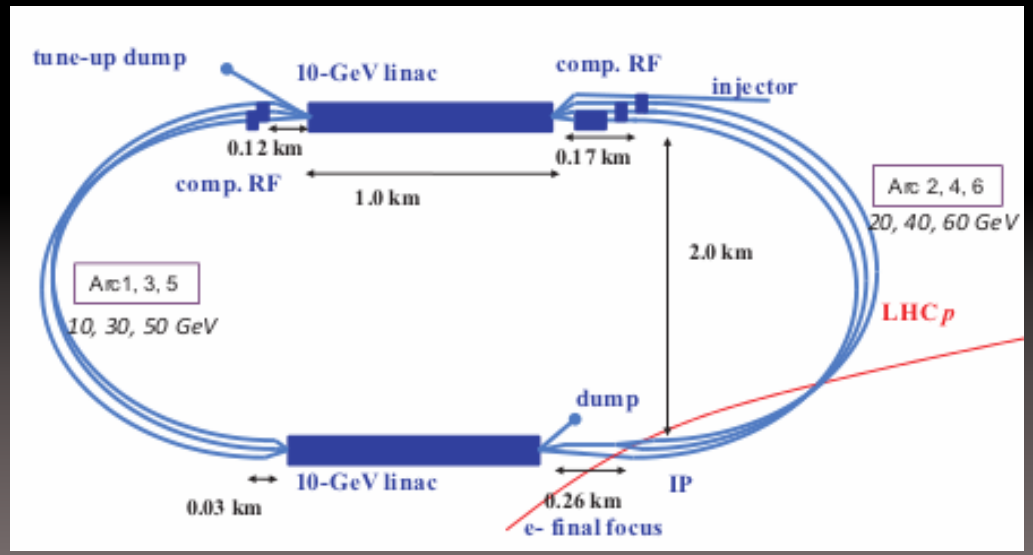
A PROPOSED ERL TEST FACILITY @ CERN

Erk Jensen, for the LHeC team and the RF group

ERL 2013, BINP, Novosibirsk, 09-Sep-2013

Motivation: ERL based e^- linac for LHeC

- LHeC CDR published: arxiv.org/abs/1206.2913
(→ O. Brünings presentation)
- Goal: Collide LHC proton beam with e^- or e^+ for DIS.
- Power consumption ≤ 100 MW!
- 60 GeV ERL with two 10 GeV Linacs
- Frequency recently fixed:
$f = 801.58$ MHz
- Synergy with SPS and LHC harmonic systems!



NB.: This is a

Some references

This is a relatively recent proposal at an early stage, which is still being discussed with CERN management and international partners.

Here some references documenting the birth of the idea:

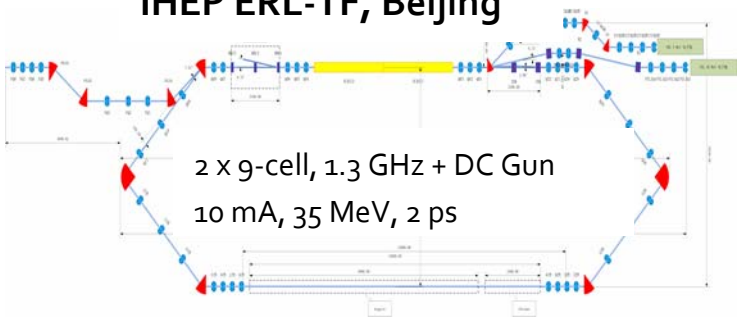
- Chamonix, 9 Feb 2012: "SC Cavities R&D for LHeC and HE-LHC"
  https://indico.cern.ch/materialDisplay.py?contribId=67&materialId=slides&confId=164089
- 15 June 2012, LHeC Workshop Chavannes: "ERL & Frequency Choice",
  http://indico.cern.ch/materialDisplay.py?contribId=51&materialId=slides&confId=183282
- 5 Sept 2012, meeting with Daresbury group:
  http://indico.cern.ch/materialDisplay.py?contribId=1&materialId=slides&confId=207665
- 22 Jan 2013, Meeting at Daresbury
  https://eventbooking.stfc.ac.uk/newsevents/lhec-meeting
- 12 March 2013: "Choice of RF Frequency":
  http://indico.cern.ch/materialDisplay.py?contribId=0&materialId=slides&confId=240837

Goals of a CERN ERL Test Facility

- Study behaviour of a high energy multi-pass multiple cavity ERL for LHeC
  - Optics, beam dynamics, RF power, couplers, synchronization & delay issues …
  - HOMs & HOM couplers, cryogenics, instrumentation, controls, LLRF …
  - Cryogenics and instrumentation test bed
- Injector studies DC gun (JLAB, KEK ?) or SRF gun (FZ Rossendorf ?, BNL ?)
- Study real SCRF cavities with beam (not interfering with HEP)
- Study reliability issues, operational issues!
- Could it be foreseen as the injector to LHeC ERL ?
- Beam facility for controlled SC magnet quench tests!
- Beam facility for HEP detector R&D
- Possible a low-energy physics facility
- Demonstrator and study facility for e-cooling (parameters?)
- FEL?, γ-ray source? …
- A real, practical, non-trivial facility not interfering with LHC to train new staff!
- Fostering collaboration (UMainz, JLAB, BNL, Cornell, ASTeC, DESY, IHEP …)!
- Ref.: https://cds.cern.ch/record/1519112 & https://cds.cern.ch/record/1595213

Similar, but different: Some low energy ERL's/Test Facilities

IHEP ERL-TF, Beijing

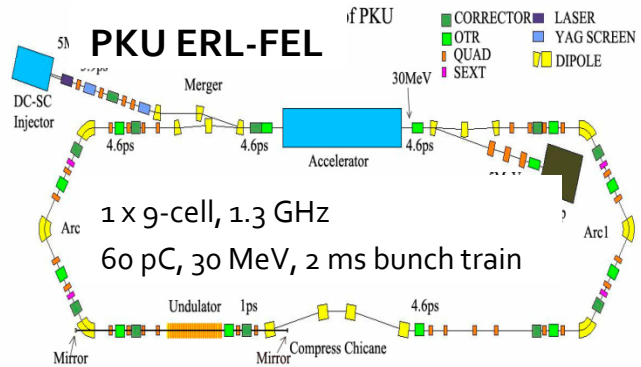


2 x 9-cell, 1.3 GHz + DC Gun
10 mA, 35 MeV, 2 ps

BERLinPro

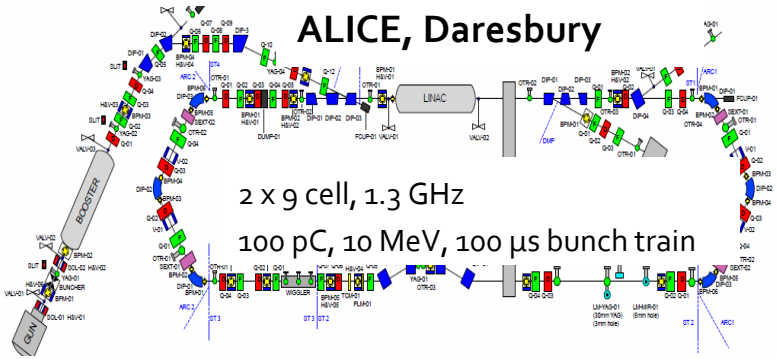
3 x 9-cell cavities, 1.3 GHz
100 mA, 100 MeV, 2 ps

PKU ERL-FEL



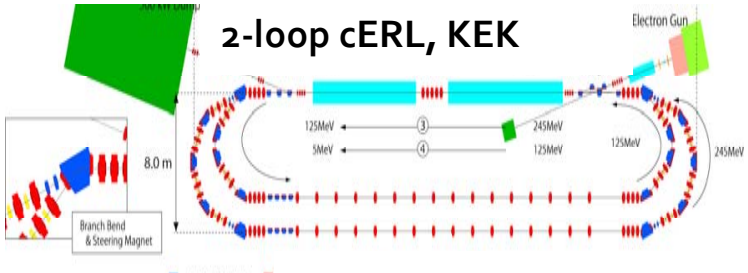
1 x 9-cell, 1.3 GHz
60 pC, 30 MeV, 2 ms bunch train

