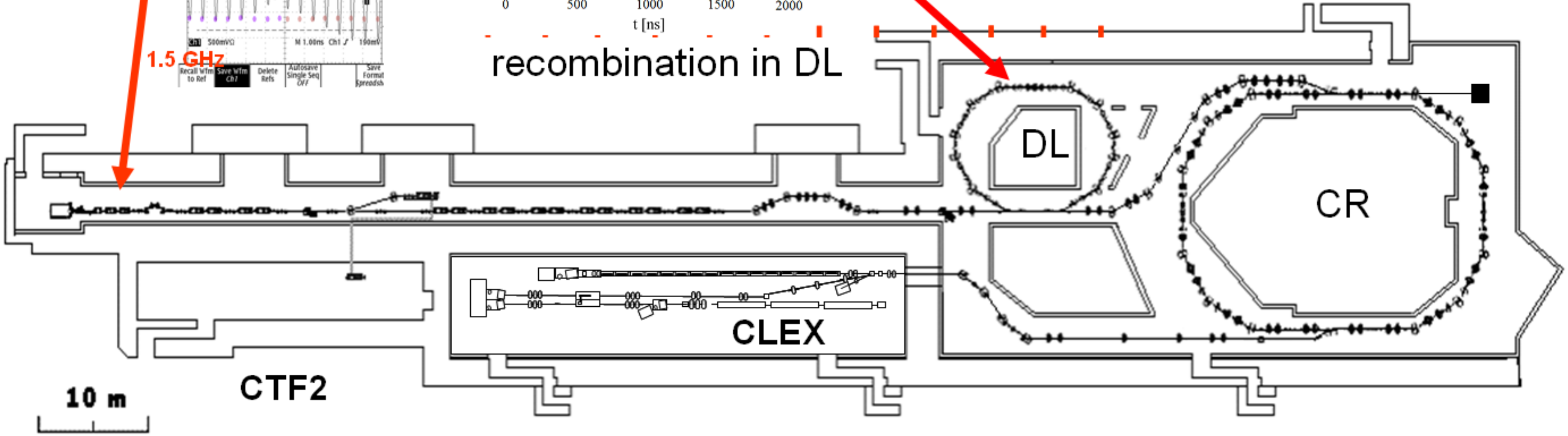
Drive beam complex commissioning

Phase coding





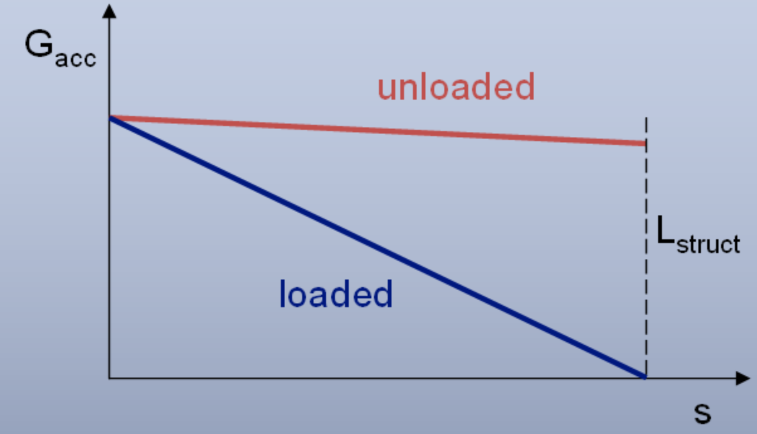
recombination in DL

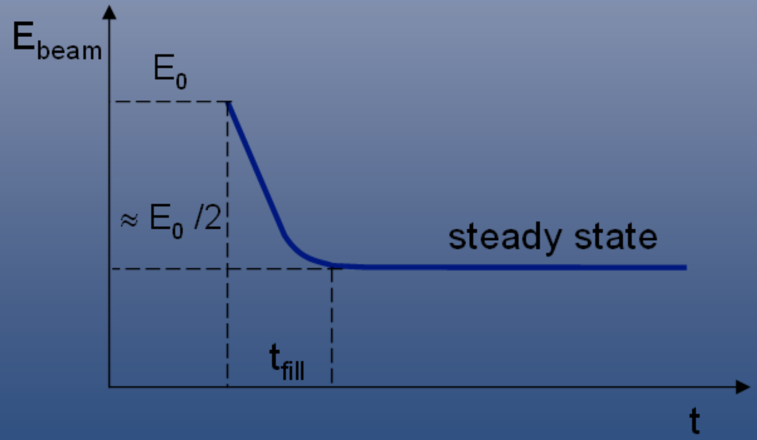


CTF3/CLIC

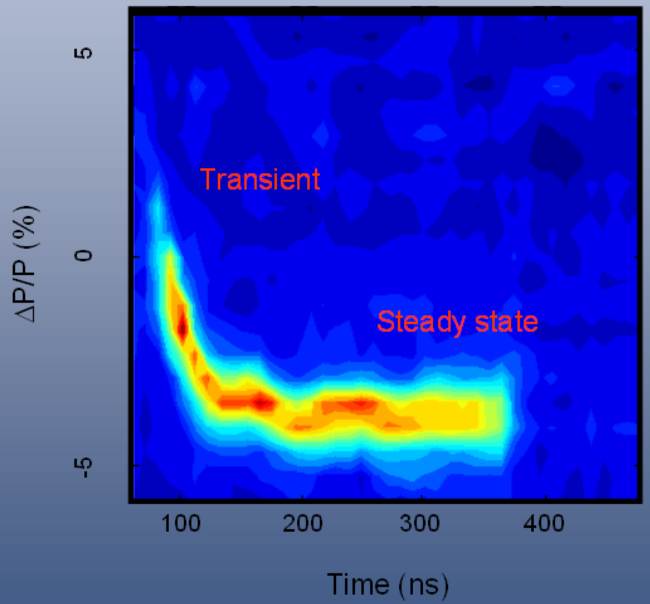
	CLIC	CTF3
Drive Beam energy	2.4 GeV	150 MeV
compression / frequency multiplication	24 (Delay Loop + 2 Combiner Rings)	8 (Delay Loop + 1 Combiner Ring)
Drive Beam current	4.2 A*24 → 101 A	3.5 A*8→ 28 A
RF Frequency	1 GHz	3 GHz
train length in linac	139 μs	1.5 μs
energy extraction	90 %	~ 50 %

CLIC parameters optimization





Time resolved beam energy spectrum measurement in CTF3



The CLIC/CTF3 collaboration

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
Finnish Industry (Finland)
Gazi Universities (Turkey)

IRFU/Saclay (France)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
J.Adams Institute, (UK)

JASRI (Japan)
JINR (Russia)
JLAB (USA)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)
NCP (Pakistan)
North-West. Univ. Illinois (USA)

Oslo University
PSI (Switzerland),
Polytech. University of Catalonia (Spain)
RAL (England)
RRCAT-Indore (India)
Royal Holloway, Univ. London, (UK)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)