Imperial College London

Science & Technology Facilities Council ISIS

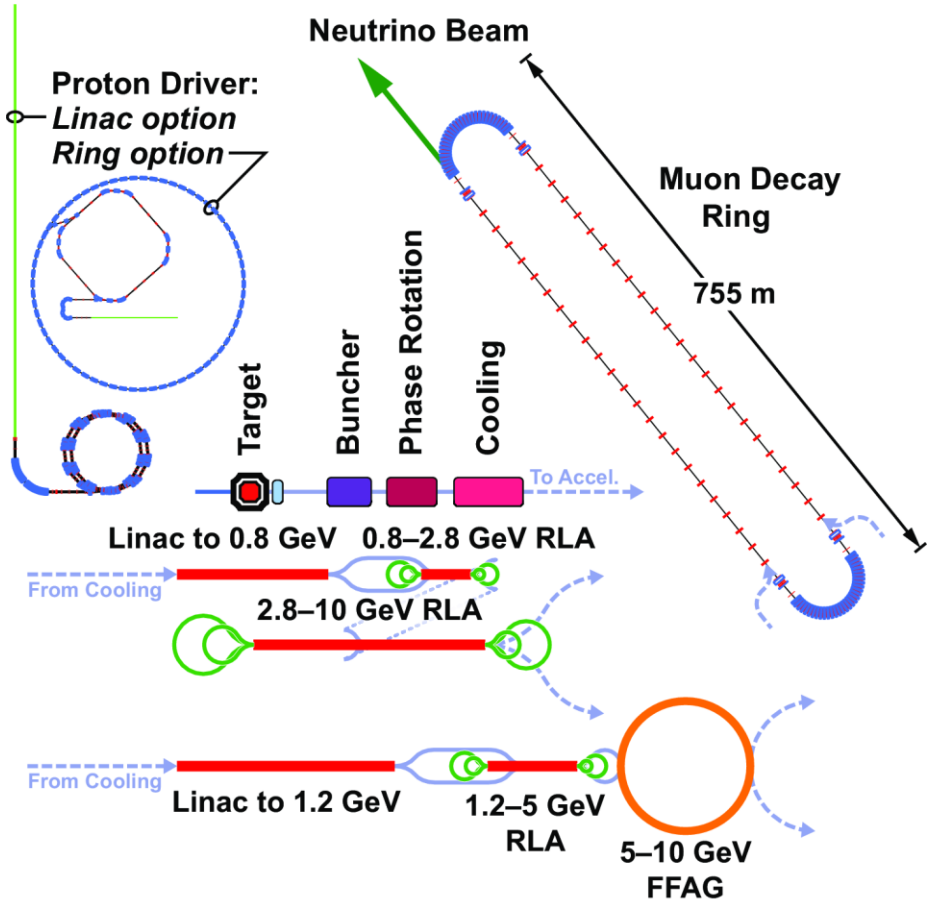
Accelerator Summary

J. Pasternak, Imperial College London / RAL STFC

10.10.2012, IDS-NF meeting, Fermilab

Outline

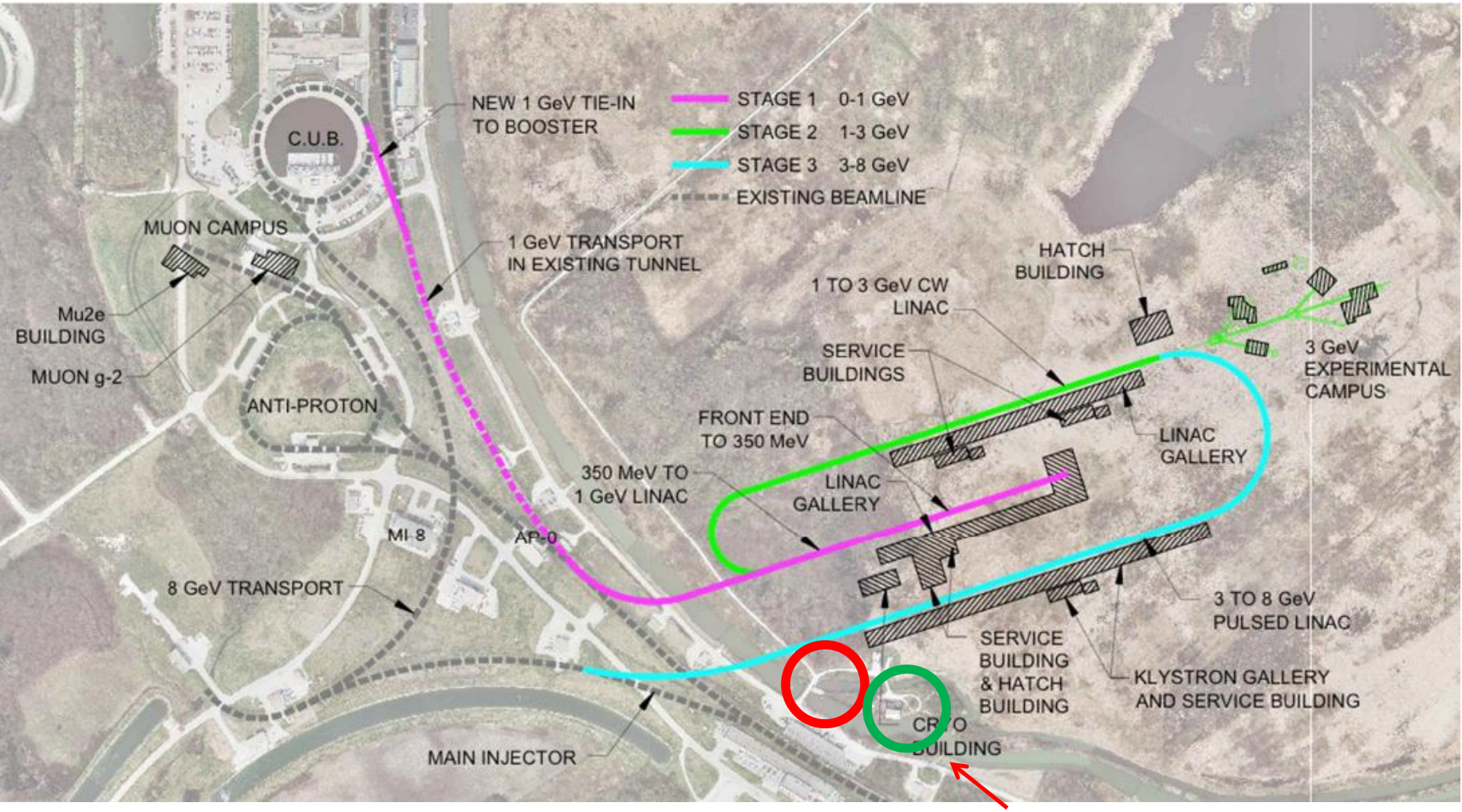
- Proton driver
- Target
- Front end
- RF in the magnetic field
- Baseline decision in the front end
- Acceleration
- Baseline decision in acceleration
- Decay ring
- Summary



Proton Driver Options for the NF

Base	Upgrades	Final Energy
ISIS	RCS Compressor?	9.6 GeV
SPL	Upgrade Linac Additional GeV of Linac Accumulator Compressor	5 GeV
Project X	Upgrade Linacs Accumulator Compressor	8 GeV

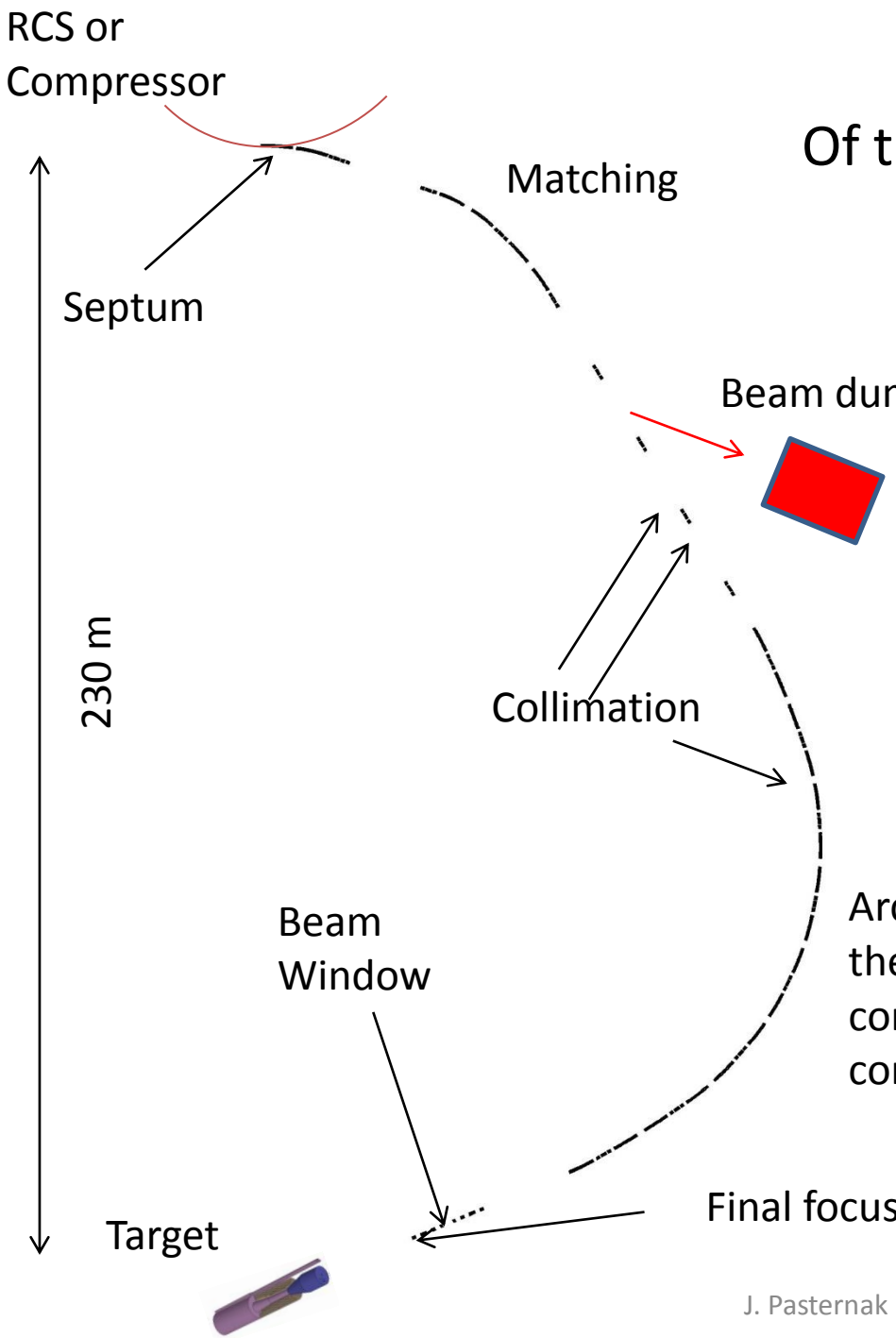
Project-X Staging



From Gollwitzer -- 9th IDS-NF Meeting

Additional Rings for the NF

Preliminary Layout
Of the beam transport to the target
(Needs to be updated)

