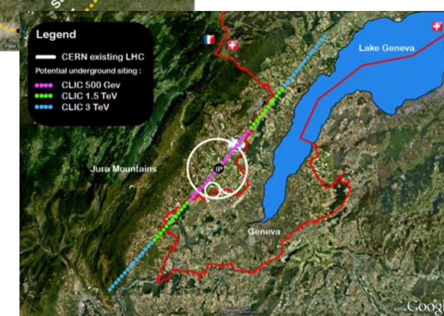
FCC-hh

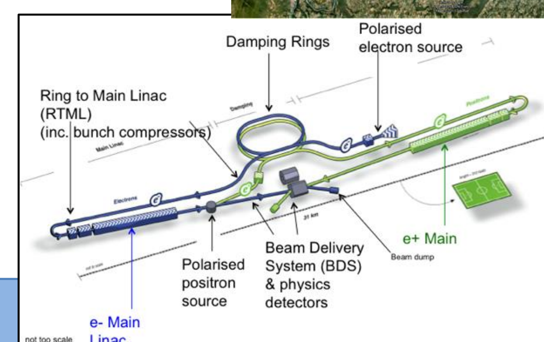
Daniel Schulte

JAI, March 2016

European Strategy

- Highest priority is exploitation of the LHC including luminosity upgrades
- Europe should be able to propose an ambitious project after the LHC
  - Either high energy proton collider (**FCC-hh**)
  - Or high energy linear collider (**CLIC**)
- Europe welcomes Japan to make a proposal to host **ILC**
- Long baseline neutrino facility





FCC Scope

Develop CDR until 2018

FCC-hh

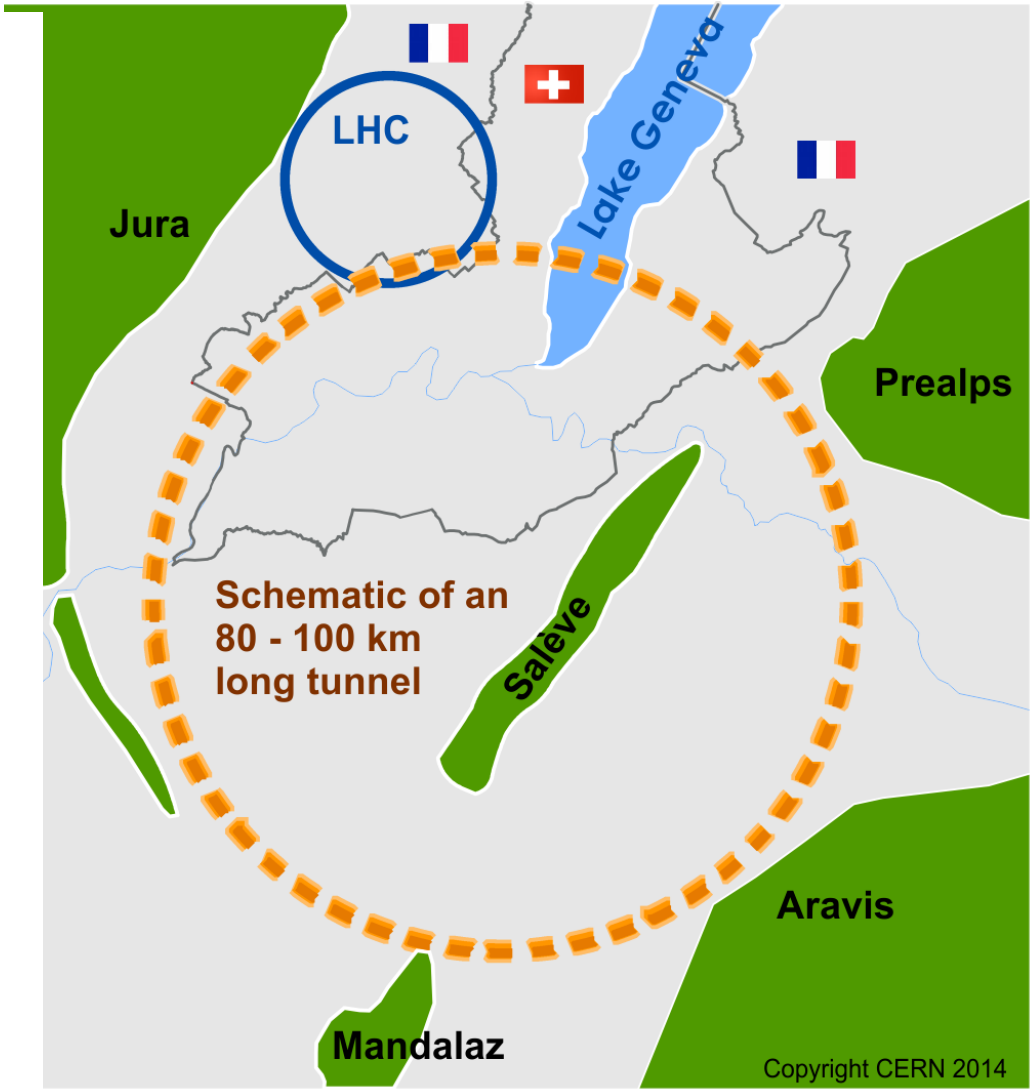
- pp collider (ion option)
- 100TeV cms energy
  - $\Rightarrow$ defines infrastructure requirements

FCC-ee

- e^+e^- collider
- potential intermediate step

FCC-he

- additional option



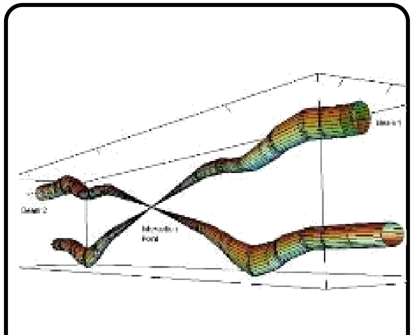
https://fcc.web.cern.ch

FCC Collaboration

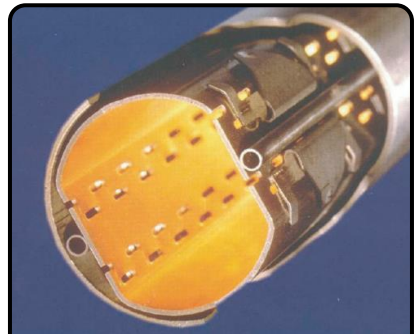
- 70 institutes
- 26 countries + EC

Status: November, 2015

Arc Design



EIR Design

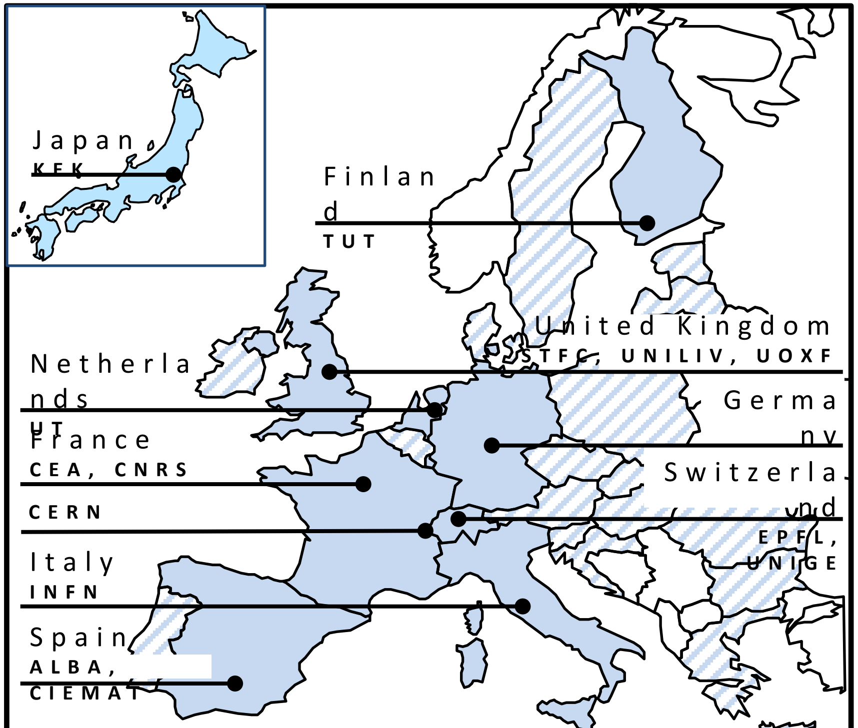


Cryo Beam Vacuum

High Field Magnet

EU co-funded design study for FCC-hh, focus on core activities

Accepted in 2015



CERN	IEIO
TUT	Finland
CEA	France
CNRS	France
KIT	Germany
TUD	Germany
INFN	Italy
UT	Netherlands
ALBA	Spain
CIEMAT	Spain
STFC	United Kingdom
UNILIV	United Kingdom
UOXF	United Kingdom
KEK	Japan
EPFL	Switzerland
UNIGE	Switzerland
NHFML-FSU	USA
BNL	USA
FNAL	USA
LBNL	USA