ALICE, Daresbury



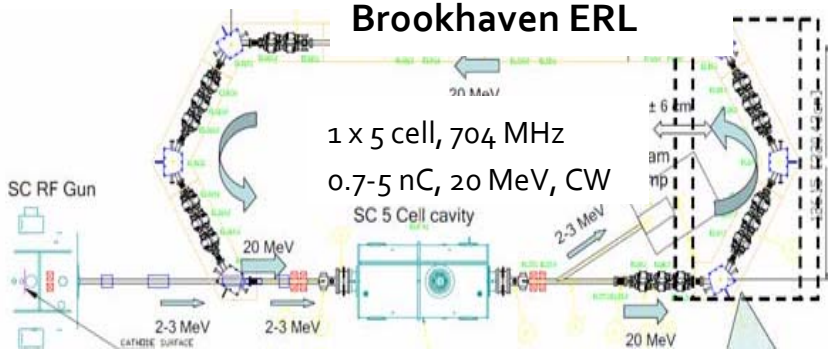
2 x 9 cell, 1.3 GHz
100 pC, 10 MeV, 100 µs bunch train

2-loop cERL, KEK



9 cell, 1.3 GHz cavities, 4 modules
77 pC, 245 MeV, 1-3 ps

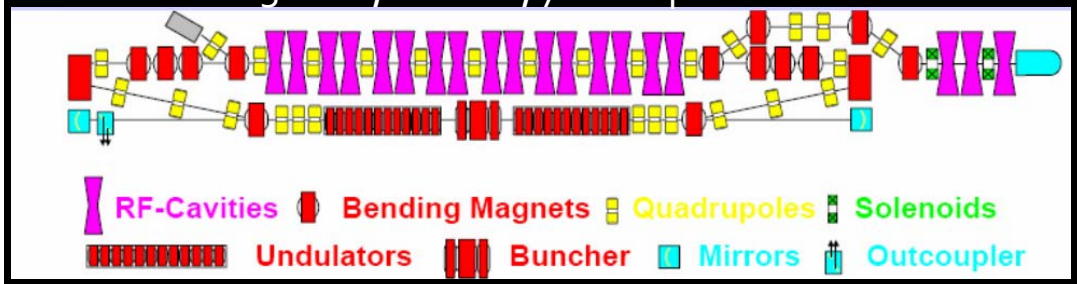
Brookhaven ERL



1 x 5 cell, 704 MHz
0.7-5 nC, 20 MeV, CW

… and of course BINP, here in Novosibirsk:

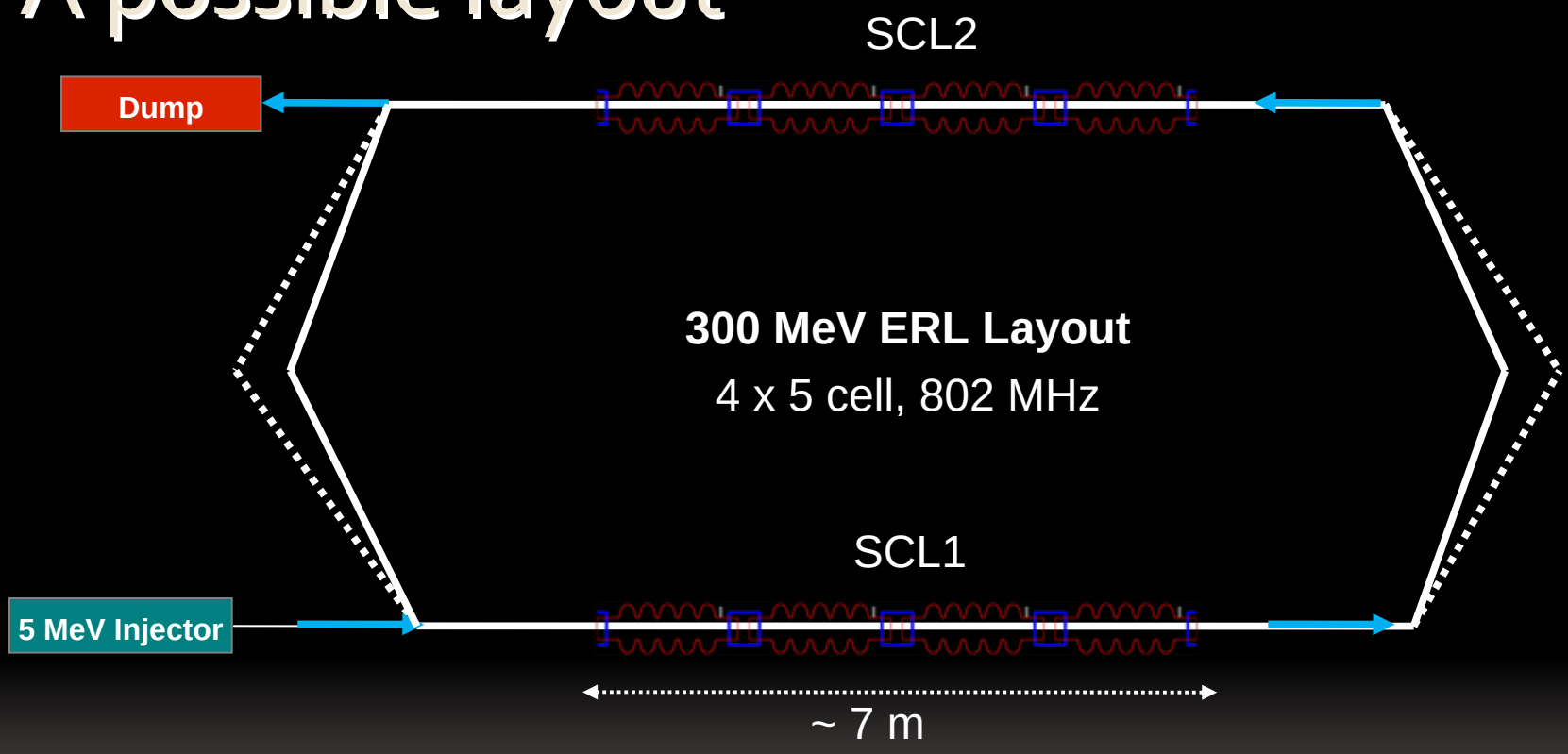
Normal Conducting 180 MHz + DC Gun
30 mA, 11 MeV, 70-100 ps



Preliminary parameters of CERN ERL-TF

Parameter	Value
Injection energy	$5\ MeV$
# of passes	$2\ (3)$
Energy gain per pass	$2 \cdot 75\ MeV\ (2 \cdot 150\ MeV)$
Max energy	$300\ MeV\ (450\ MeV\ \ldots 900\ MeV)$
Operation frequency	$801.58\ MHz$
RF power/CM	$< 50\ kW$
# cells/cavity · cavities/CM · CMs	$5\ \cdot\ 4\ \cdot 2\ (4)$
Bunch charge	$2 \cdot 10^9\ e = 320\ pC$
Beam current	$4 \cdot \frac{320\ pC}{25\ ns} \approx 50\ mA\ (100\ mA)$
Duty factor	CW

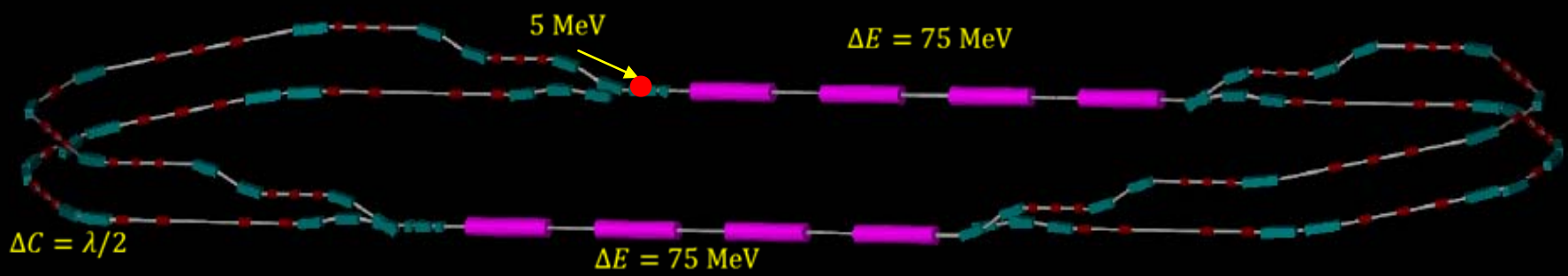
A possible layout



ERL-TF 300 MeV – Initial Layout

Alex Bogacz (JLAB)