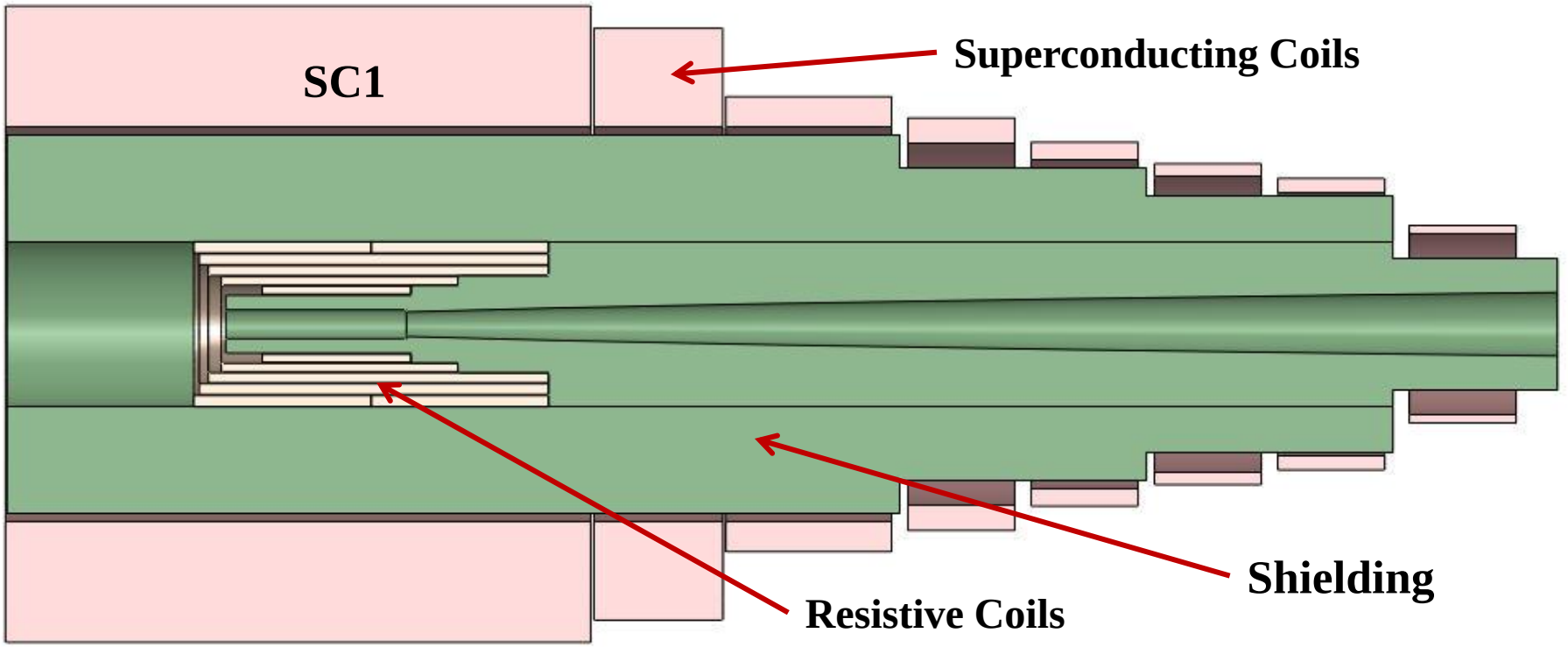


Better idea would be to set the dump as a default configuration so an additional kicker system would be required to send the beam to the target.

Arc to manipulate
the longitudinal dynamics via
controlling eta (to maintain the bunch
compression without the RF system).

From J. Pasternak

Target
Coil and Shielding Concept (IDS120h)



Key Parameters: SC1 IR = 120cm Stored Energy 3GJ

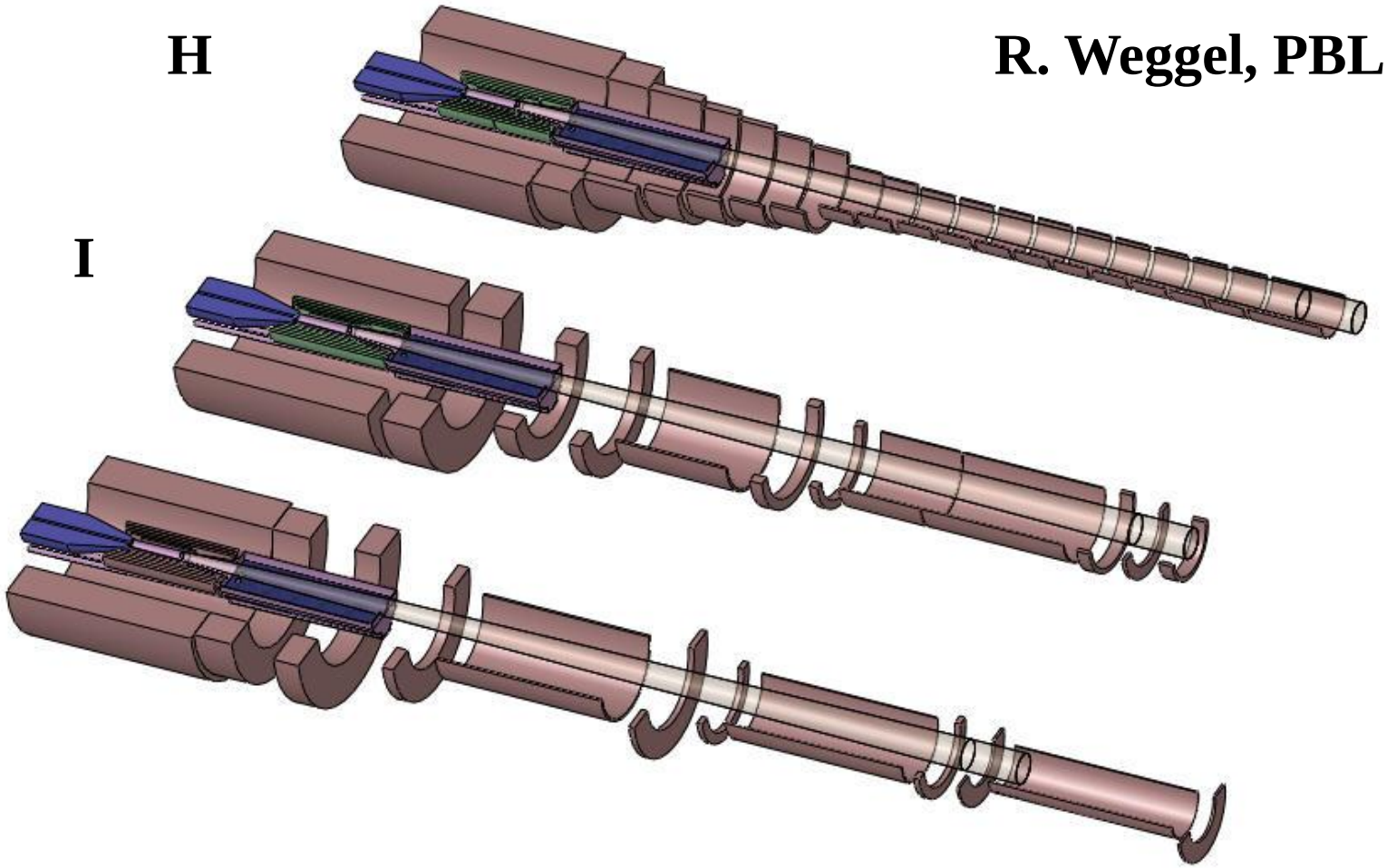
B = 20 T

Introduce Discrete Cryo Modules

H **R. Weggel, PBL**

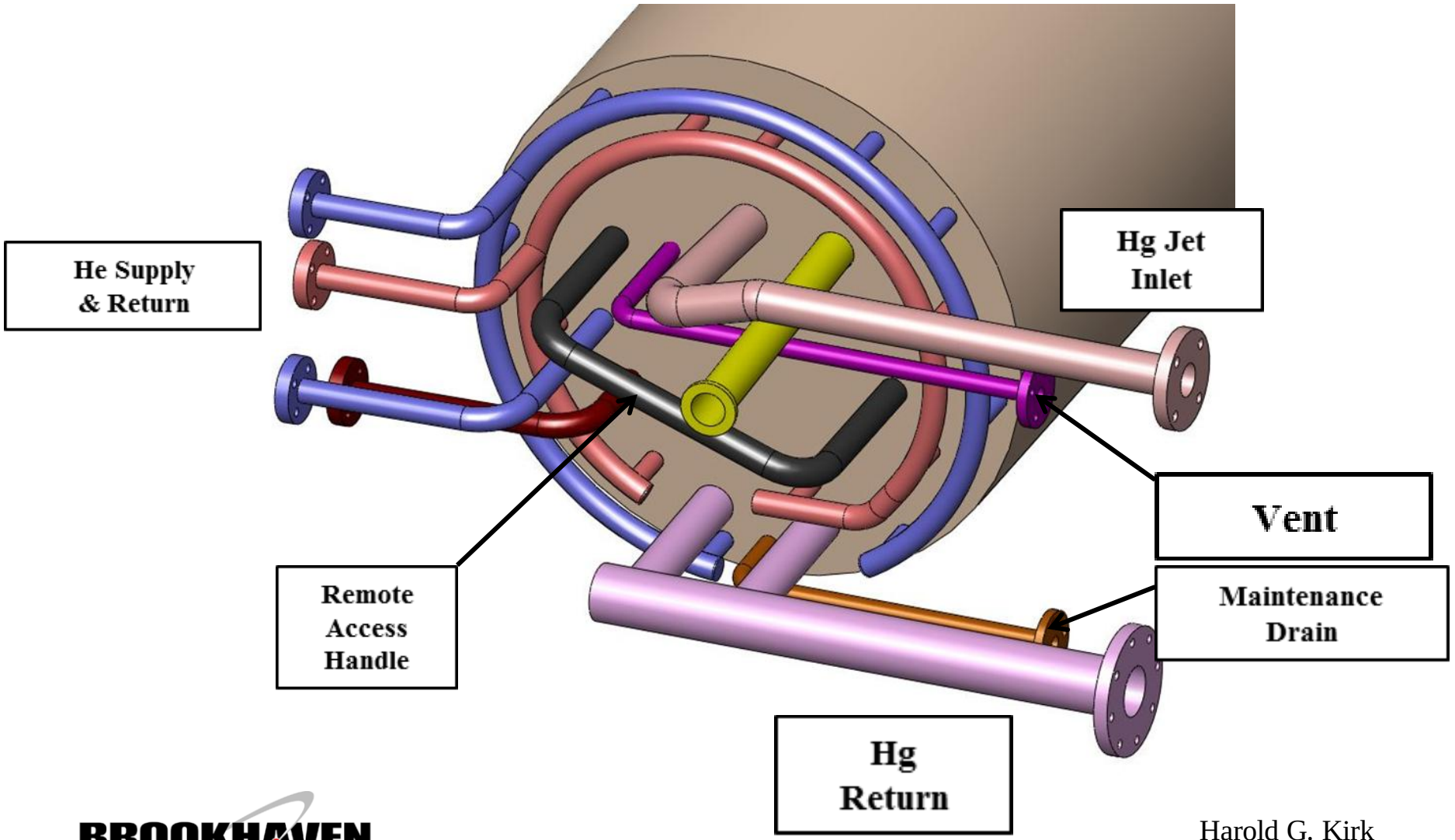
I

J



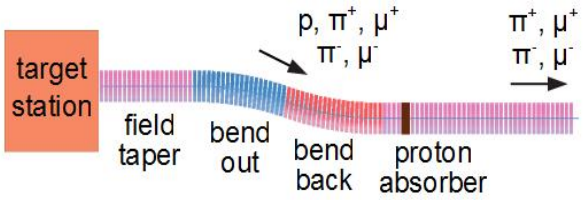
Harold G. Kirk
Brookhaven National Laboratory

Target Module Services



chicane works!