Basic Parameters

	LHC	HL-LHC	FCC-hh Baseline	FCC-hh Ultimate
Cms energy [TeV]	14	14	100	100
Luminosity [$10^{34}cm^{-2}s^{-1}$]	1	5	5	<30
Machine circumference	27	27	100	100
Arc dipole field [T]	8	8	16	16
Bunch distance [ns]	25	25	25	25 (5)
Background events/bx	27	135	170	1020 (204)
Bunch length [cm]	7.5	7.5	8	8

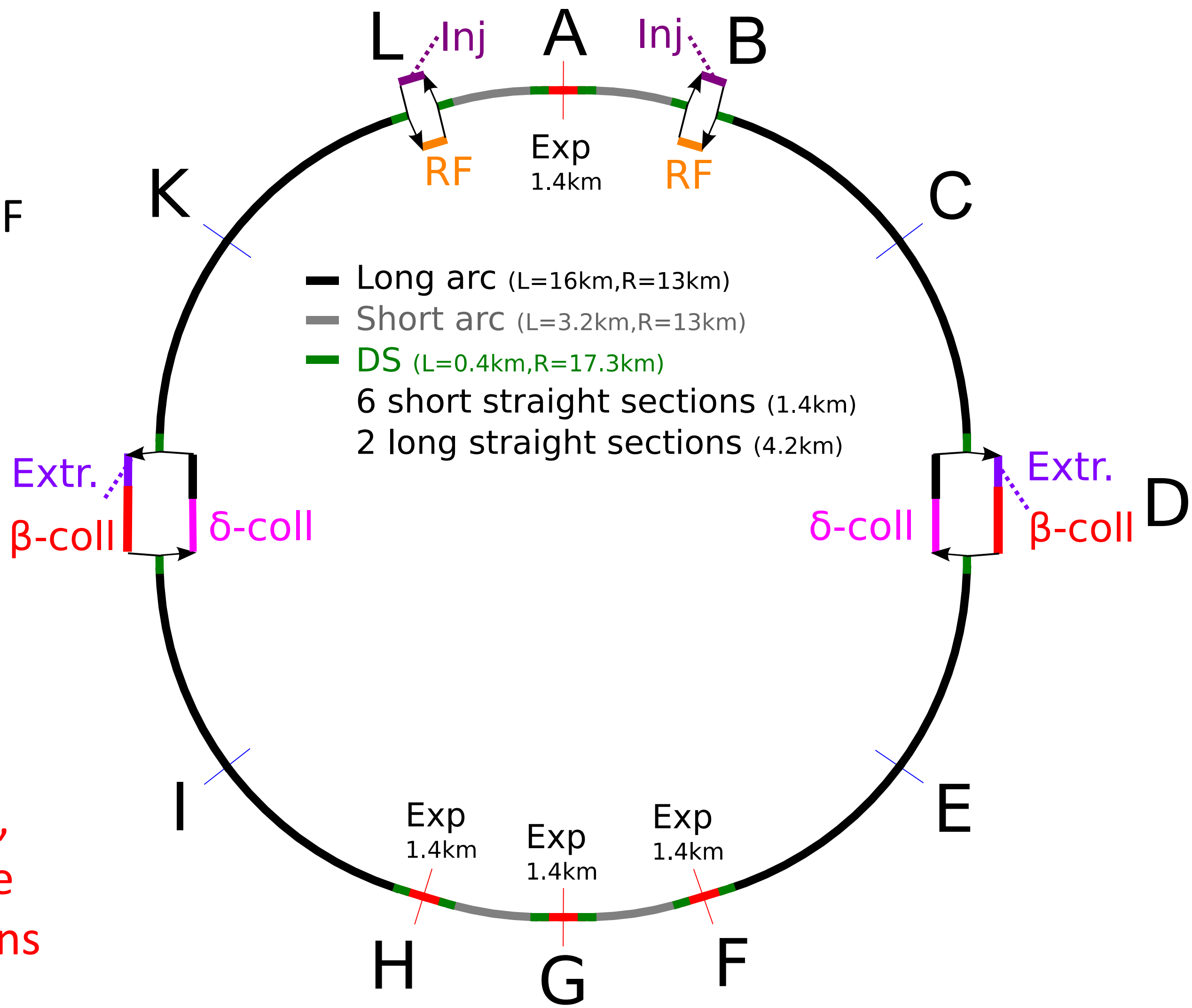
Baseline 1250fb^{-2} per 5 year cycle (considering shutdowns, stops, MDs, …)
= 2fb^{-2} per day with no problems

Ultimate 5000fb^{-2} per 5 year cycle
= 8fb^{-2} per day

Total 17.5ab^{-2}

FCC-hh Layout

- Two high-luminosity experiments (A and G)
- Two other experiments (F and H)
- Two collimation and extraction insertions
  - Exact layout being developed
- Two injection insertions
- Insertion lengths (1.4km, 4.2km for J and D) will be reviewed as optics designs are optimised