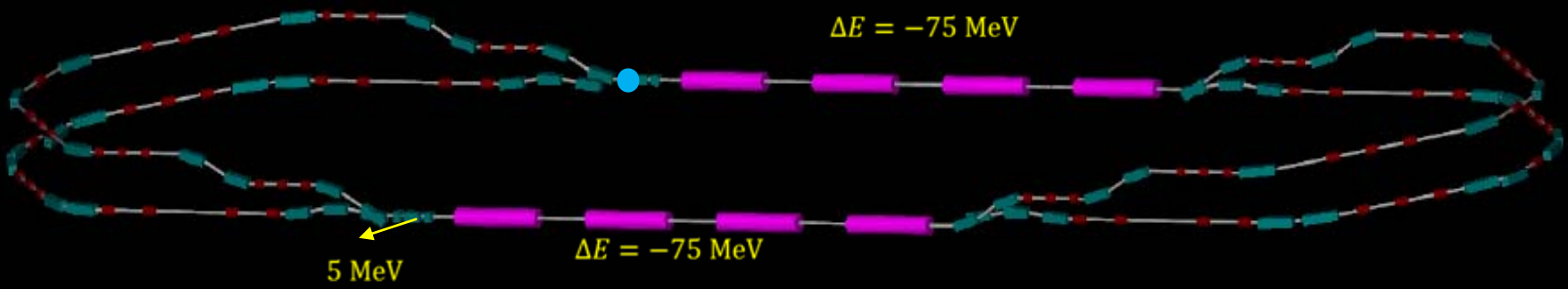
2 passes up:



ERL-TF 300 MeV – Initial Layout

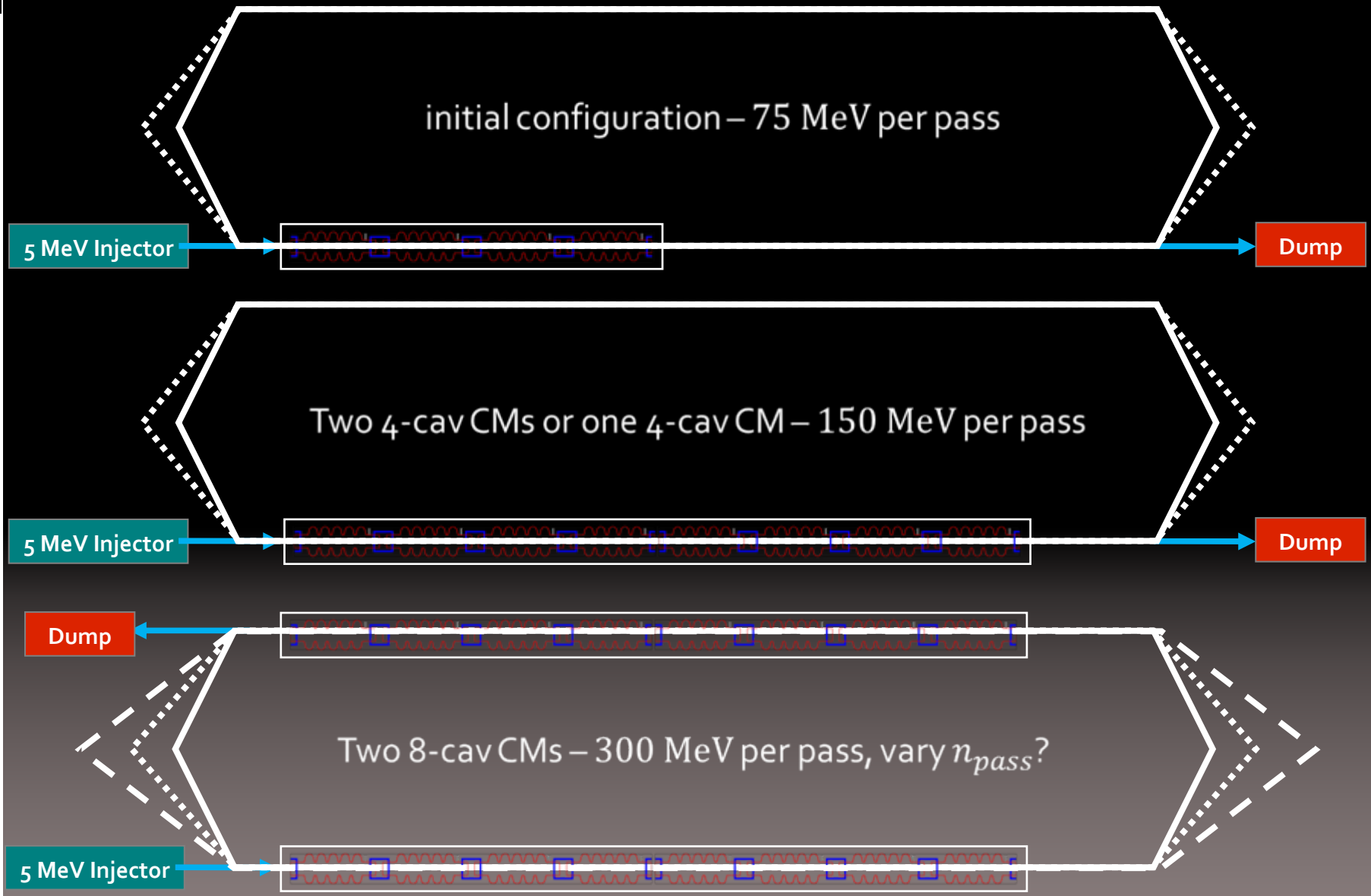
Alex Bogacz (JLAB)

2 passes down:

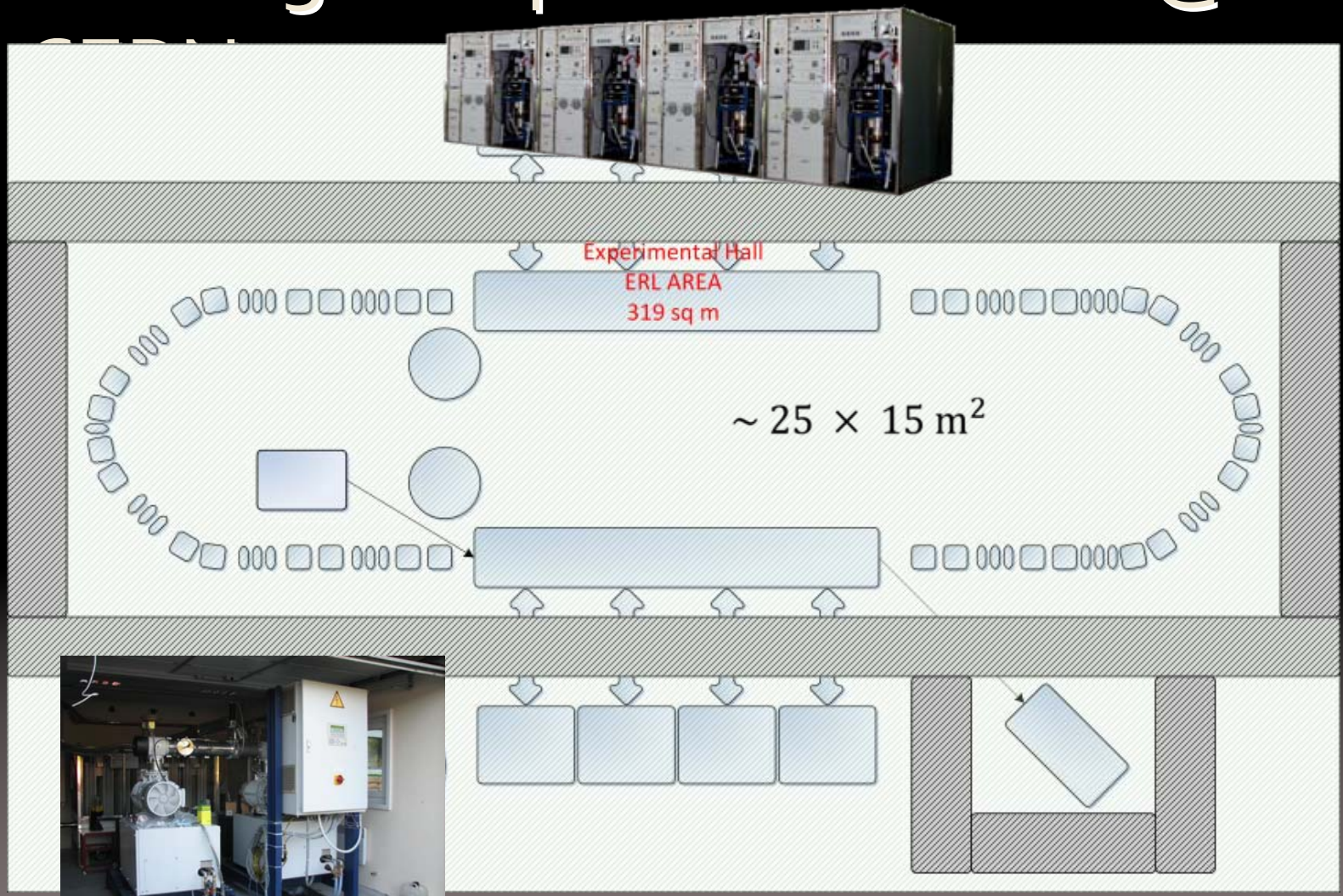


Variations – built-in flexibility

Alessandra Valloni (CERN)