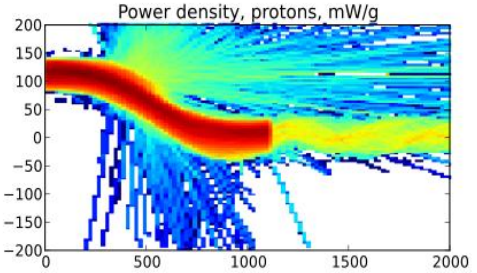
From D. Neuffer



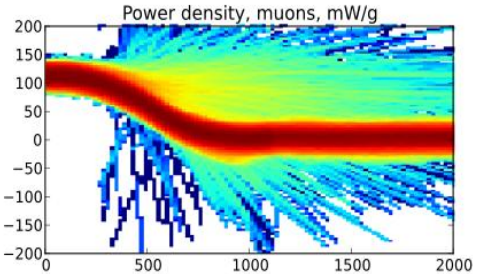
Chicane schematics

Chicane does not reduce transmission by much:

- 0.098 → 0.094 (?) within acceptan
  - ~0.107 without chicane/absorber
- Removes unwanted high energy particles
  - eliminates prepulse from high-energy muons
- Works for both μ+ and μ-



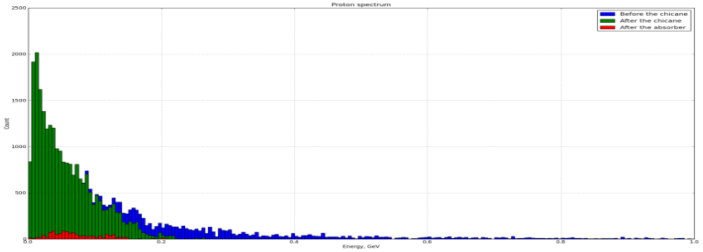
Power density, protons, mW/g

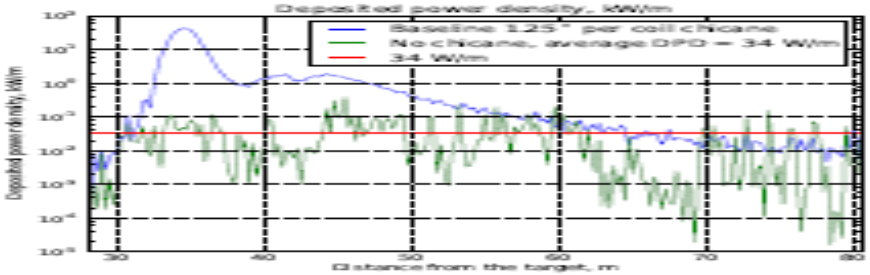


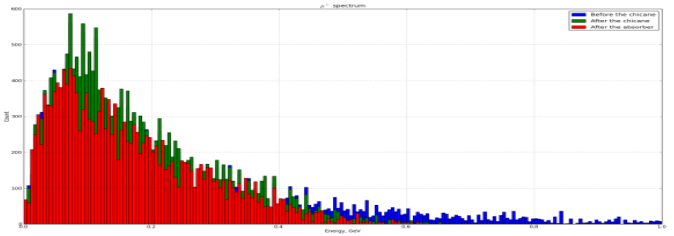
Power density, muons, mW/g

Integrate into Engineering design?

- Optimize chicane/absorber parameters







Phase Rotation CAD Model

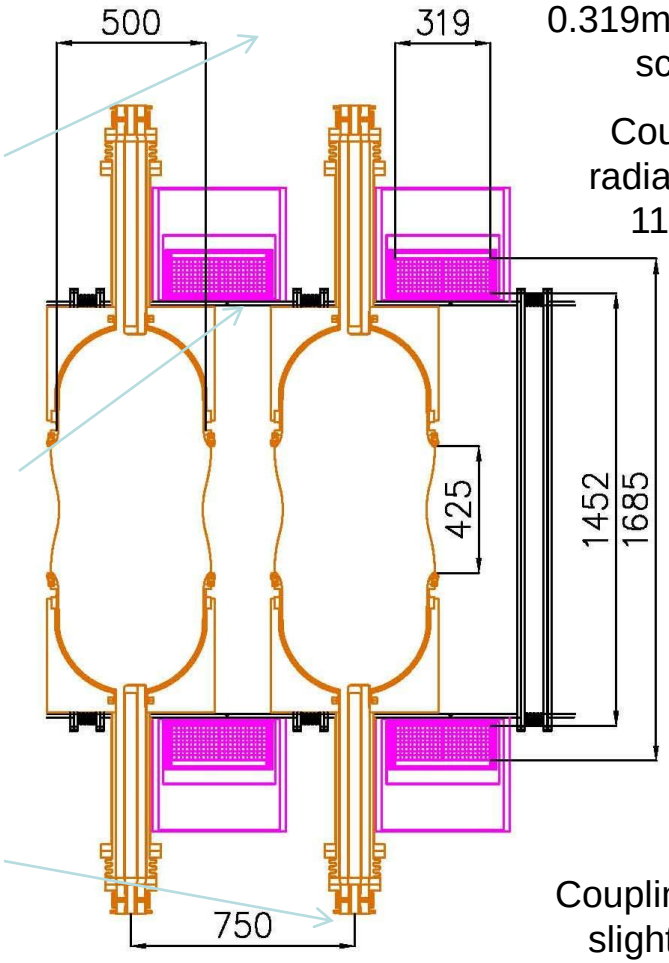
Cavity based on MICE cavity but stretched to 0.5m.

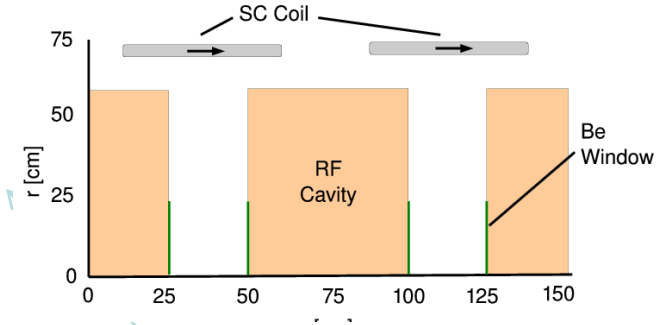
Bellows required.Only place to position these is between coupling coils.

Cell length 0.75m as schematic.

Coupling coil shown at 0.319m **NOT** 0.5m as schematic.

Coupling coil radial thickness 116.5 mm.

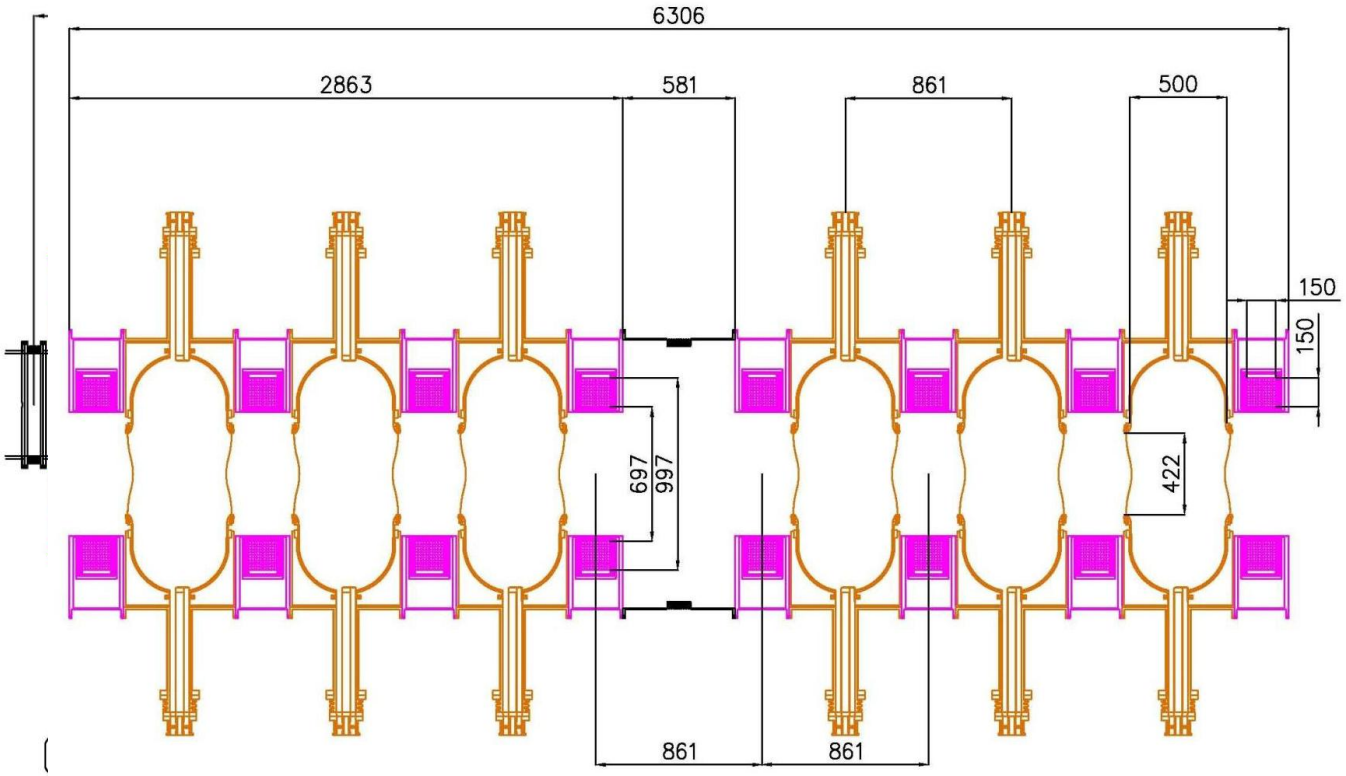




Coupling coil diameter slightly larger than schematic by 92mm

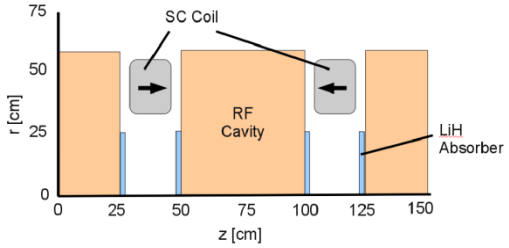
Phase Rotation Cell

Cooling Section CAD Model



Cooling Cell Section showing 2 modules

Total Cooling Section Cell length is approximately 95.7m. NOT 75m as schematic.

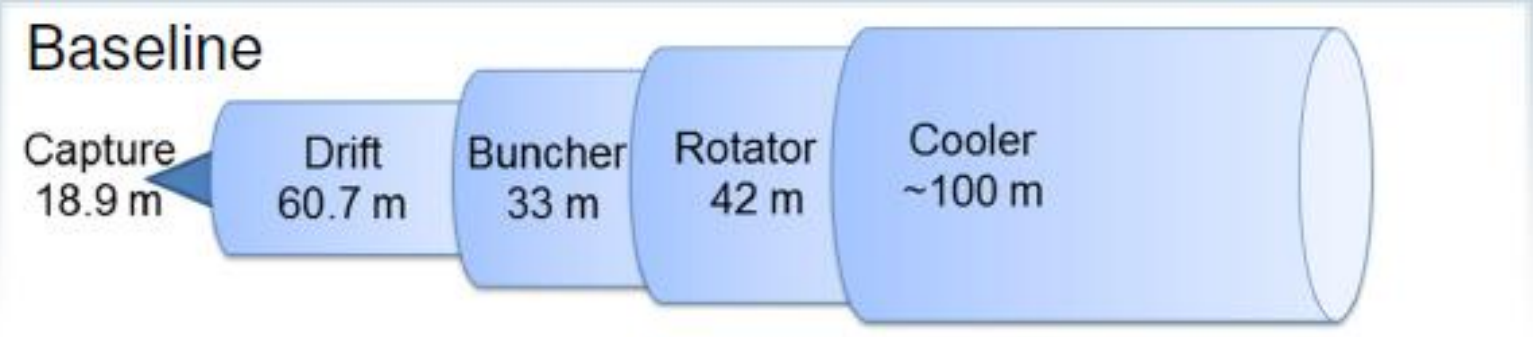


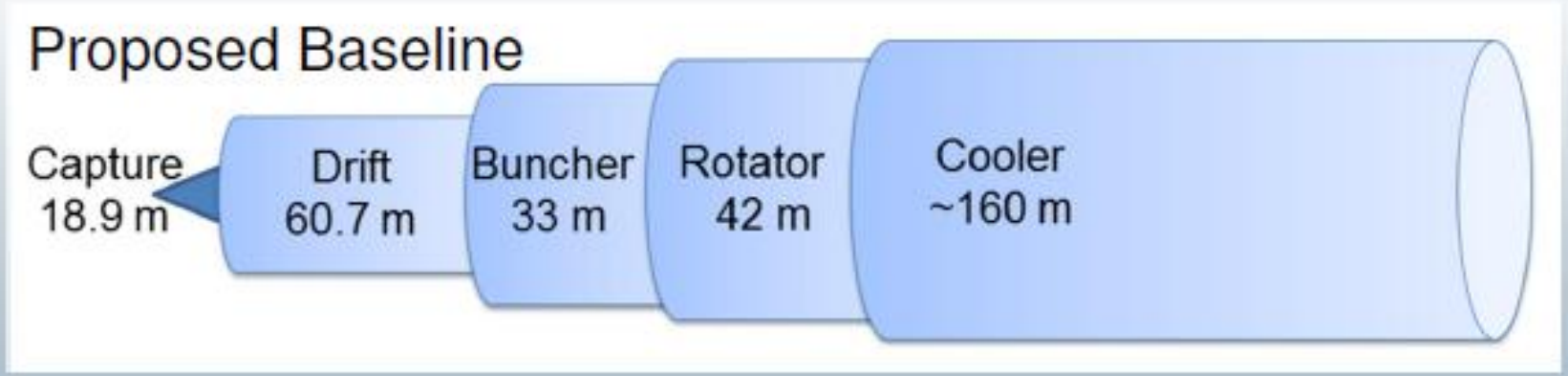
Fitting coils between cavities is a problem…