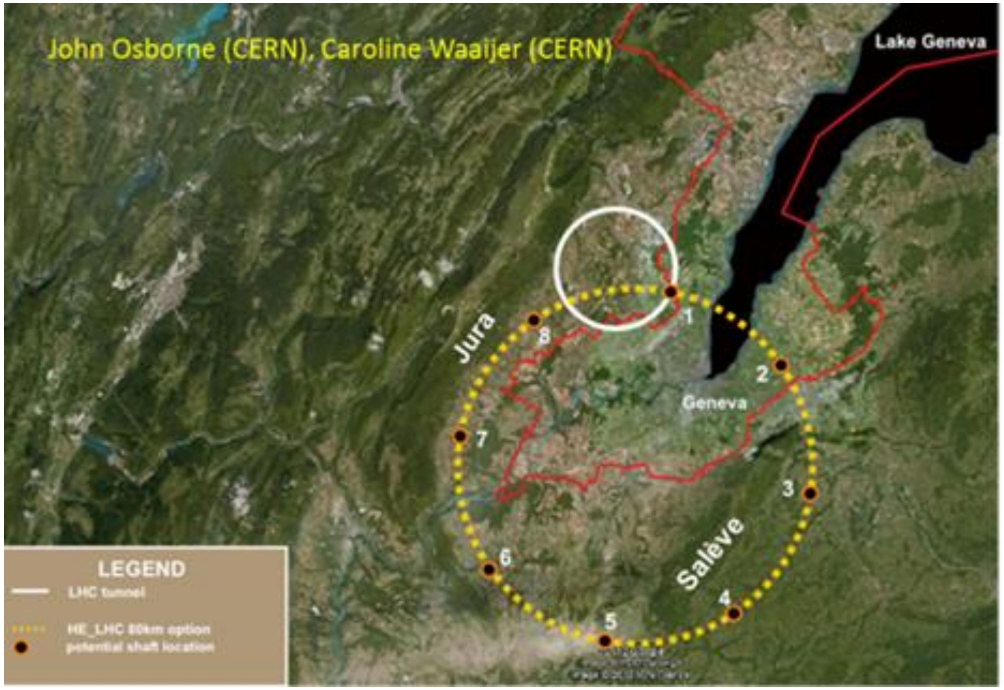


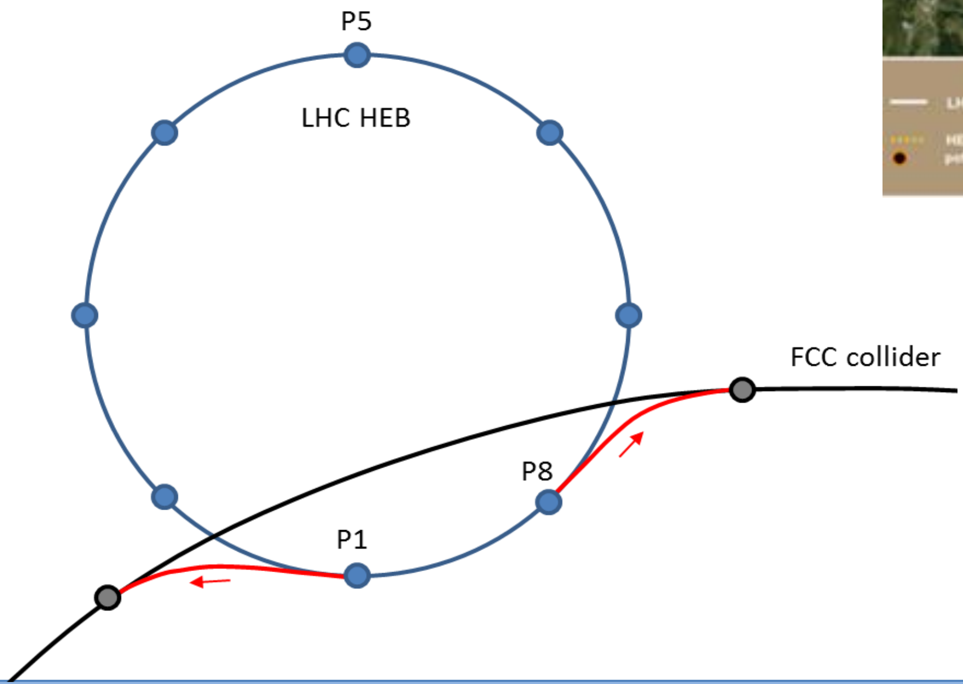
FCC Injection and Site Study

Detailed site studies are ongoing

- Geology
- Surface buildings
- …

⇒ 100km ring fits well into the Geneva area





LHC can be used as injector

Also consider SPS and FCC tunnel for injector

- SPS located at the right place

Arc Cell Layout

B. Dalena, A. Chance, J. Payet

Longer cell

⇒ fewer and shorter quadrupoles

⇒better dipole filling factor

Shorter cells

⇒ more stable beam

⇒ smaller beam

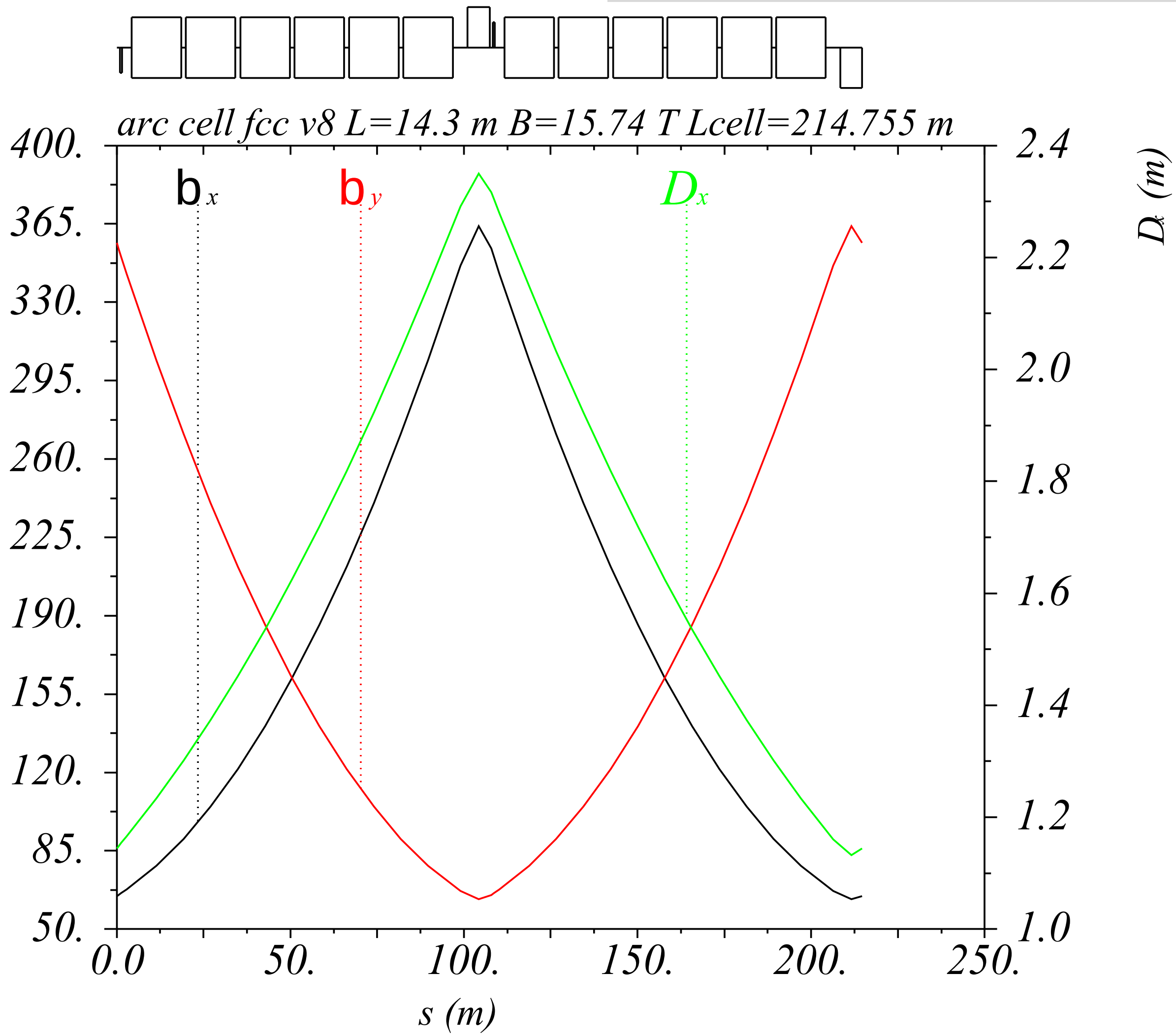
12 dipoles with L=14.3m

L_{cell}=214.755m