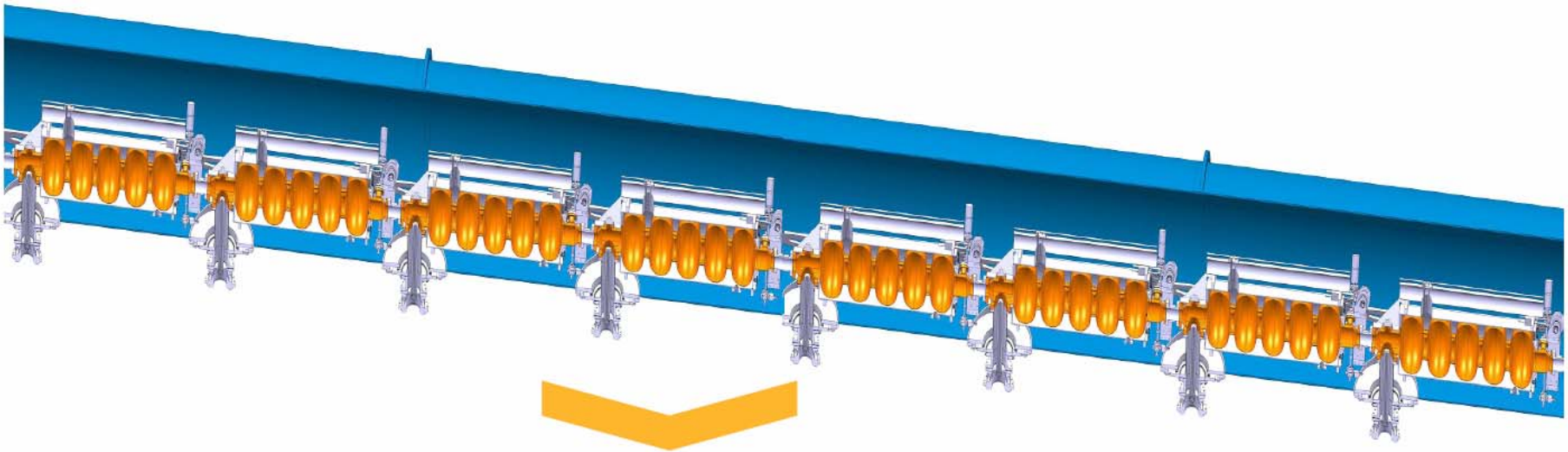


Looking at experimental halls @ CERN



801.59 MHz 8-cavity CM?

Alessandra Valloni (CERN)

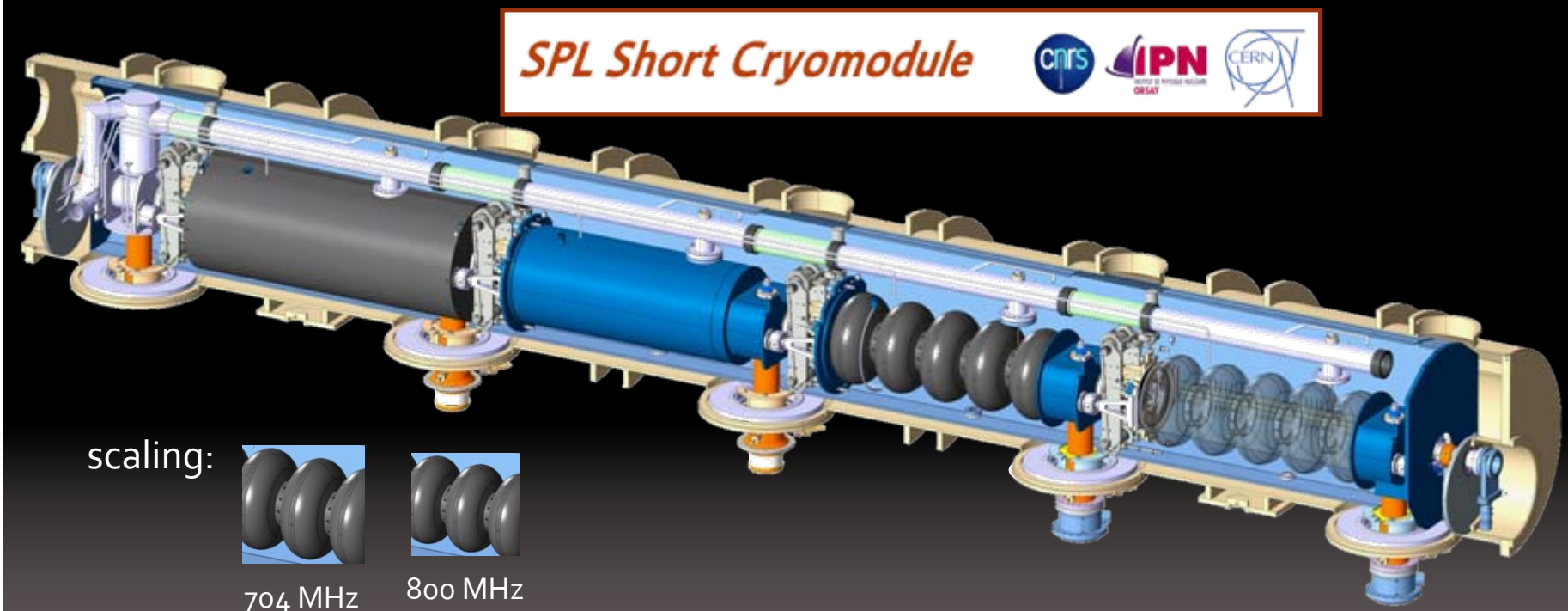


ONE CRYOMODULE: 8 RF CAVITIES

Parameter	Value
Input energy	5 MeV
ΔE	149.7 MeV
Energy after 1st pass	154.7 MeV
Energy after 2nd pass	304 MeV
Total length CM	12.6 m

Relevant ongoing work at CERN: SPL (704 MHz) CM

Vittorio Parma (CERN)