Cell length increased to →86cm (from 75) + breaks in periodicity

- **probably some loss in cooling –**
- **must study and consider alternatives …**

New Baseline (NBL) Parameters (1)





From D. Stratakis

Experimental status of RF operation in the magnetic field

Cavity Summary

Cavity	Peak surf. field w/o B Field, w/o Beam (MV/m)	Peak surf. field w/ B Field, w/o Beam (MV/m)	Peak surf. field w/o B Field, w/ Beam (MV/m)	Peak surf. field w/ B Field, w/ Beam (MV/m)
201 MHz	21	12	-	-
805 MHz Pillbox (Be buttons)	40	33	-	-
All Seasons	25	25	-	-
HPRF (Cu buttons)	60	60	45*	45*

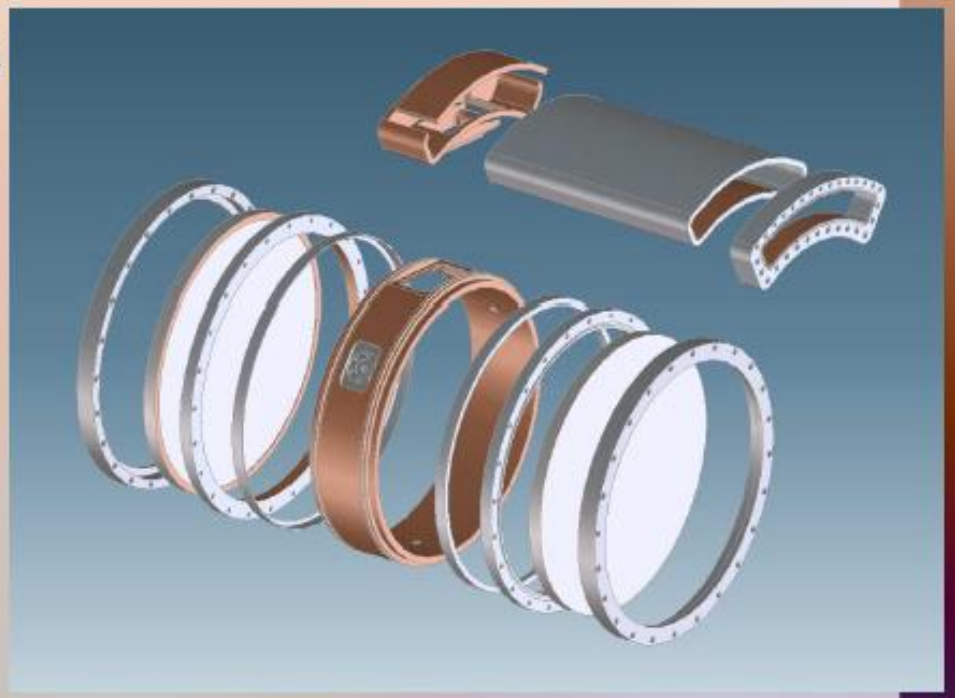
From B. Freemire

* DA doped H_2

New Pillbox Cavity Design

From B. Freemire

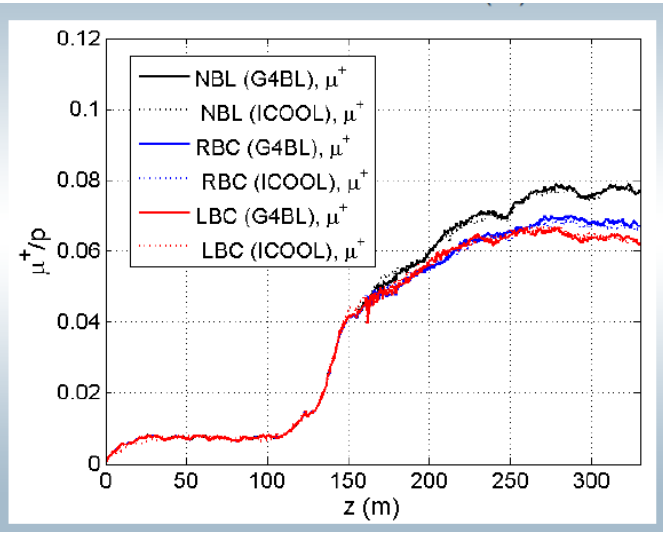
- A new Be wall cavity has been designed; fabrication to begin after review
- Modular
  - Easy removal of walls
  - Test Cu vs. Be walls
  - Possible to increase cavity length or add other hardware



- New coupler design should eliminate sparking

There are also expected tests of 201 MHz MICE cavity in the magnetic field.

Lattices with low magnetic field in the cavities



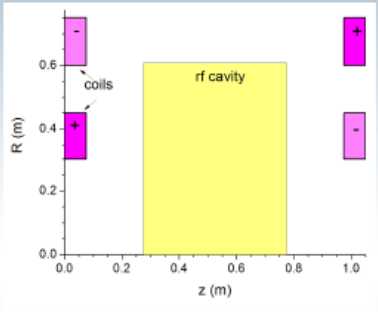
Bucked Coils (BC) scheme

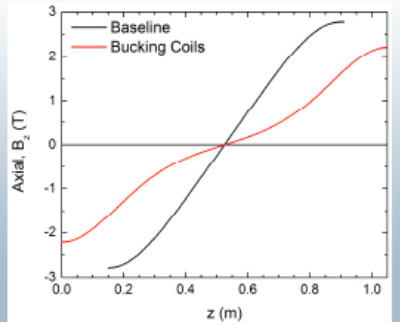
From D. Stratakis

Idea presented by R. Fernow in IDS-NF (2008) and A. Alekou at the IDS-NF (2010-2012)

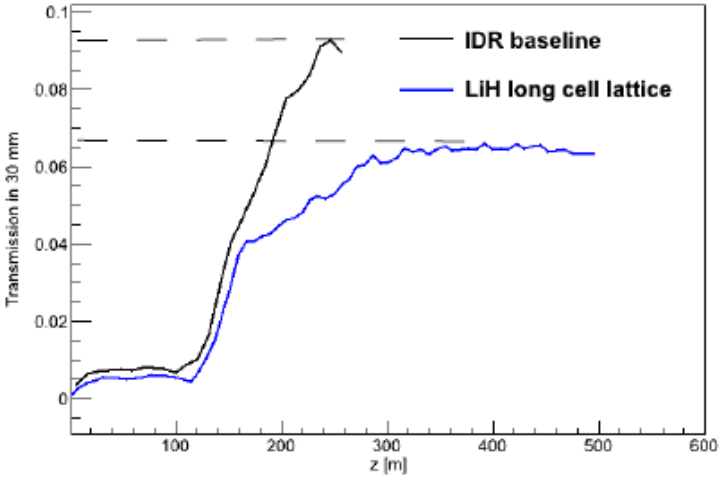
With bucked coils, the magnetic field drops within the cavity area.

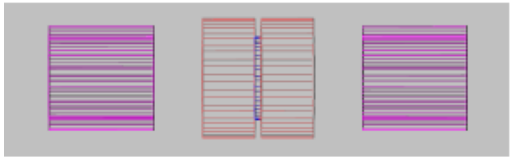
The concept shows promising [illegible] details later)





Shielded RF Cooling Channel





LiH length	46 mm
RF peak field	19 MV/m
RF phase	30 degrees
RF length	500 mm
Be window thickness	0.4 mm
Apertures	400 mm
Coil length	1000 mm
Coil radial thickness	100 mm
Coil inner radius	400 mm
Coil current	22 A/mm²

Shielded RF Cooling Channel, C. Rogers

Front End Baseline Decision at this meeting

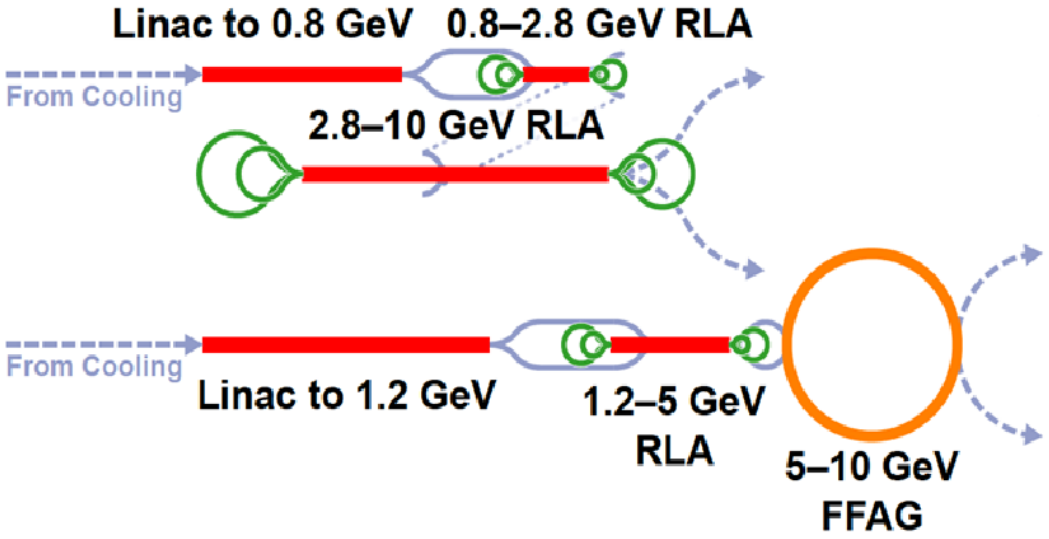
- There is no current clear understanding, if the problem of RF operation in the magnetic field is seriously limiting the baseline.
- More experimental studies are needed and are planned.
- Mitigating scenarios proposed to lower the magnetic field has lower performance compared with the baseline.
- They also do not remove completely the magnetic field from the cavity (the remaining field is lower, but still in the range of 0.3-1 T).

- The baseline solution is not based on the lattices with lower magnetic field.
- All changes into the IDS-NF baseline for the RDR will be driven by the feasibility based on engineering study.