• to be reviewed with update magnet design

Fill factor about 80%

Field (100km ring): (16-ε)T



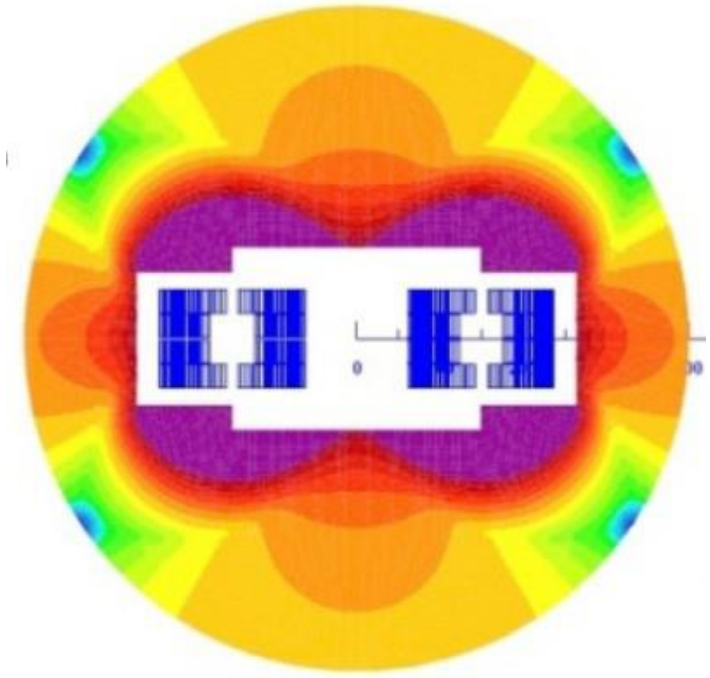
Magnets

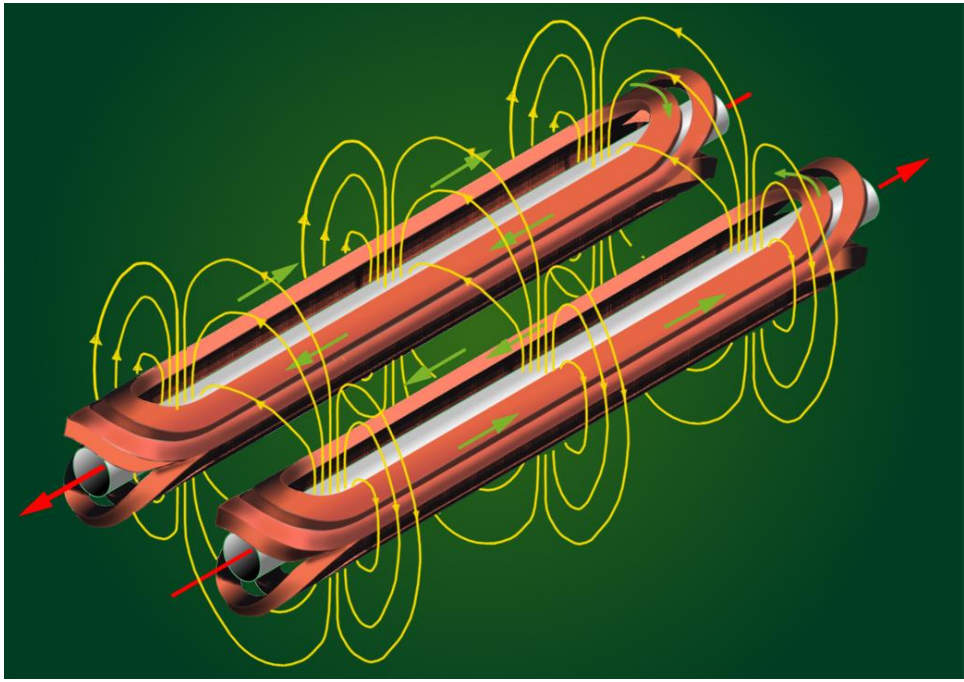
FCC goal is 16T operating field

- Requires to use Nb_3Sn technology
- At lower field levels used for HL-LHC

Also potential for 20T is being explored

- Requires use of HTS





Also field quality is important

- at injection energy
- At top energy

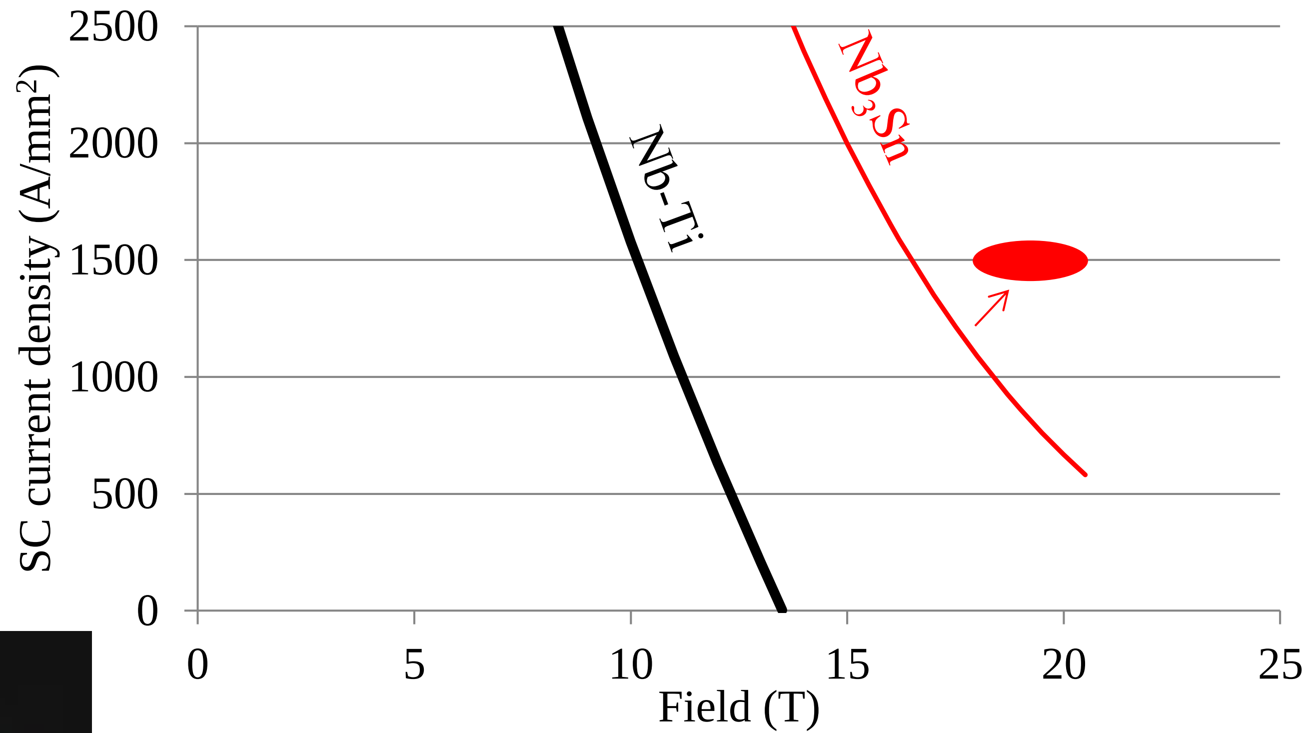
Important parameter is the required aperture of the coils

- Larger is more expensive

Limits for the Field

The cable can quench (superconductivity breaks down)