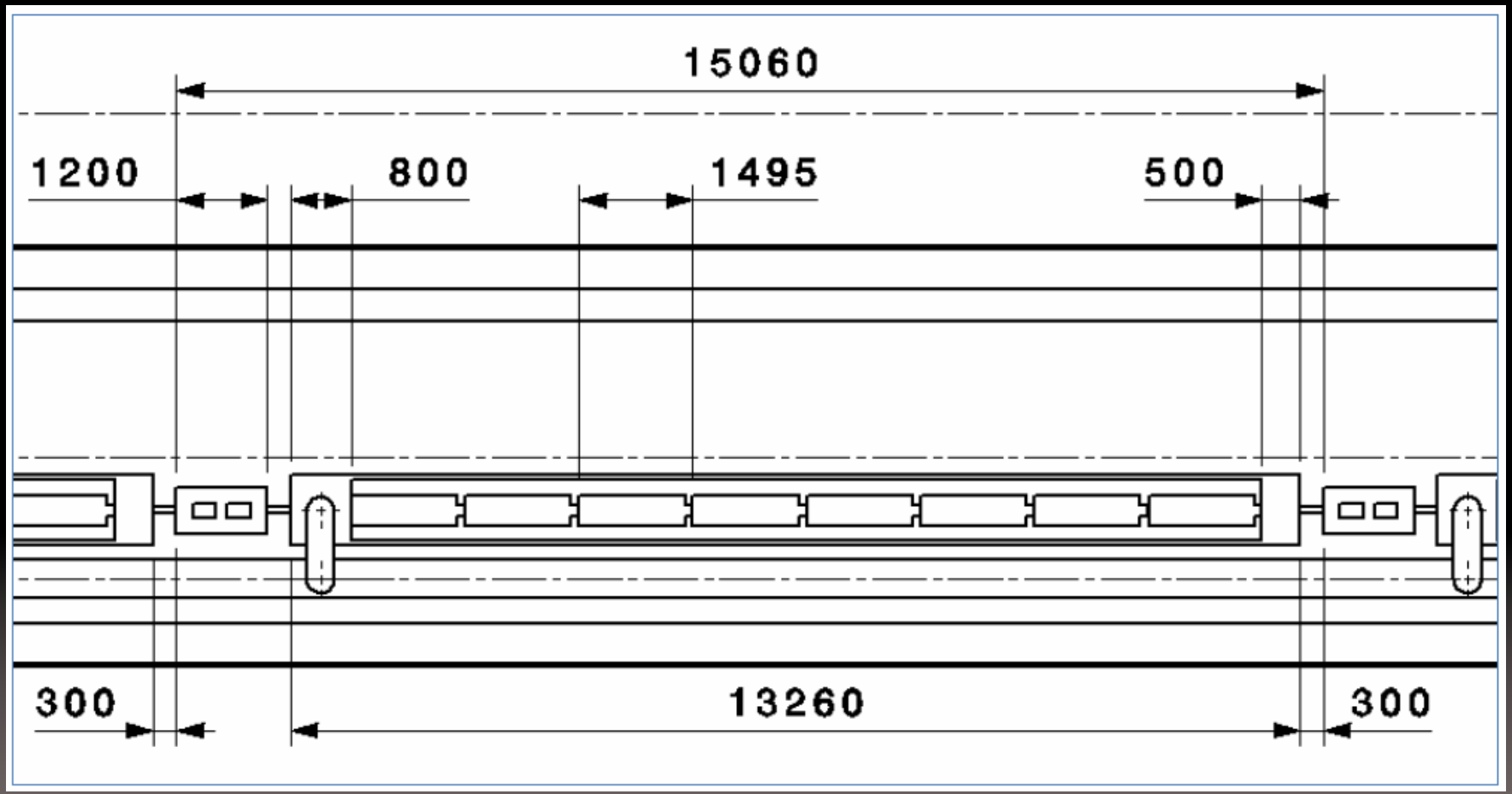


scaling:

704 MHz

800 MHz

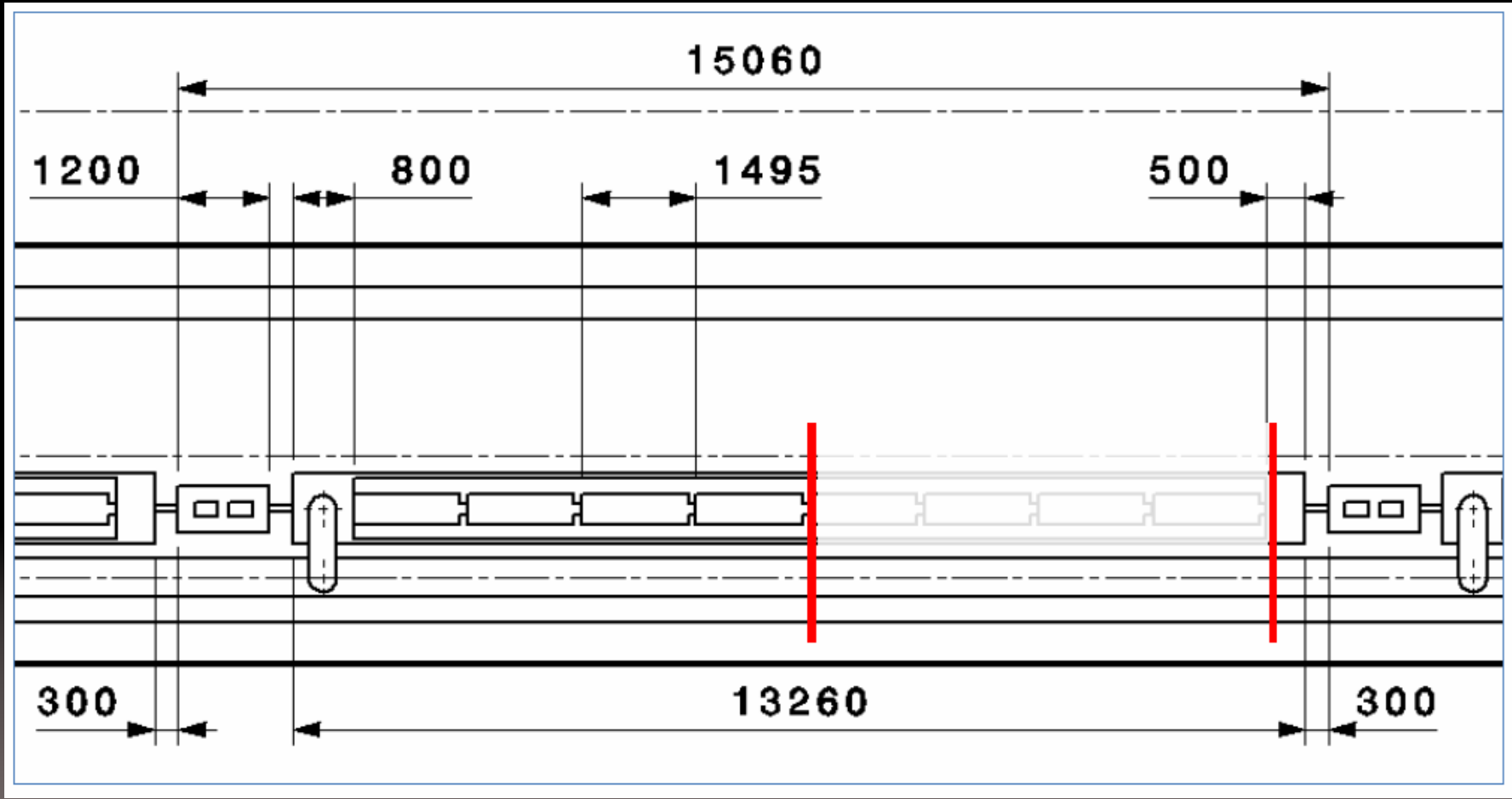
SPL $\beta = 1$ long (8-cav.) CM in the linac



Remark: designed for slope 1.7 %

Vittorio Parma (CERN)

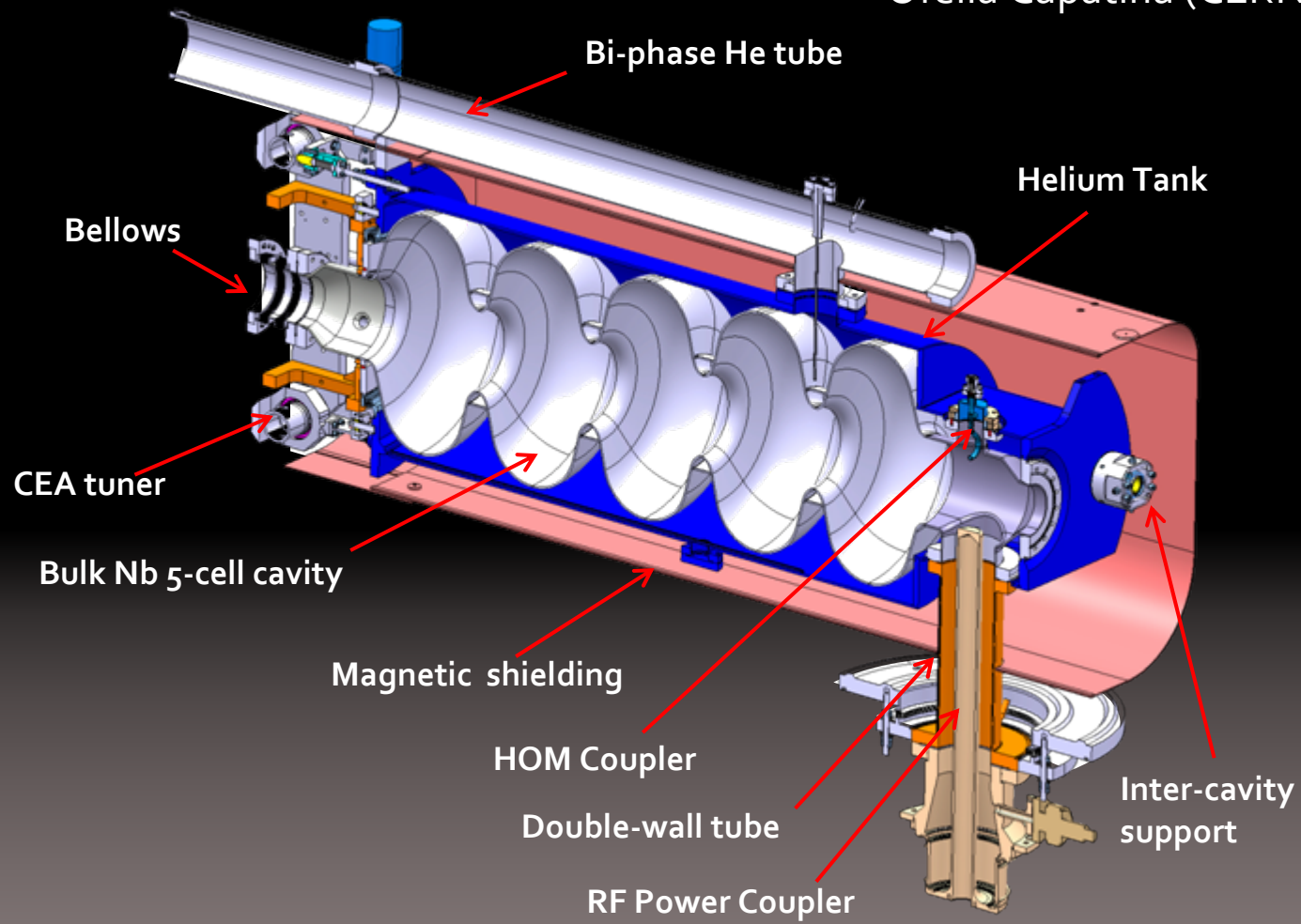
SPL $\beta = 1$ short (4-cav.) CM; length ~7 m