10 GeV acceleration scenarios due to large θ_{13} Argument at NuFact'12

Option I

Option II



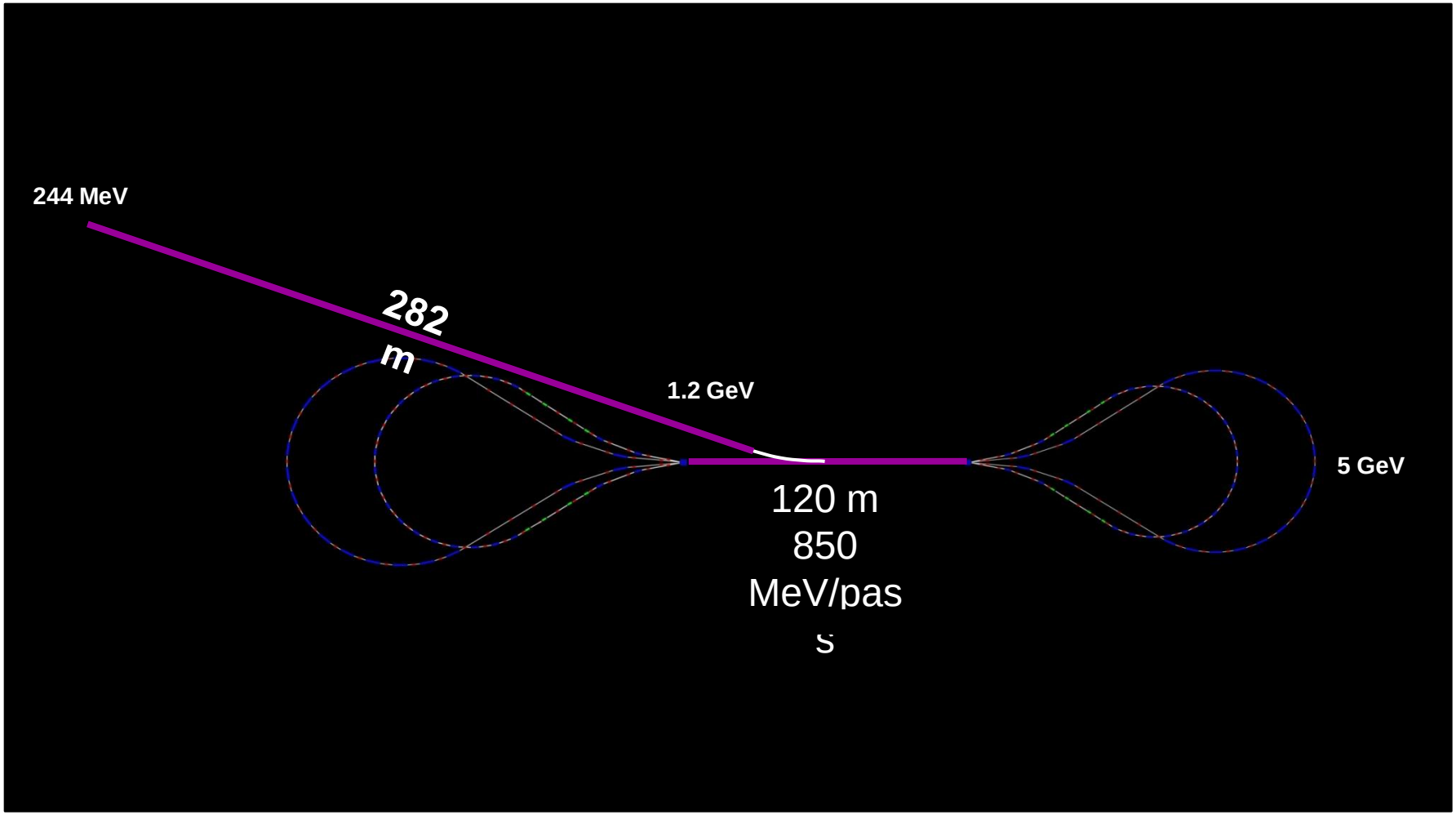
For 10 GeV muon acceleration two options have been proposed:

- **Option I:** using linac and two Recirculating Linear Accelerators (RLAs) – it is very similar to the previous baseline part up to 12.6 GeV

- **Option II:** using linac+RLA+ Nonscaling Fixed Field Alternating Gradient (NS-FFAG) ring – NS-FFAG could use the same technology developed for 12.6-25 GeV ring.

Option II was selected at the Nufact'12 due to 5 GeV breaking point, which was favoured as better for an intermediate staging for physics at that time.

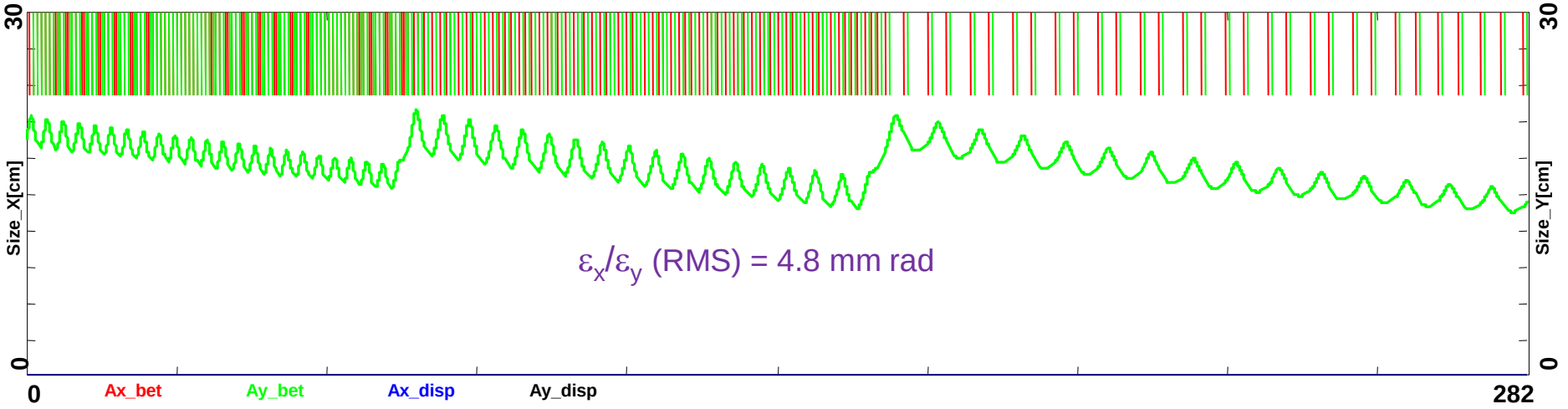
Linac and RLA – 'in plane' Layout

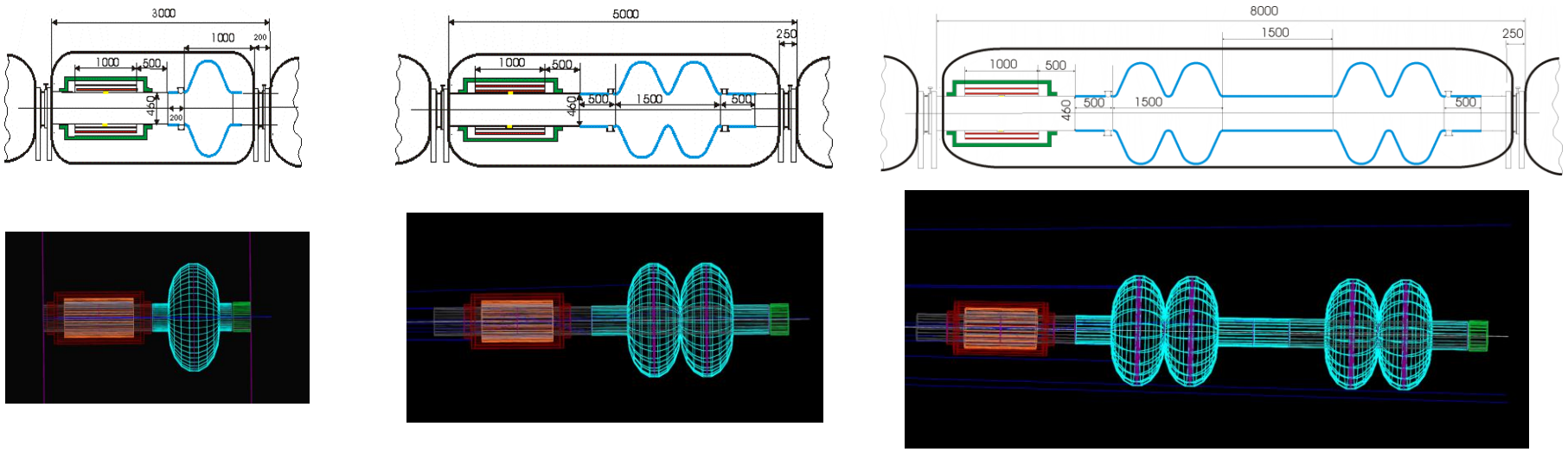


From A. Bogacz

Linac (beam envelope at 2.5σ)