- if the current is too high
- If the magnetic field is too high

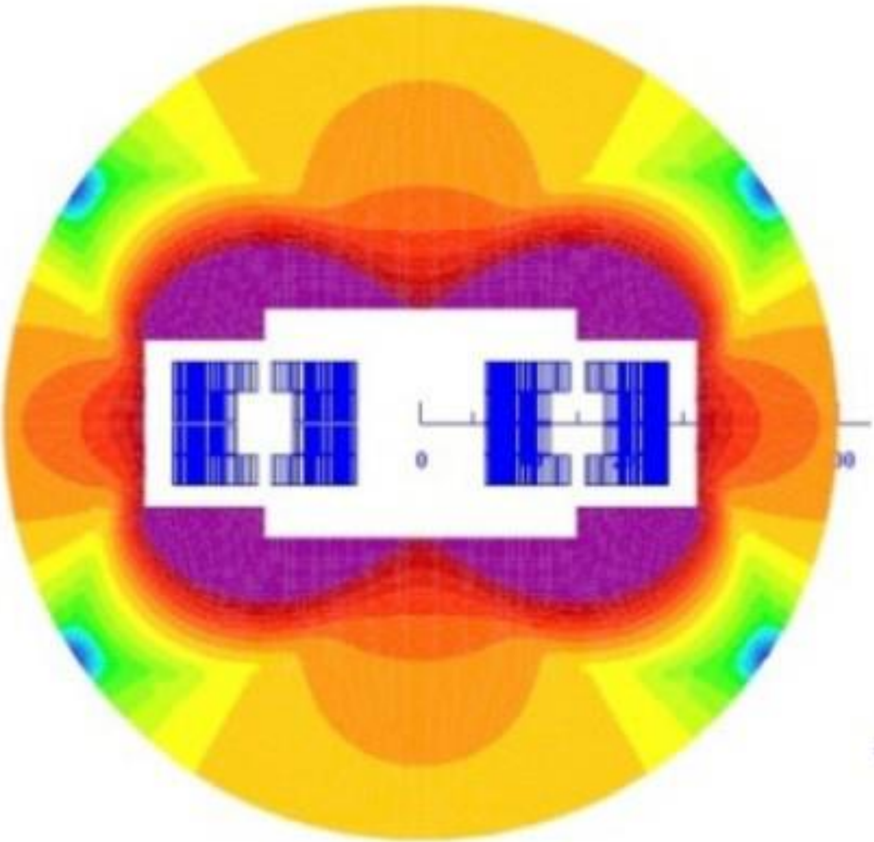


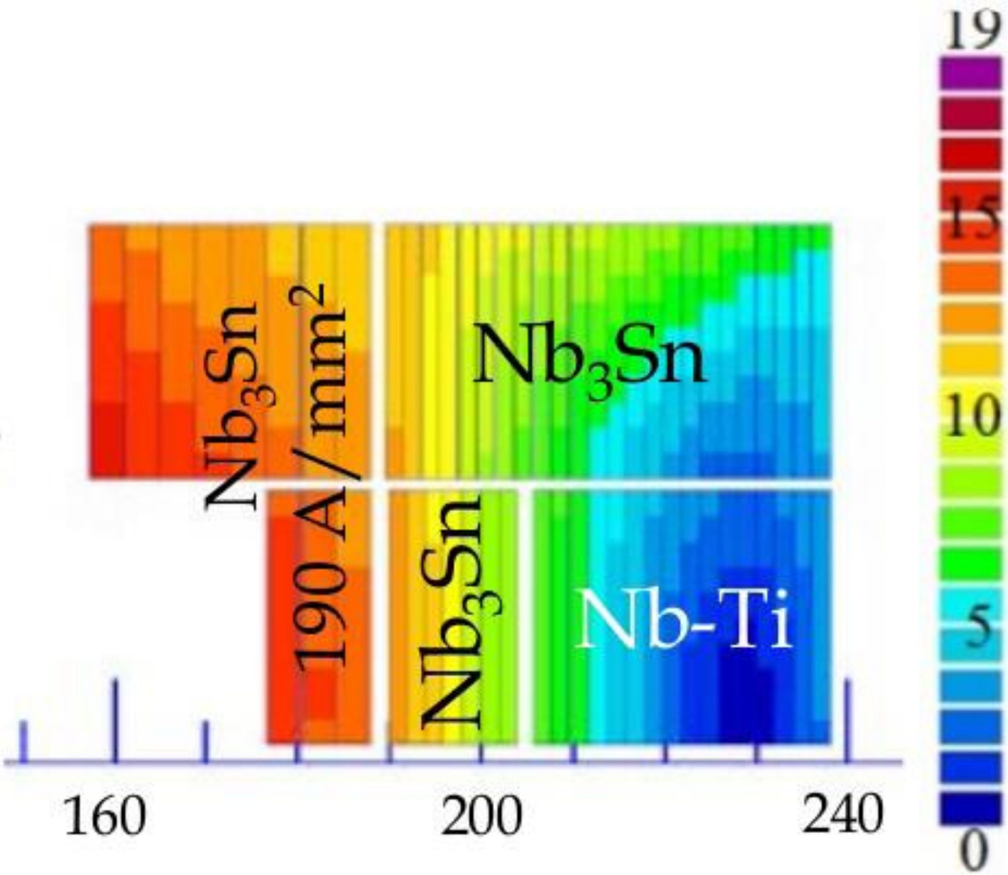
- This limits the achievable field
  - In theory
  - Even lower limit in practice (shown)
- Can use different materials
  - Nb-Ti is used for LHC
  - Nb_3Sn is used for high luminosity upgrade

Cost Effective Magnet Design

Nb_3Sn is much more costly than Nb-Ti

$\Rightarrow$Use both materials

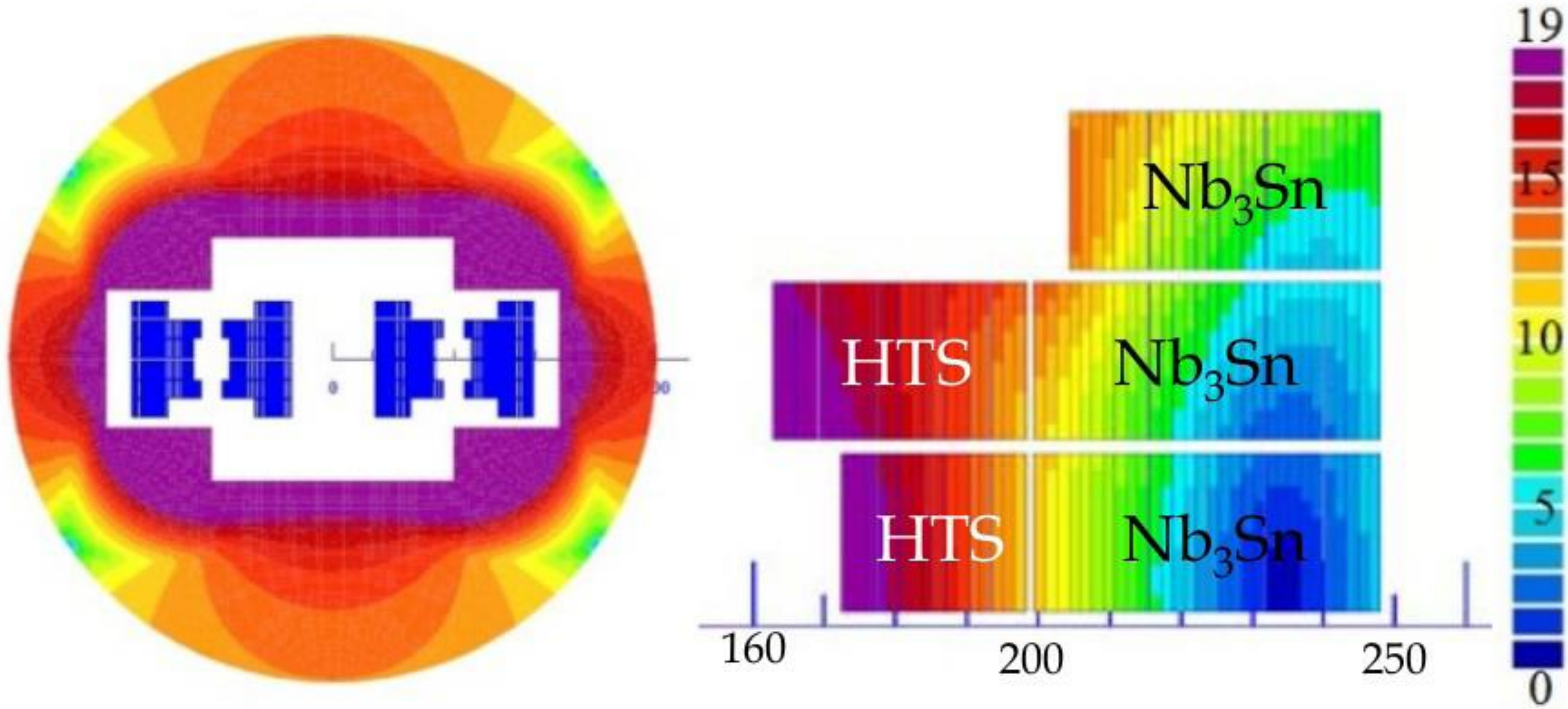




Coil sketch of a 15 T magnet with grading, E. Todesco

HTS is even more expensive than Nb_3Sn

⇒ Even more complex design



Coil sketch of a 20 T magnet with grading, E. Todesco

Initial Beam Parameters

$$\mathcal{L} = \frac{N^2}{4\pi\sigma_x\sigma_y} n_b f_r$$

$$\sigma^2 \propto \beta\epsilon$$

$$\mathcal{L} \propto \frac{N}{\epsilon}\frac{1}{\beta_y} N n_b f_r$$

$$\mathcal{L} = \xi \frac{1}{\beta}\frac{N}{\Delta t}\eta_{fill}$$

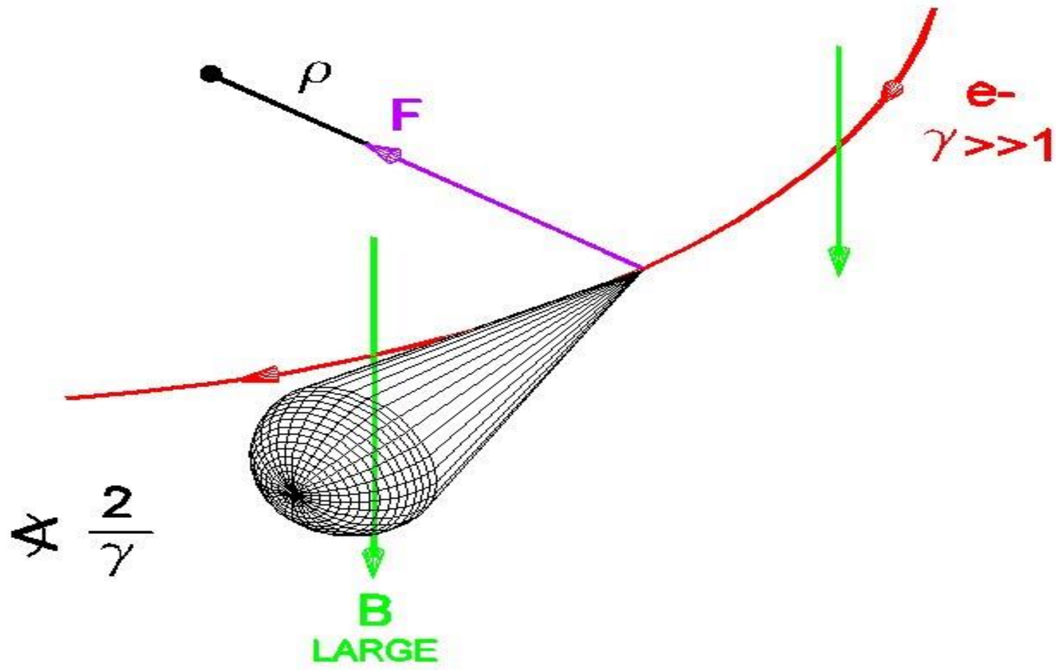
	FCC-hh Baseline	FCC-hh Ultimate
Luminosity L [10^{34}cm^{-2}s^{-1}]	5	20
Background events/bx	170 (34)	680 (136)
Bunch distance Δt [ns]	25 (5)	
Bunch charge N [10^{11}]	1 (0.2)	
Fract. of ring filled η_{fill} [%]	80	
Norm. emitt. [μm]	2.2(0.44)	
Max ξ for 2 IPs	0.01 (0.02)	0.03
IP beta-function β [m]	1.1	0.3
IP beam size σ [μm]	6.8 (3)	3.5 (1.6)
RMS bunch length σ_z [cm]	8	
Crossing angle [σ□]	12	Crab. Cav.
Turn-around time [h]	5	4