Vittorio Parma (CERN)

SPL CM Design

Ofelia Capatina (CERN)

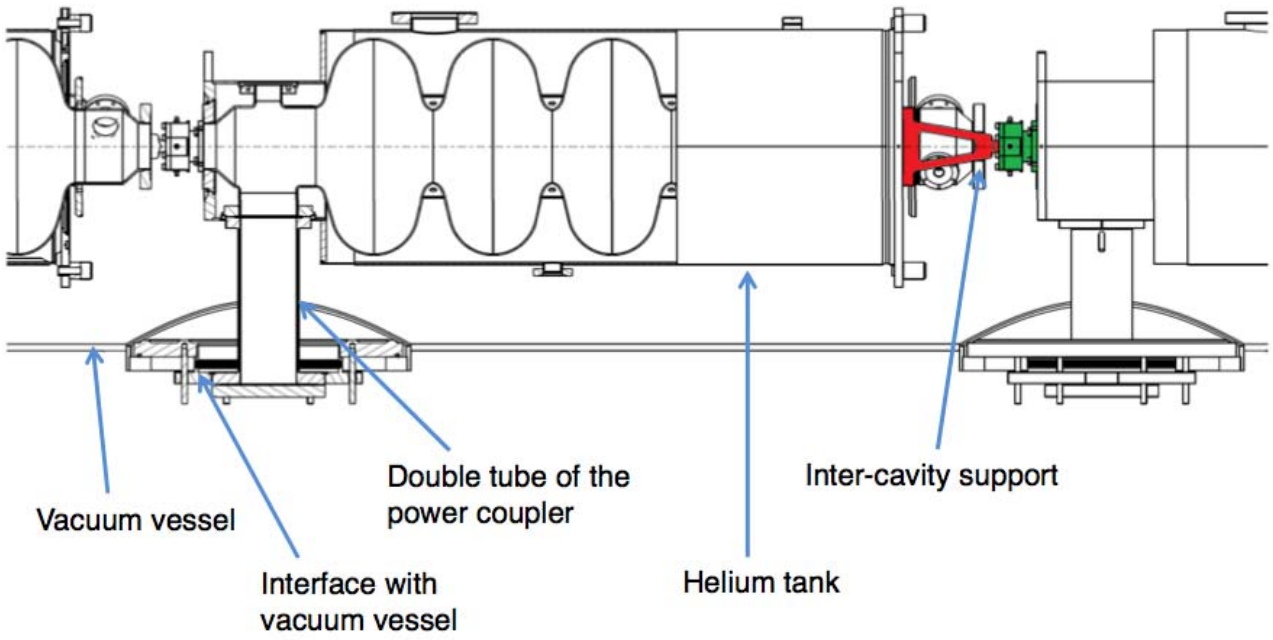


SPL CM Design

Arnaud Vande Craen (CERN)

1. Overview of cavity supporting system

Power coupler as support concept



SPL CM Design

Arnaud Vande Craen (CERN)

Requirements of the cavity supporting system

- Provide support of components: cavities, helium vessels, tuners, etc.
- Guarantee cavity (beam axis) alignment during entire life cycle
- Minimize thermal load

Cavities positioning tolerance with respect to beam axis:

BUDGET OF TOLERANCE				
Step	**Sub-step**	**Tolerances (3σ)**	**Total envelopes**	
Cryo-module assembly	Cavity and He vessel assembly	*± 0.1 mm (TBD)*	Positioning of the cavity w.r.t. beam axis **± 0.5 mm**	Construction precision
	Supporting system assembly	*± 0.2 mm (TBD)*		
	Vacuum vessel construction	*± 0.2 mm (TBD)*		
Transport and handling (± 0.5 g any direction)	N.A.	*± 0.1 mm (TBD)*	Stability of the cavity w.r.t. beam axis **± 0.3 mm**	Long-term stability
Testing/operation	Vacuum pumping	*± 0.2 mm (TBD)*		
	Cool-down			
	RF tests			
	Warm-up			
	Thermal cycles			

SPL CM Assembly sequence

Rossana Bonomi(CERN)

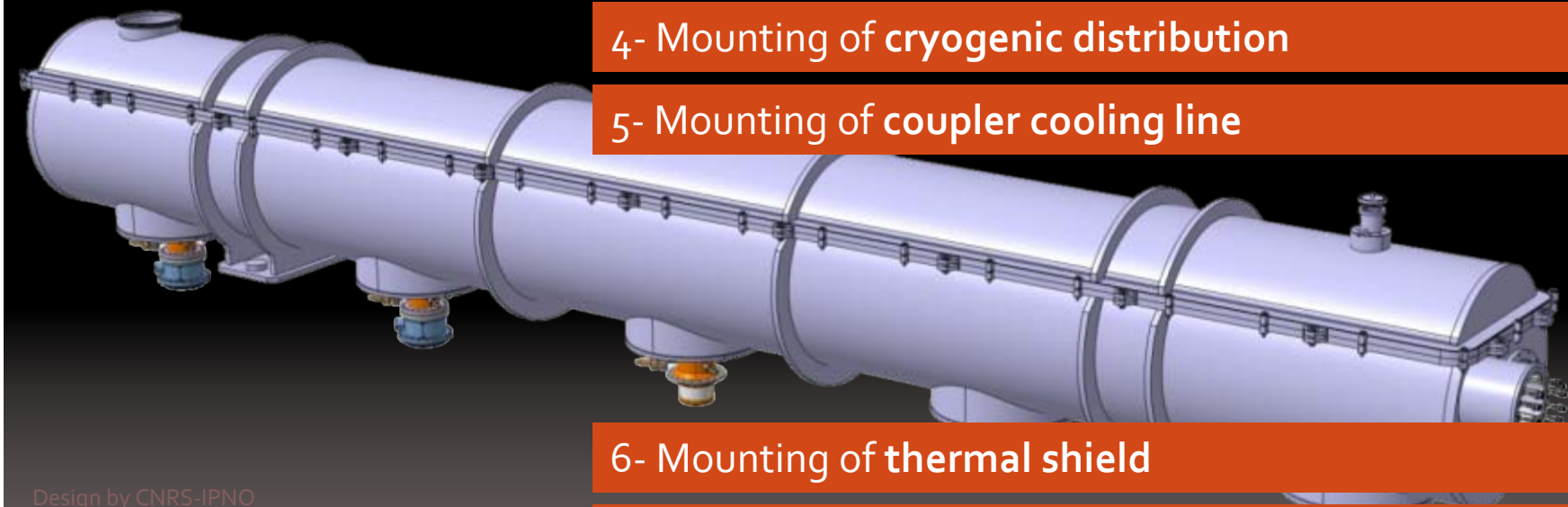
1- String of dressed **cavities** from clean room

2- Mounting of **magnetic shields**

3- Mounting of **tuners** and **inter-cavity supports**

4- Mounting of **cryogenic distribution**

5- Mounting of **coupler cooling line**



6- Mounting of **thermal shield**

7- **Insertion** in vacuum vessel

8- **Closing** vacuum vessel

Design by CNRS-IPNO
(courtesy of S.Rousselot)

Not latest design !