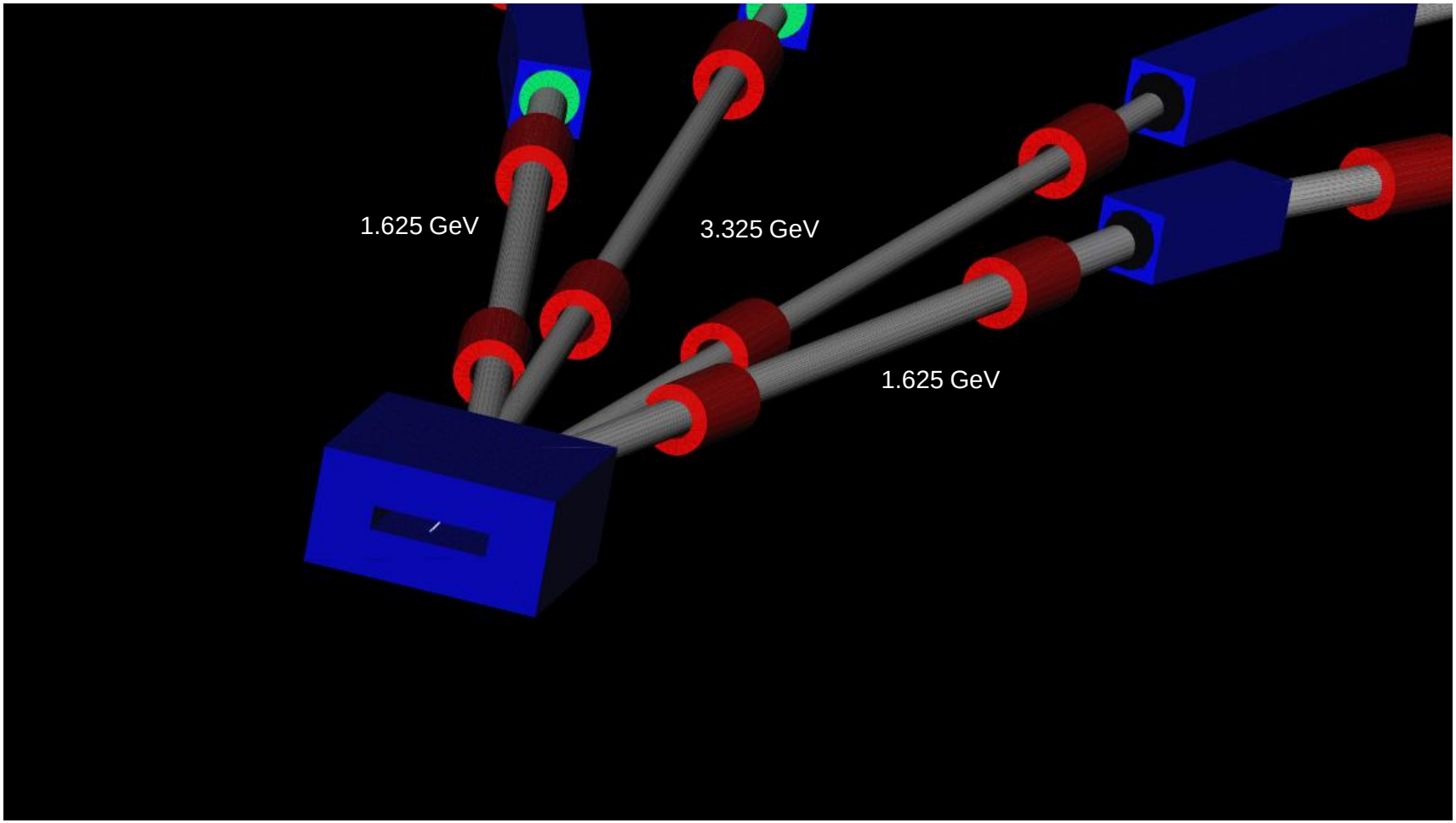
15 MV/m, r = 23 cm





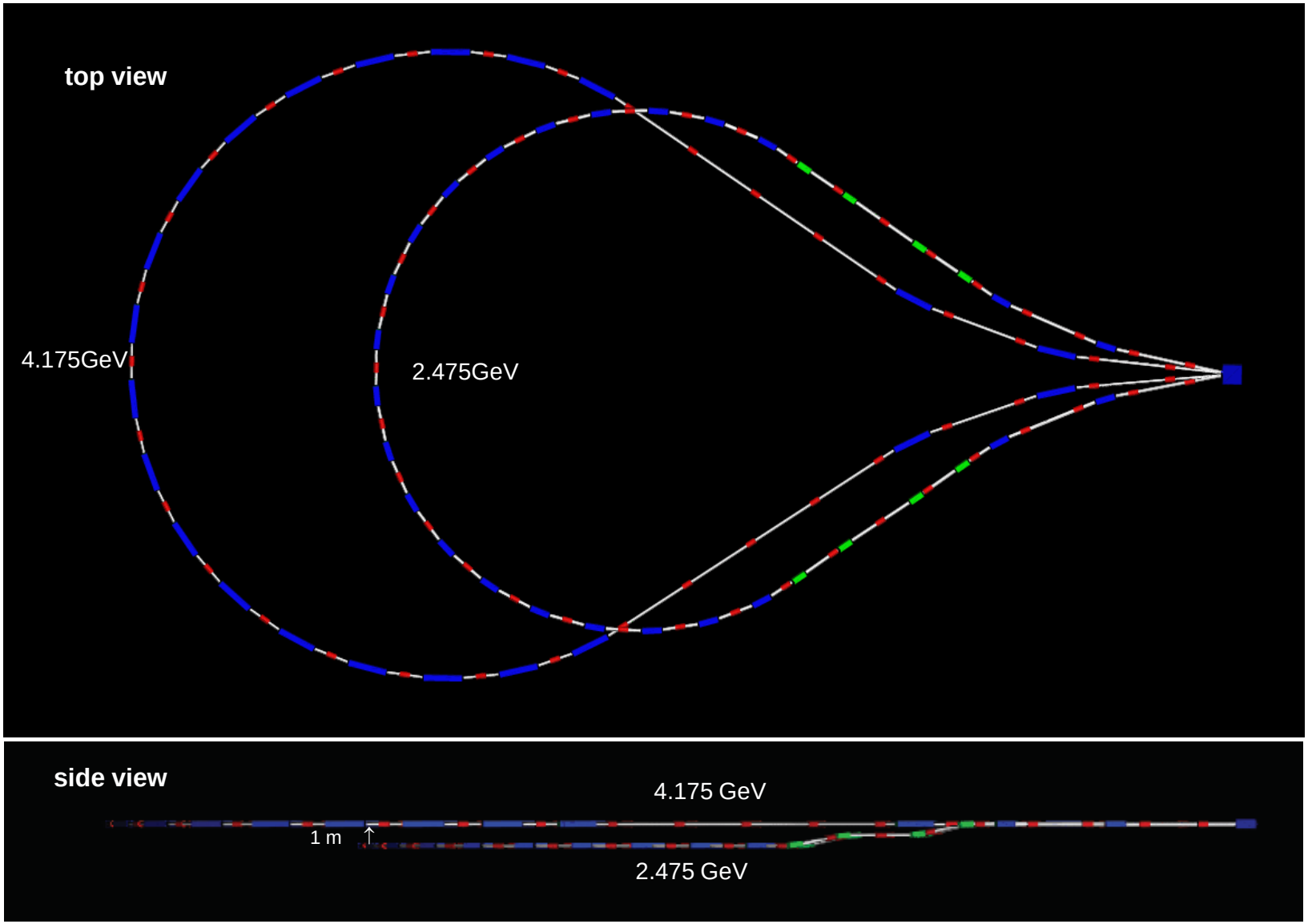
From A. Bogacz

Switchyard – Arc 1 and 3



From A. Bogacz

Arc 2 and Arc 4

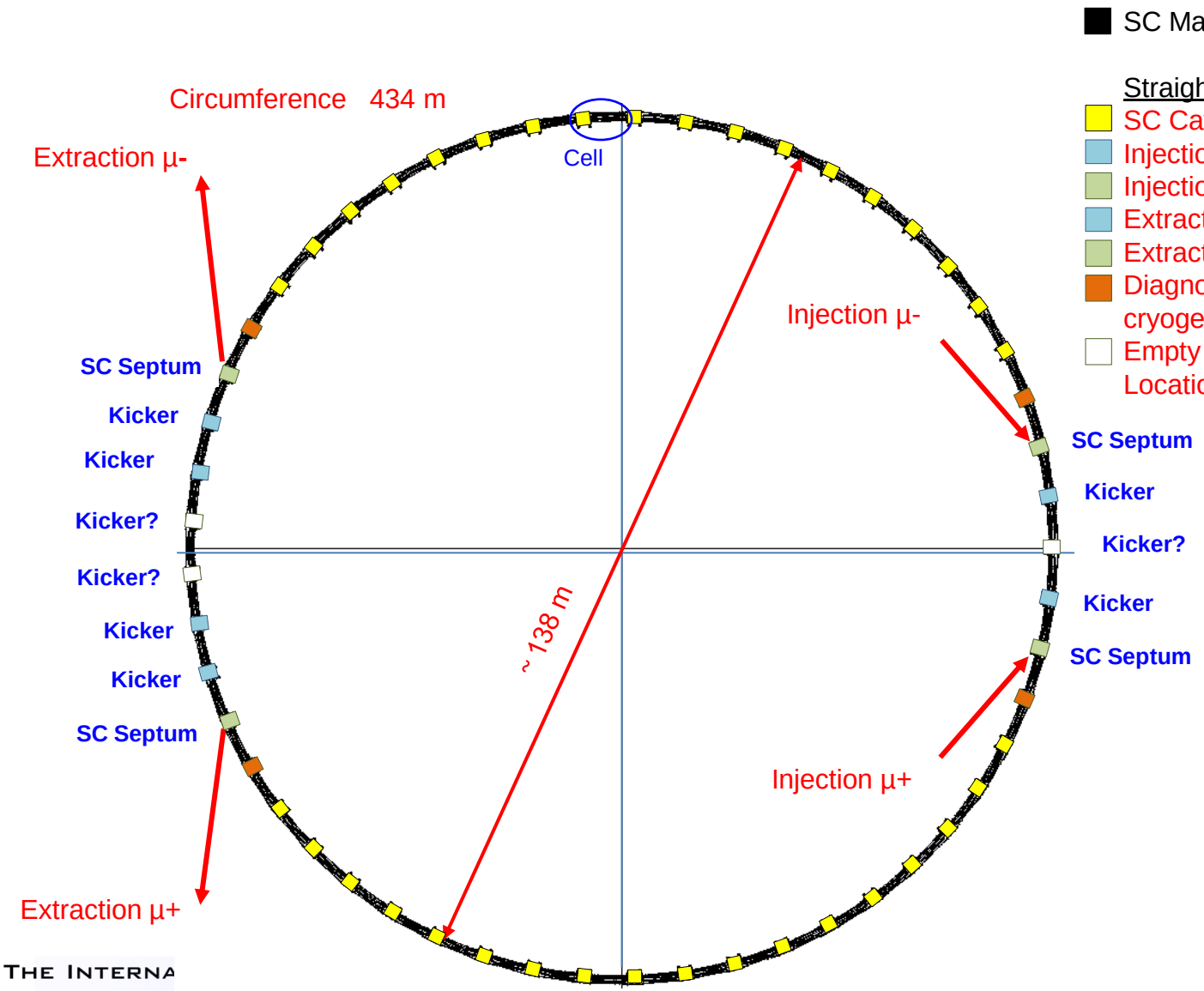


From A. Bogacz

FFAG Designs Comparison

	25 GeV machine	10 GeV machine Scott (preliminary)	10 GeV machine Jaroslaw (preliminary)
Circumference [m]	669	434	369.9
Number of RF cavities	50	36	26
RF voltage [MV]	1196	864.8	~625
Number of turns	11.6	6.7	8.5
Number of cells/magnets	67/201	53/159	49/147
Drift length [m]	5	3.8	3.8
Magnetised length [m]	~263	~153.1	~108.3

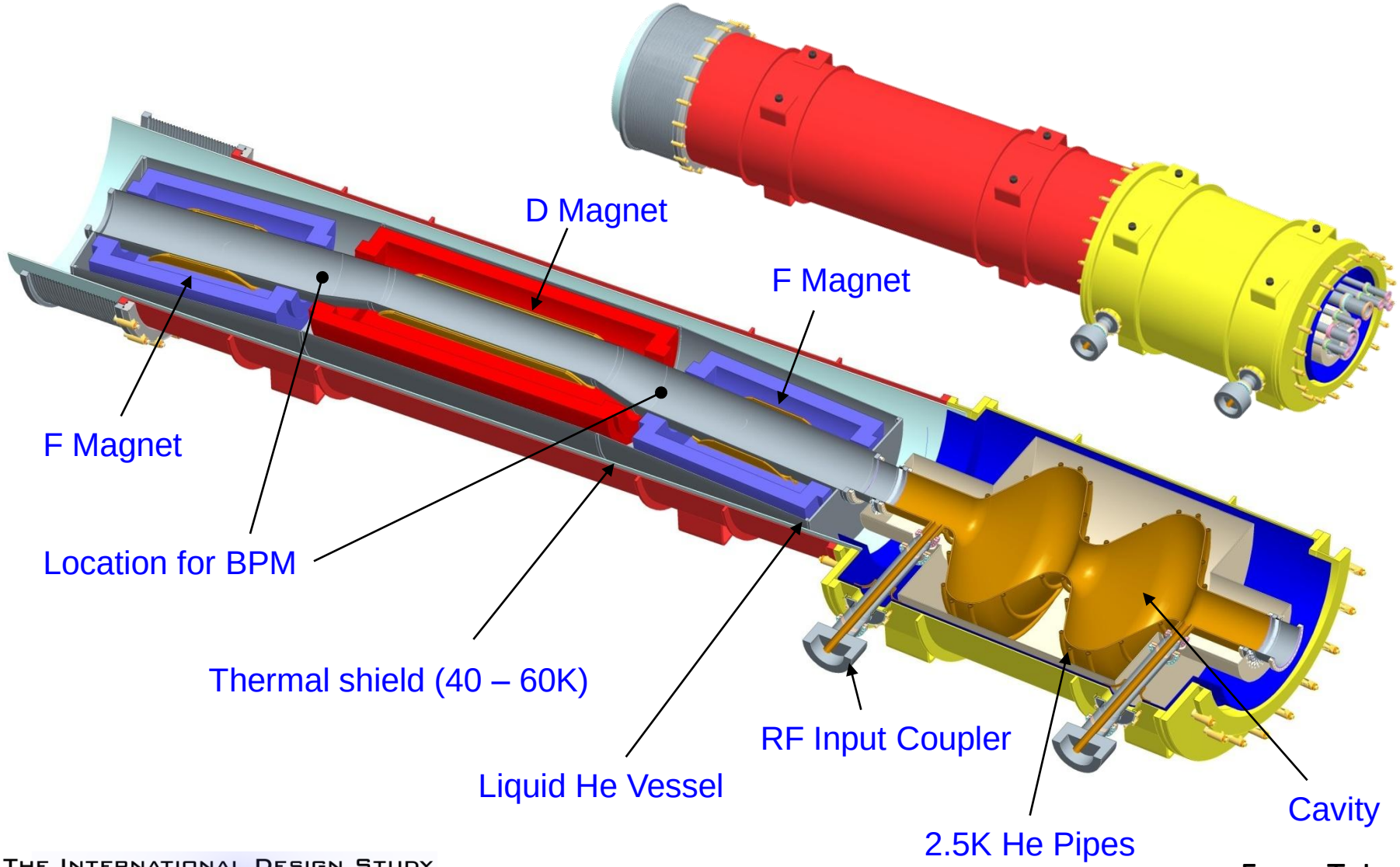
ns-FFAG Layout with continuous cryomodules



SC Magnet Modules	53
Straights Sections	
SC Cavities (2 cells per cavity)	36
Injection kickers	2
Injection SC septums	2
Extraction kickers	4
Extraction SC septums	2
Diagnostics, pumping and cryogenic service stations	4
Empty straights/Possible Kicker Locations.	3