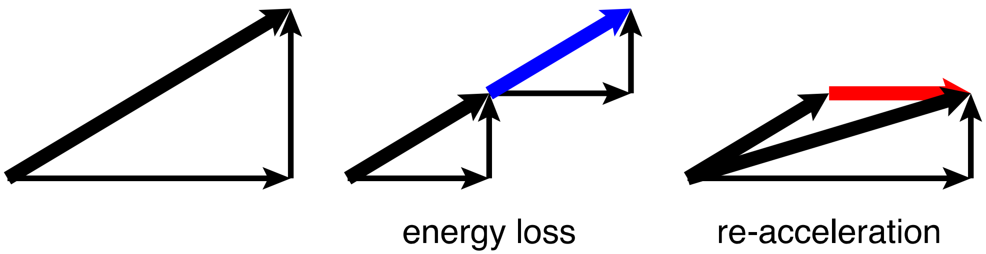
Synchrotron Radiation

At 100 TeV even protons radiate significantly

Total power of 5 MW
⇒ Needs to be cooled away

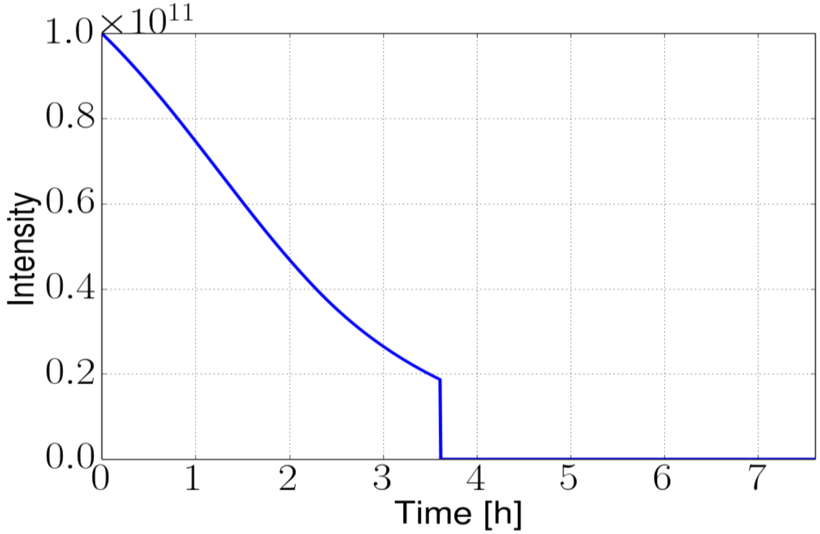
Equivalent to 30W/m /beam in the arcs

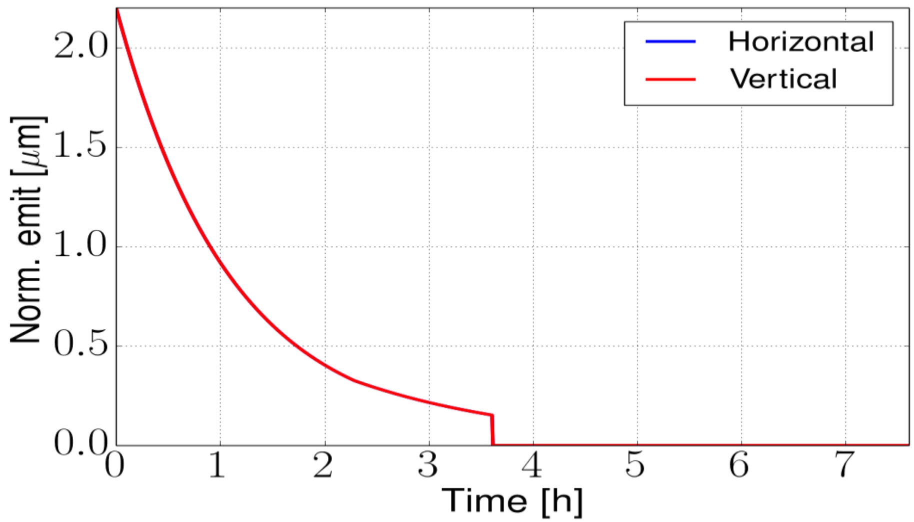




Protons loose energy
⇒ They are damped
⇒ Emittance improves with time
- Typical damping time 1 hour

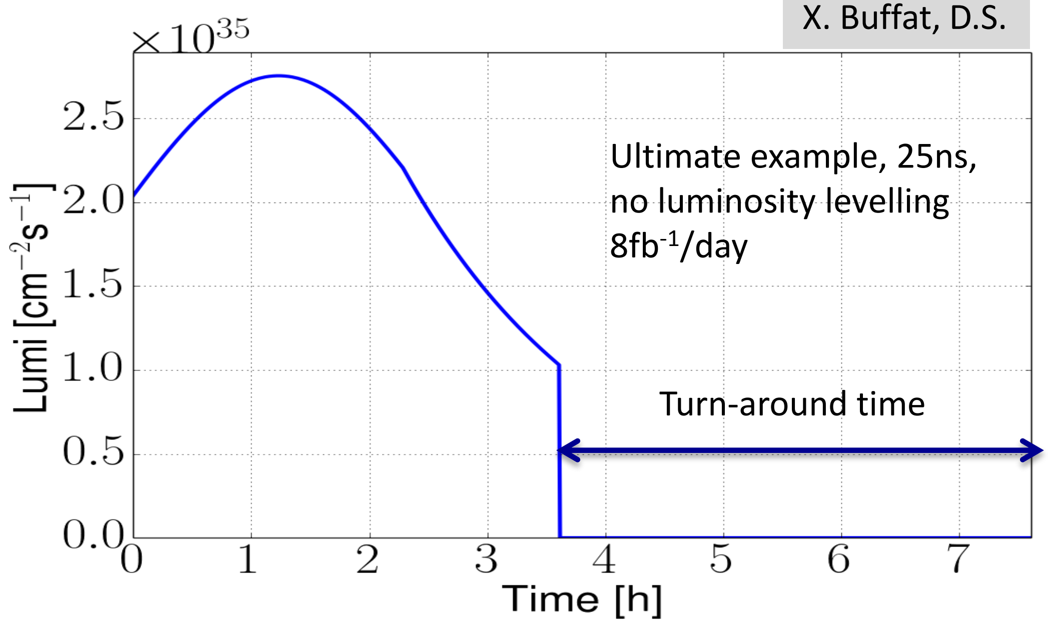
Luminosity Run Example





X. Buffat, D.S.

Example with ultimate parameters shown



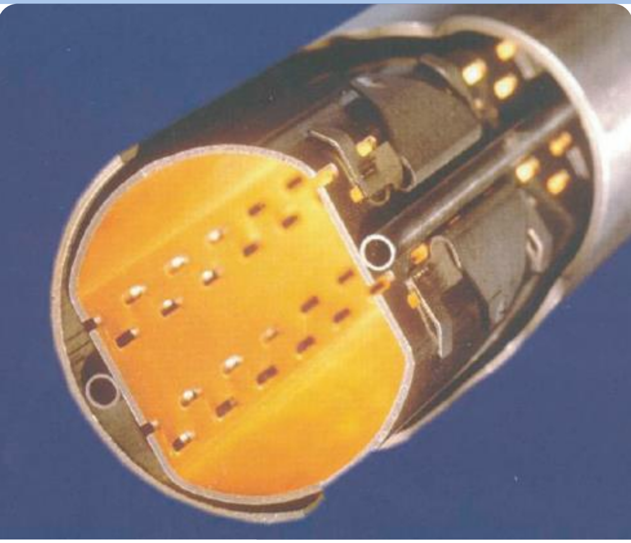
Burn beam quickly

But emittance shrinks

$\Rightarrow$ Can reach $8fb^{-1}$/day

$\Rightarrow$ $5000fb^{-1}$ per 5 year cycle

Beam Screen Design



LHC screen

Space for support: O(1mm)