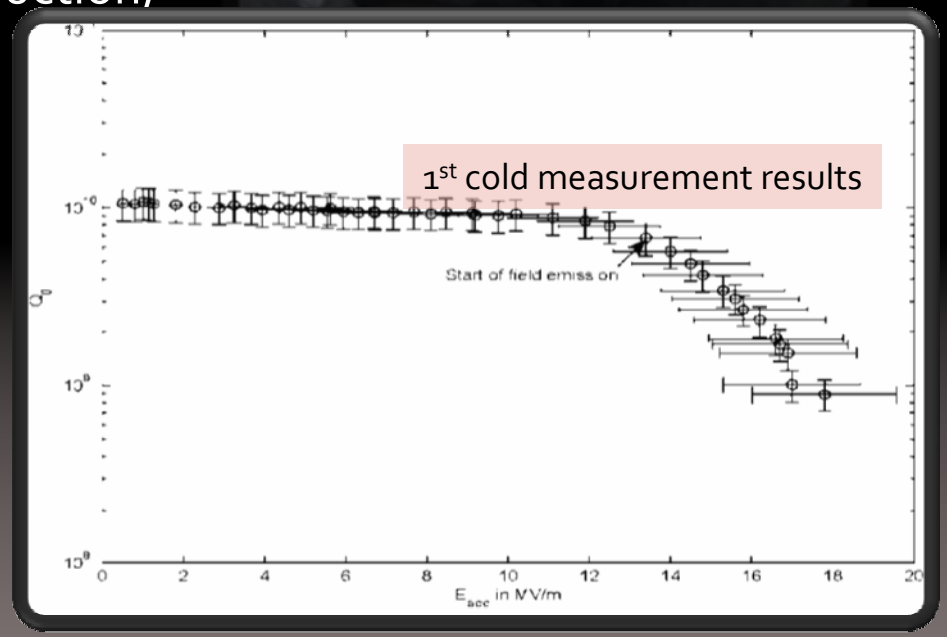
Cryo-load estimate (very preliminary)

- Ref: 75 MeV in a 4-cavity module (20 $\frac{\mathrm{MV}}{\mathrm{m}}$): heat load @1.8 K: 250 W, scales as:

$$\frac{heat\ load}{250\ \mathrm{W}} \approx \left(\frac{energy\ gain}{75\ \mathrm{MeV}}\right)^2$$

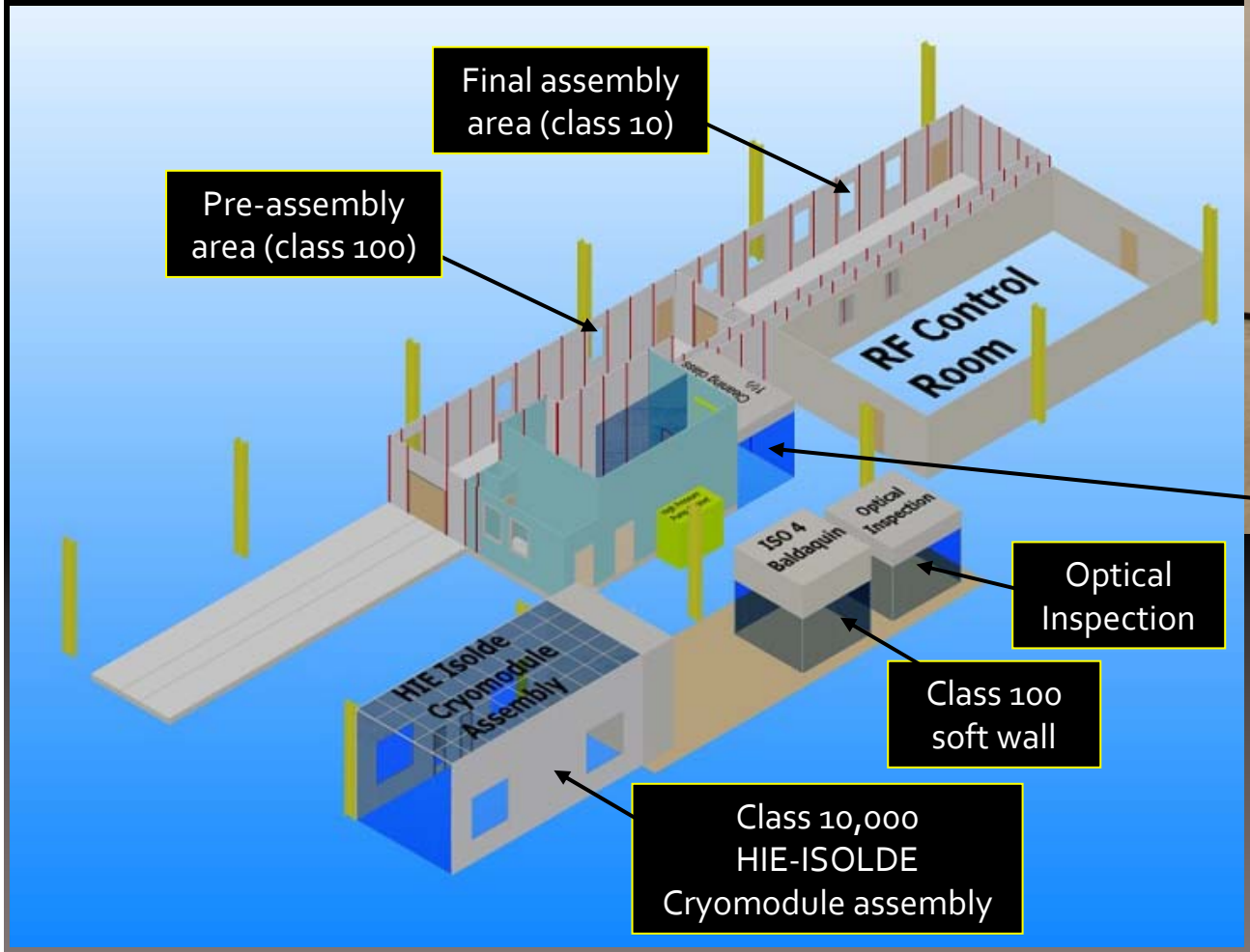
SPL Cavities

- 1st industrially produced cavity received Aug/12 from RI.
- Treated, rinsed & tested at CERN, 1st results encouraging (very preliminary).
- First of five 5-cell cavities in production,
- SM18 upgrade advancing well
- Clean room assembly planned I/2014



SM18 Cleanroom upgrade

Janic Chambrillon (CERN)



HPR Cabinet (BNL-SPEC)

SPL time-line (version 4/13)

Karl Schirm (CERN)

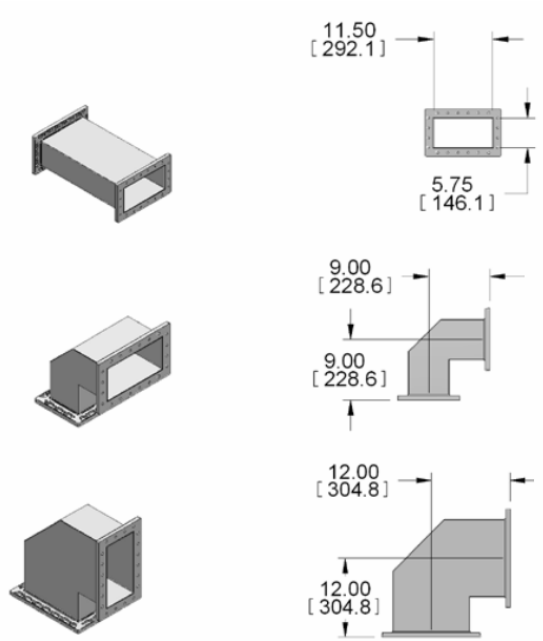
SPS 801 MHz system renovation

Eric Montesinos (CERN)

- CERN is upgrading the old SPS 801 MHz system ("Landau" cavities)