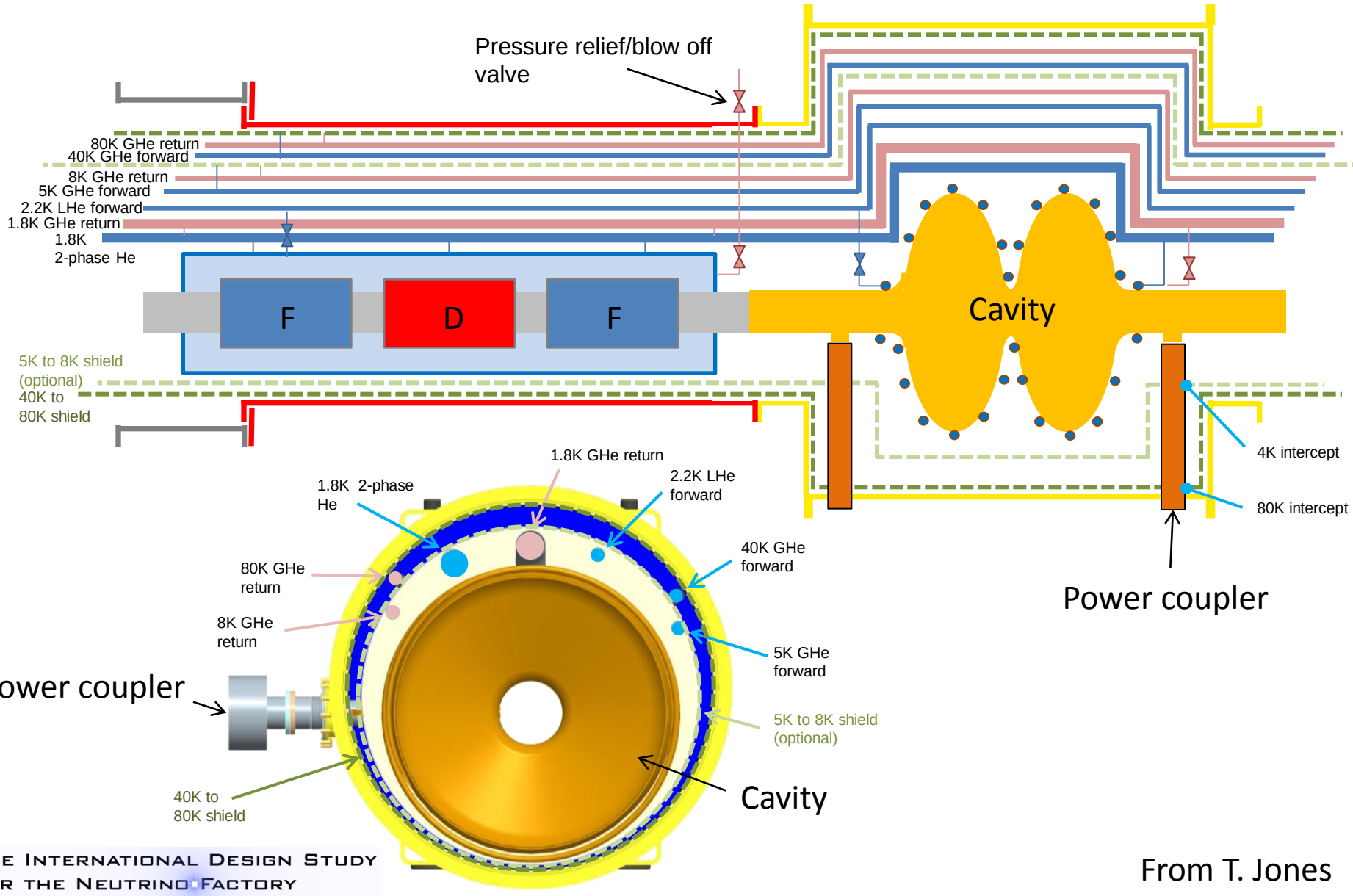
From T. Jones

ns-FFAG cell in a continuous string



From T. Jones

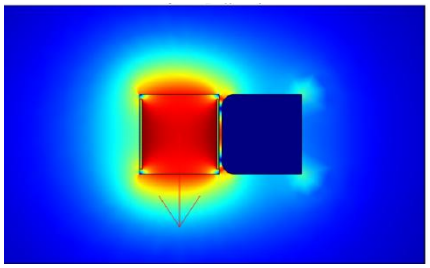
Cryogenic schematic – Continuous string

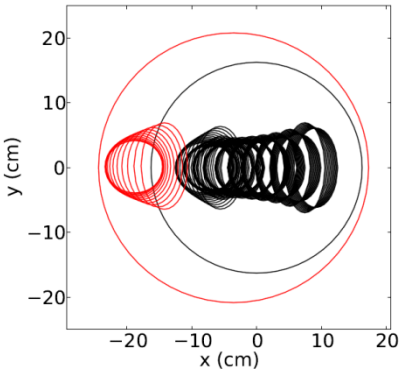


From T. Jones

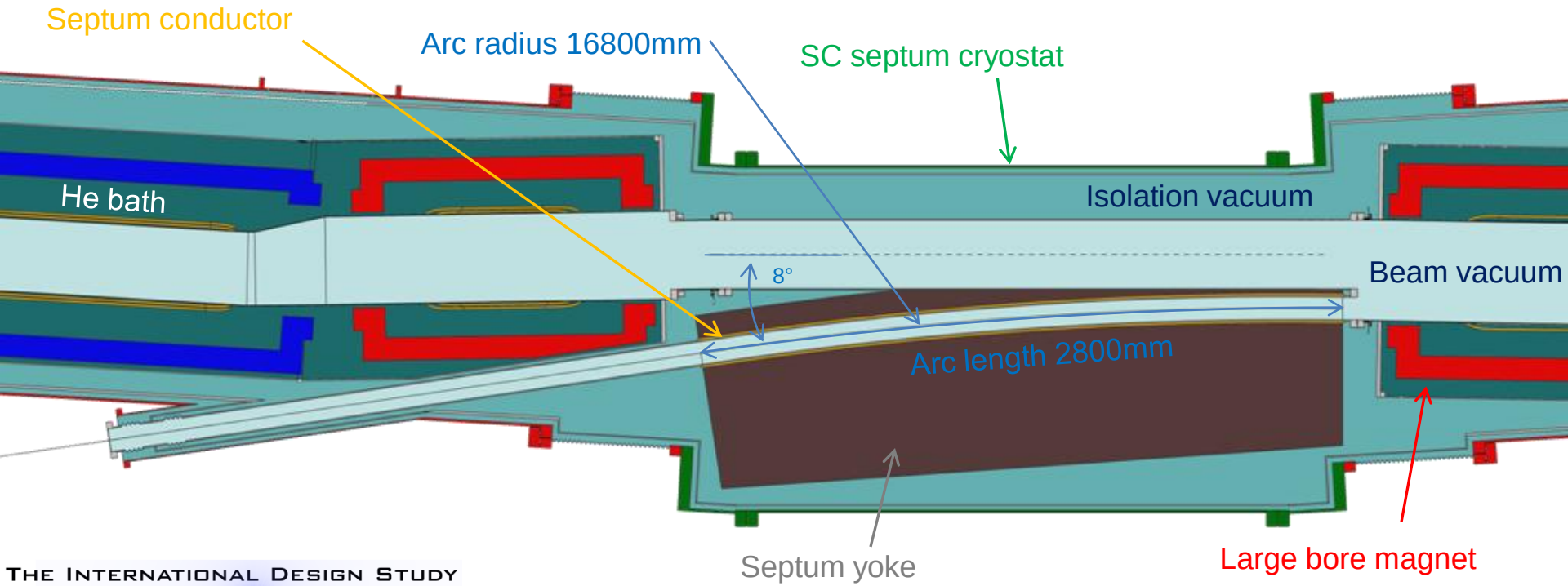
Septum magnet – NF ns-FFAG

- Septum design on-going.
- Image below is a work in progress schematic of superconducting 2T extraction septum. 3D design is required to ascertain feasibility.

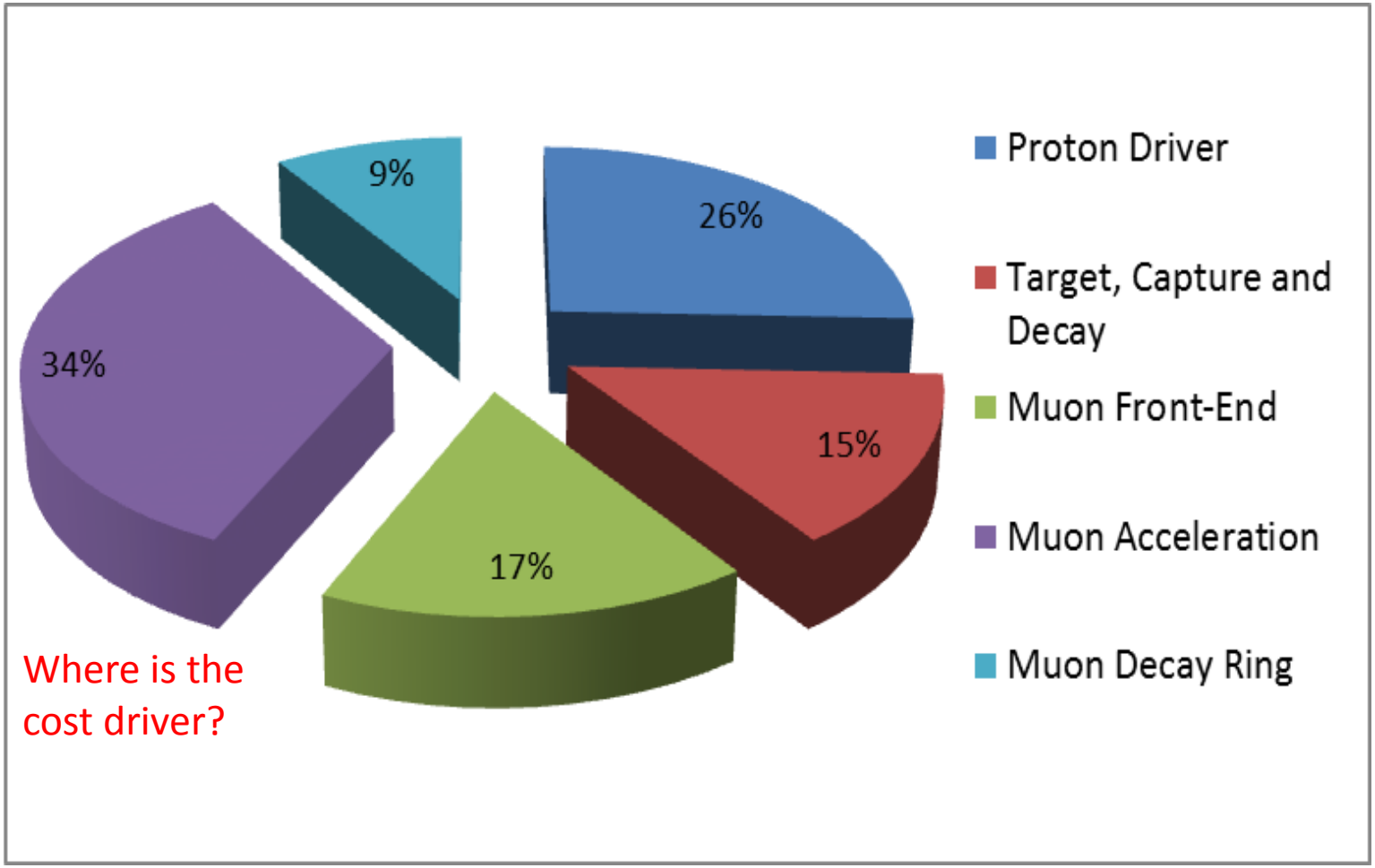




Images above and right ref:
NF Interim Design Report



Relative Cost of Systems in EUROnu Report



From A. Kurup

Muon Acceleration

- Caveats
  - All costs have been scaled from the FFAG cost model unless otherwise stated. This assumes a similar beam line composition (per metre) to the FFAG.
  - The pre-linac solenoid costs have been scaled by length from the cost of the capture solenoids.
  - It has been assumed that the RF cavities for the pre-linac and RLAs cost the same as the FFAG RF cavities.
  - The aperture for the pre-linac cavities is bigger than the FFAG cavities but the gradient is less. The difference in cost is assumed to be small.
  - It has been assumed that the cost of a single-cell cavity (in the pre-linac) is half of a double-cell FFAG cavity.
  - It has been assumed that one RF power system can power 4 single-cell cavities.
  - It has been assumed that there is no transfer line between the pre-linac and RLA 1.
  - The length of the transfer line from RLA 2 to the muon decay ring has been crudely estimated. The cost of the beam line components for the transfer line was based on as-built costs of a higher momentum proton beam transfer line based at CERN from 2002 (and includes an average CHF:GBP exchange rate for 2002 and a UK based inflation factor).
- Missing items
  - Magnet power supplies and distribution.