Total magnet aperture 50mm

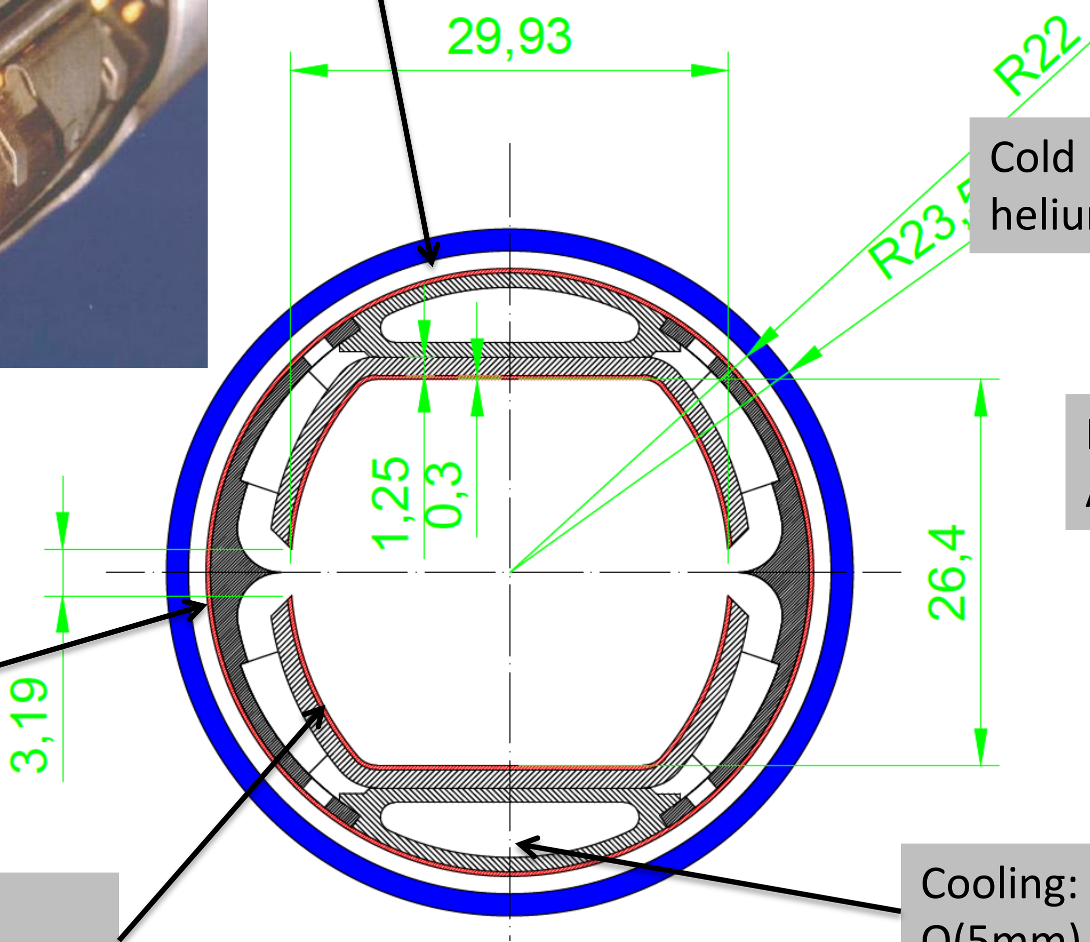
Cold bore + space for helium 1.5mm+1.5mm