New CERN 801 MHz, 60 kW CW IOT transmitter
5 units received & tested, 4 to come

Thales trolley with IOT, 60 kW CW @ 801 MHz, BW-1dB > 6 MHz



Standard WR1150 waveguide components

Other cryomodules at CERN

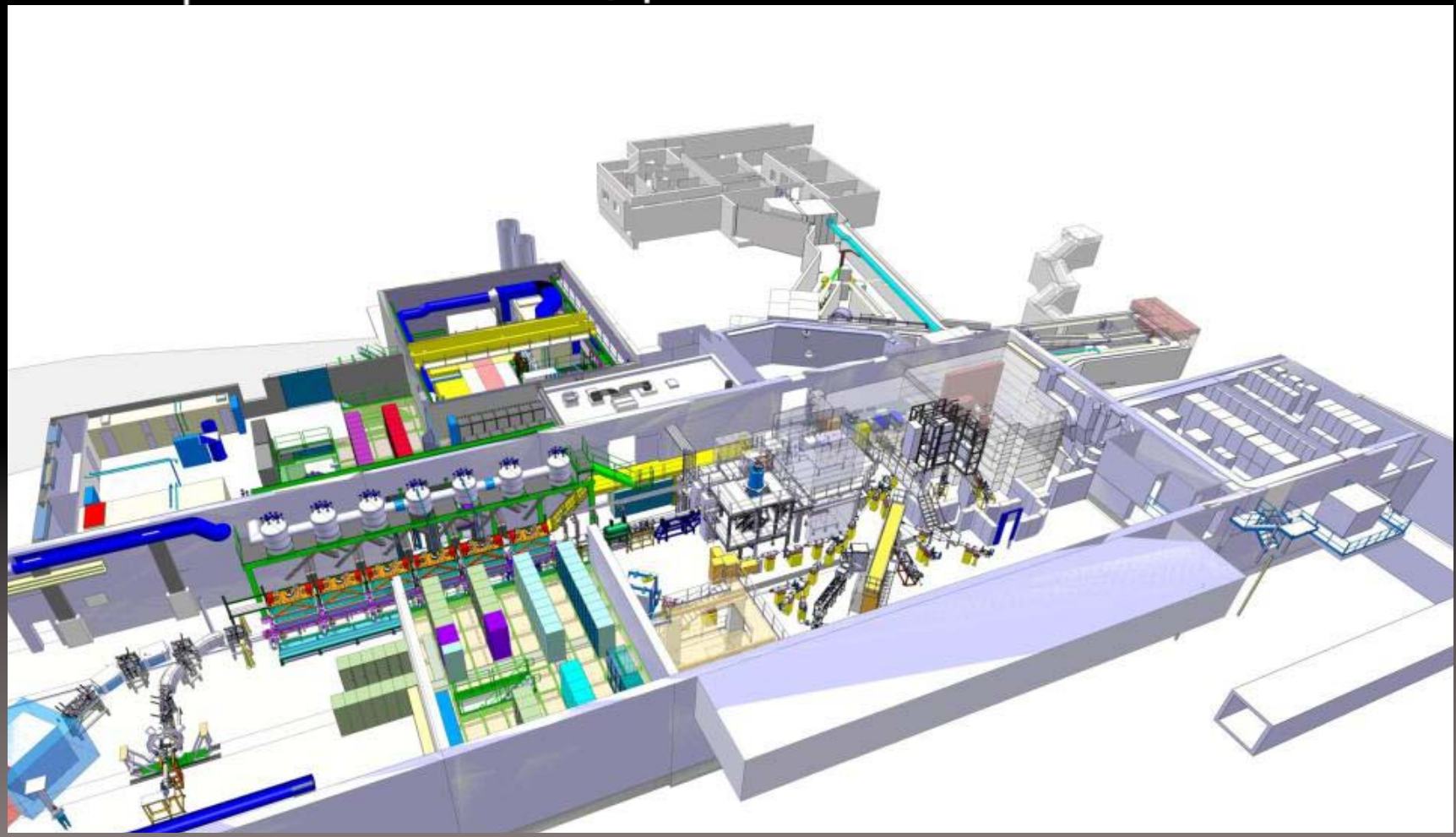
- LHC: 400 MHz;
- Nb sputtered on Cu
- 4 single-cell elliptical cavities in 1 CM
- 4 CM's in tunnel.

Other cryomodules at CERN

- Cryostats for RF tests

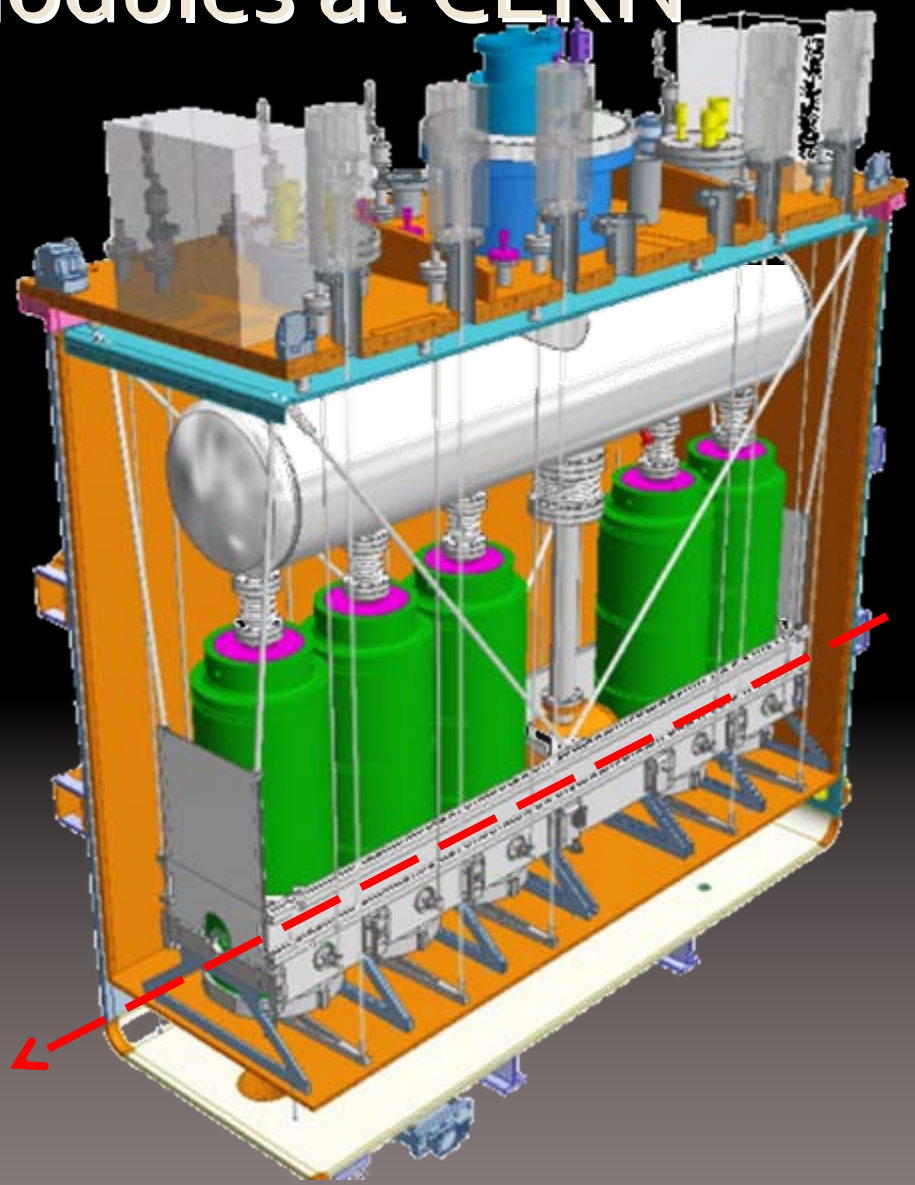
Other cryomodules at CERN

- HIE-ISOLDE: 6 high β + 2 low β CM's in series; Nb sputtered on Cu 1/4-wave resonators



Other cryomodules at CERN

- HIE-ISOLDE: high β CM



Conclusions

- ERLs – a fascinating concept, modern and energy efficient! CERN cannot ignore!
- As a 1st step to embark on ERL's, we propose an ambitious yet feasible ERL TF @ CERN.
- This facility is complementary to & synergetic with other proposals.
- As 1st step to the 1st step, we will – jointly with motivated, expert international partners – develop the necessary concepts and start prototyping.