Costing methodology – to date

- Most costs have been based on similar systems with a touch of “educated estimating”. A great deal of research and good communication has enabled us to provide reasonably accurate figures. The NF systems are all unique and require detailed engineering input to improve on the current estimates.
- We have used a linear scaling methodology for varies systems and items. This is reasonably accurate for conventional systems. However, the majority of magnets, RF systems and Cryogenic systems does not scale linearly. This is in need of revision!

From N. Collomb

Costing methodology – improvement

- Closer collaboration with companies, laboratories and institutes will provide more accurate costs and includes miscellaneous items previously omitted.
- Apply non – linear scaling for systems where figures are not available. This is particularly the case where the manufacturing costs occur. A breakdown of labour and material must be used as a scaling basis.
- Material scaling as a function of length and aperture for instance needs to be refined.
- Where sufficient details are known a ‘bottom up’ approach needs to be applied with estimates from suppliers.

From N. Collomb

Muon Acceleration Baseline Decision at this meeting

- There is no need for any intermediate energy stage for the NF (no cost advantage due to a different baseline length specification, a different decay ring design and a detector location).
- According to the current cost exercise both options perform very similar .
- NS-FFAG is a new type of accelerator with some operational risk

- Take Option I (without FFAG and 2 RLAs to 10 GeV) or even modify the old 12.6 GeV option with 2 RLAs.

But...

- According to the current cost exercise both options perform very similar.

The error bars are huge, especially as the RLA cost model is scaled from the FFAG one. Are we sure we want to remove a possibility to have options in the system, which is the clear cost driver?

- NS-FFAG is a new type of accelerator with some operational risk

The proof of principle has been demonstrated during the EMMA commissioning at Daresbury Lab.

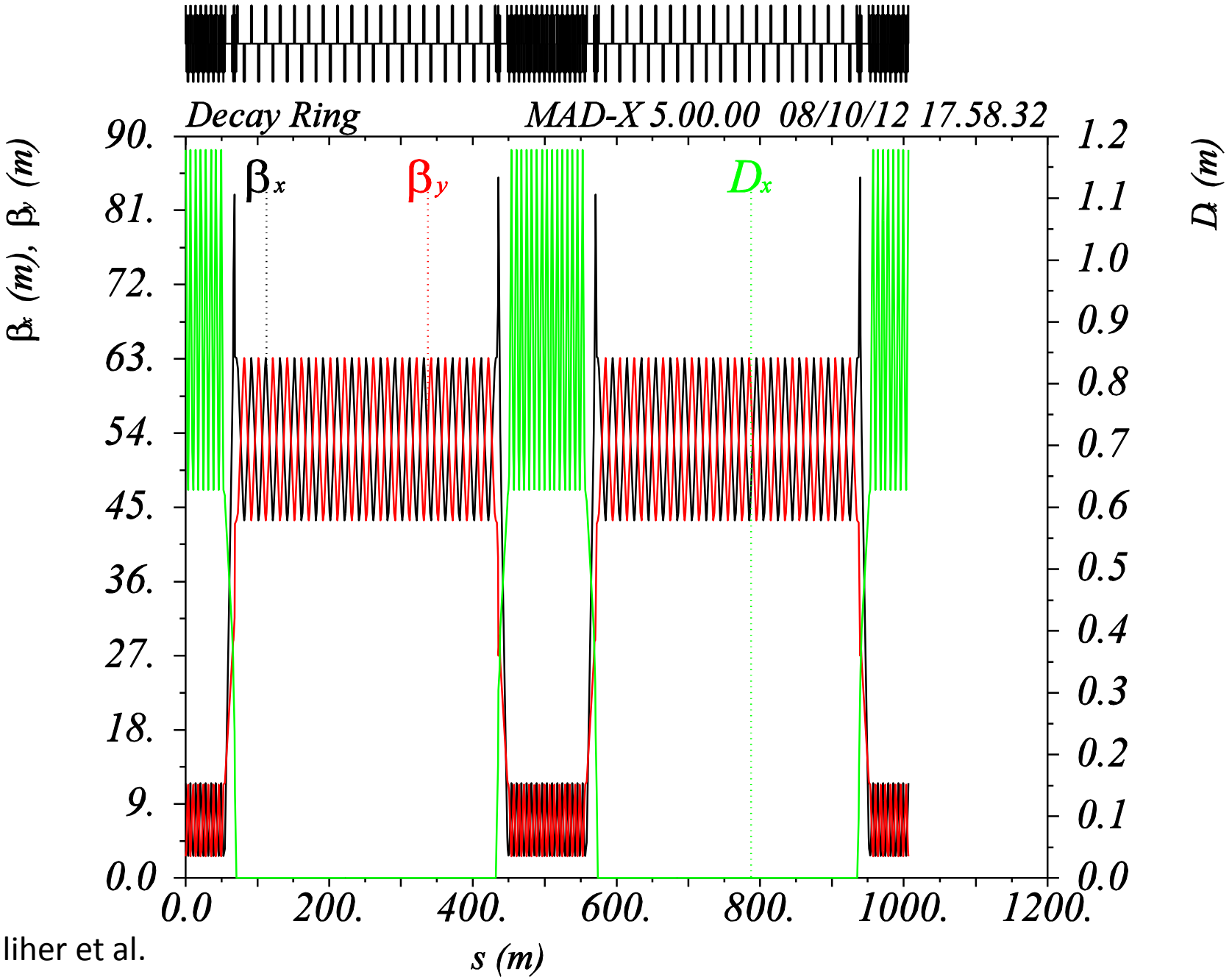
Consequences ...

• Development of muon FFAG will be stopped within IDS-NF and slowed down in general:

- SC septum integration and feasibility of extraction,
- design of the magnets (mains, SC septum and kickers),
- cryogenics and layout,
- performance in the end-to-end simulations and coupling to RLA.
- further optimisation of cost reduction for muon acceleration.

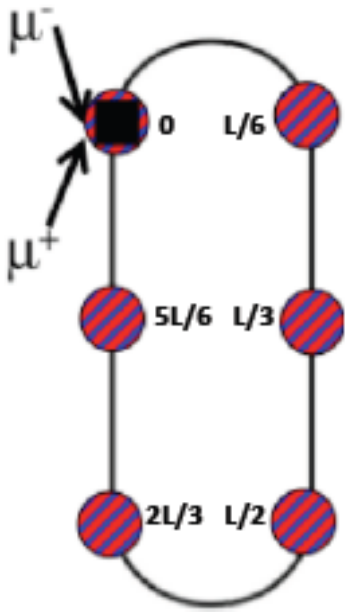
•It may send a bizarre message that muon acceleration does not need FFAGs (incorrect).

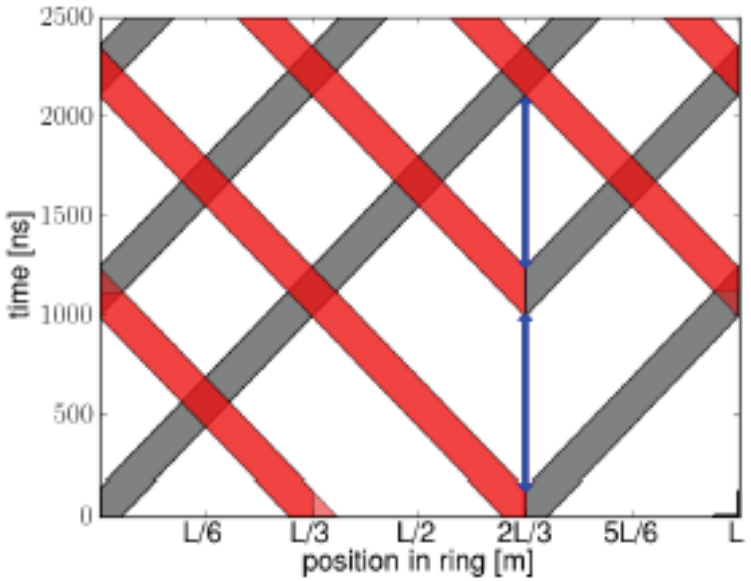
Optics of 10 GeV Decay Ring



D. Kelliher et al.

Injection Scheme





- Simultaneous injection of each bunch pair into crossing point
- Delay between consecutive bunch pairs (n + 1/3)*L
- Kicker rise/fall time is L/(3c) -t_{bunch}

D. Kelliher et al.

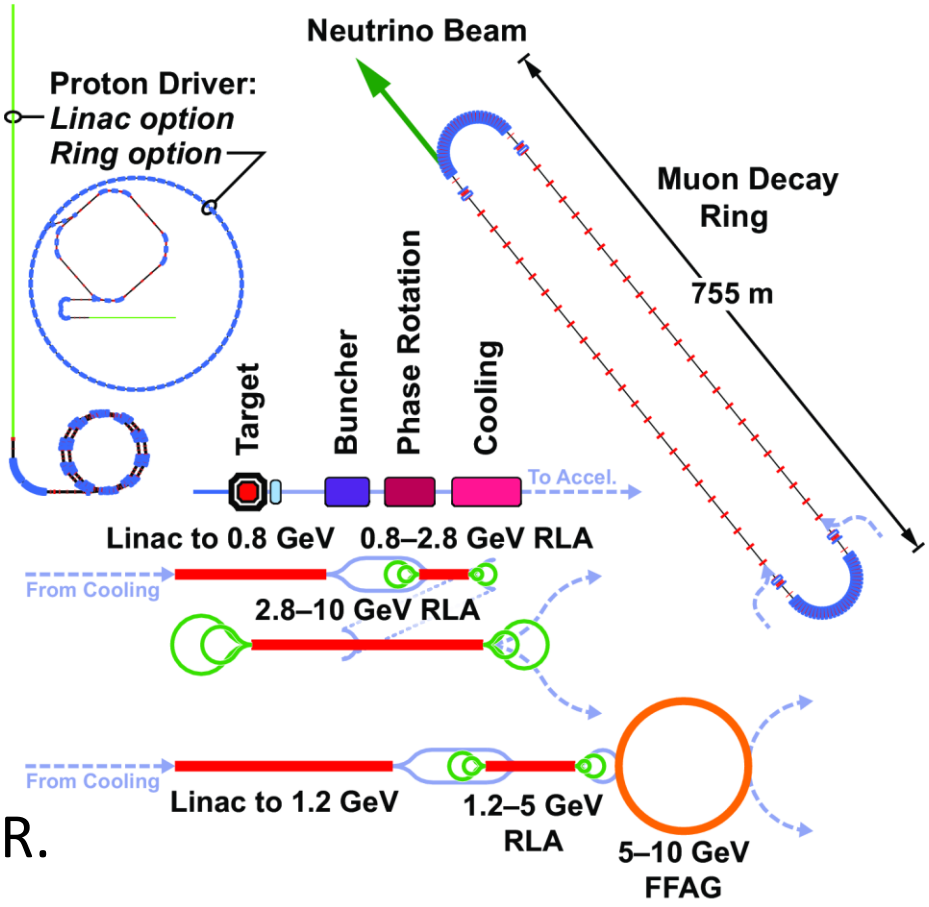
Some parameters of the 10 GeV ring

- Circumference 1006 m
- γ_T 13.927
- Production efficiency 35.8%
- Assumed total momentum spread $\pm 2.5\%$
- Production straight length 360 m
- Arc length 106.2 m
- $(Q_H, Q_V) = (9.71, 9.55)$

D. Kelliher et al.

Influence of this meeting on the IDS-NF (on the accelerator site)

- This is a very important meeting!
- Strong progress in many areas.
- First official costing results.
- A lot of input from engineering.
- Important baseline decisions in the front-end and acceleration.
- Setting stage for completing the RDR.



Thank You