Impedance: Aperture >26mm

Stress in quench: 1.25mm steel

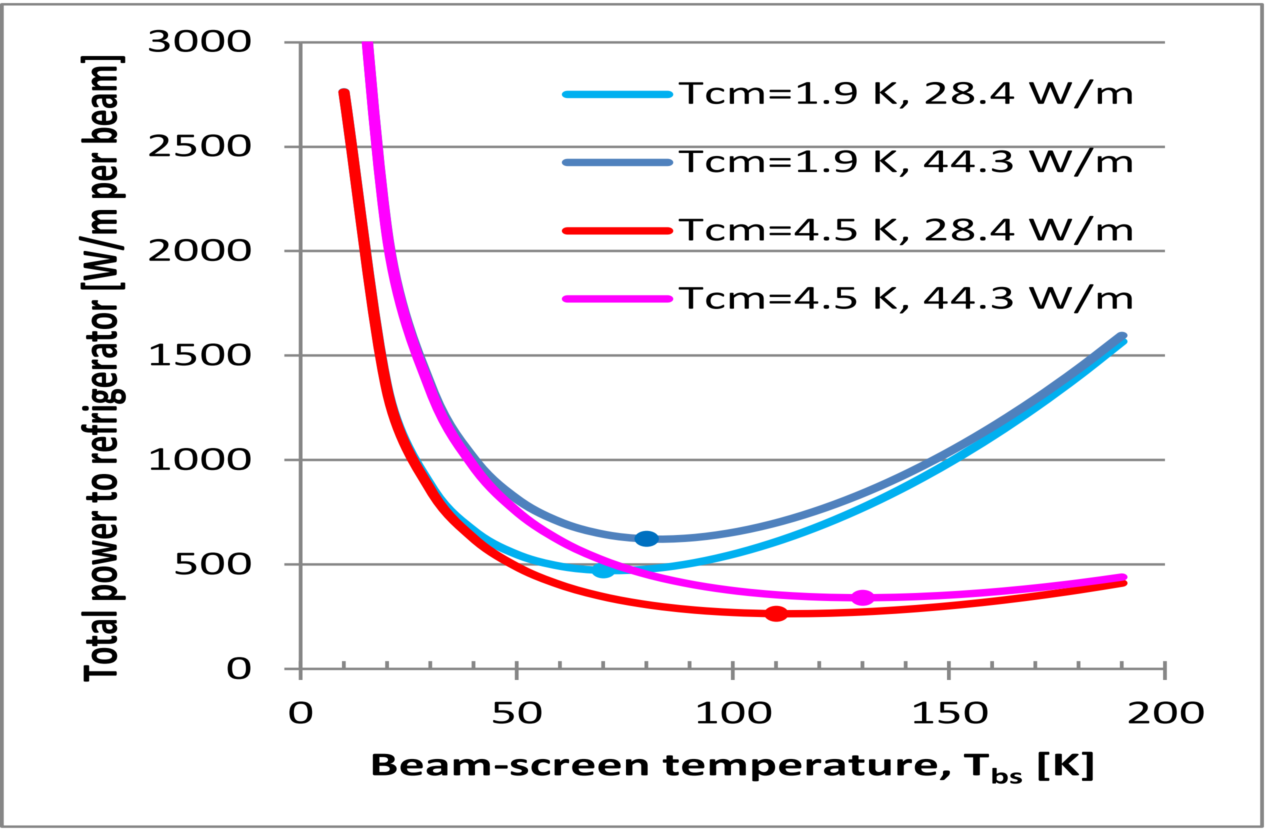
Impedance: 0.3mm copper coating

Cooling: O(5mm) outer diameter

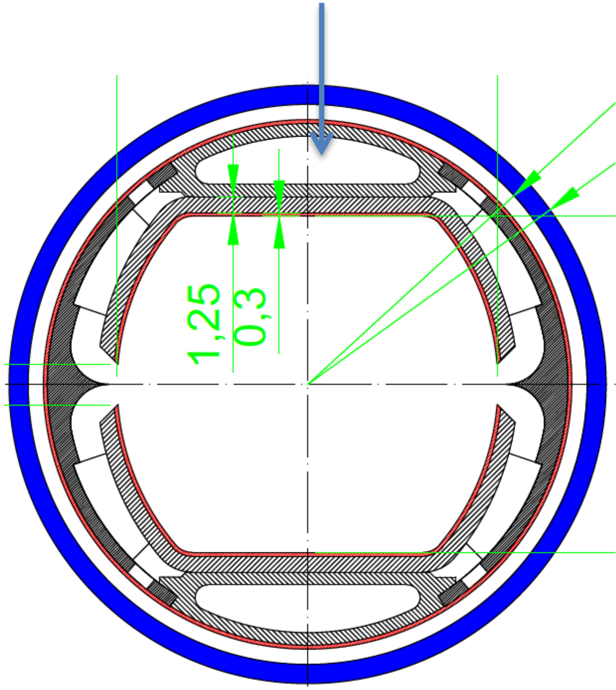


Cooling

L. Tavian, C. König, Ph. Lebrun



Cross section determines length that can be cooled



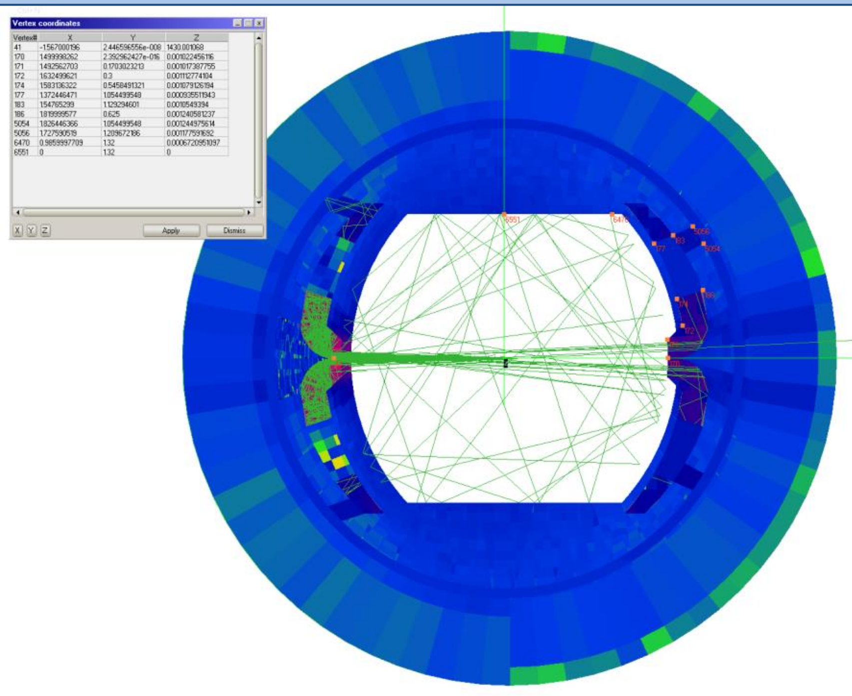
16K beamscreen would require 300MW for cooling

50K requires 100MW => current baseline

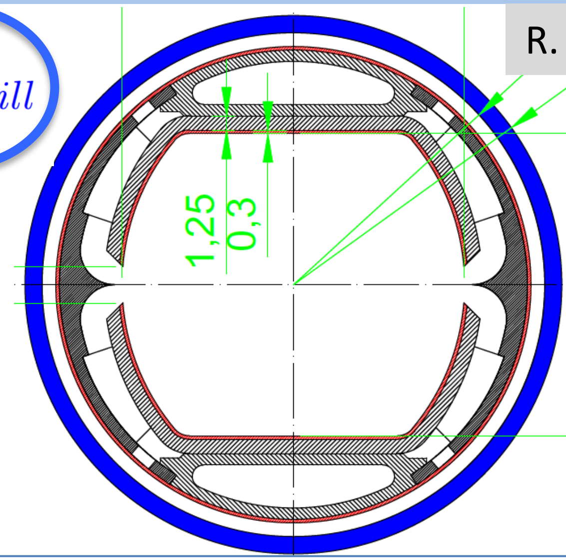
For 4K magnets would prefer T>100K

- But more impedance

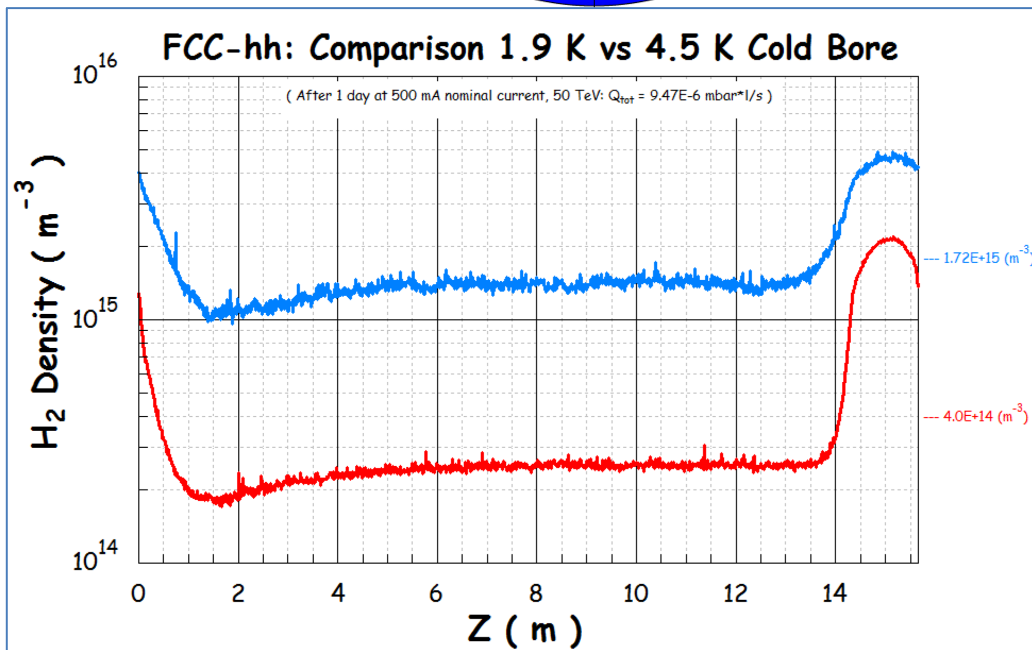
Vacuum Quality



$$\mathcal{L} = \xi \frac{1}{\beta} \frac{N}{\Delta t}\eta_{fill}$$



R. Kersevan



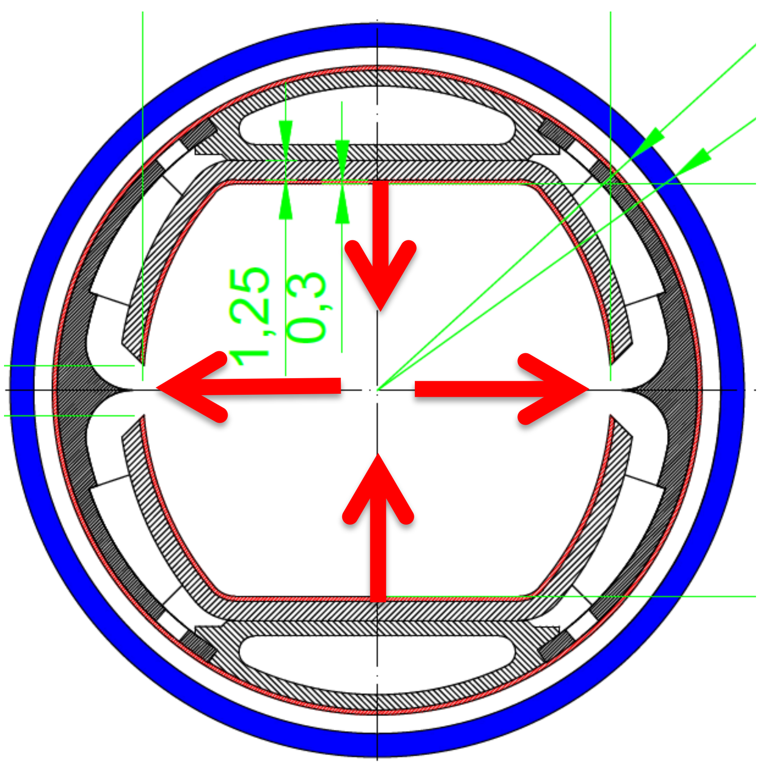
For 2K cold bore meet target after 1 day

- twice better than LHC design
- but need to work on connections

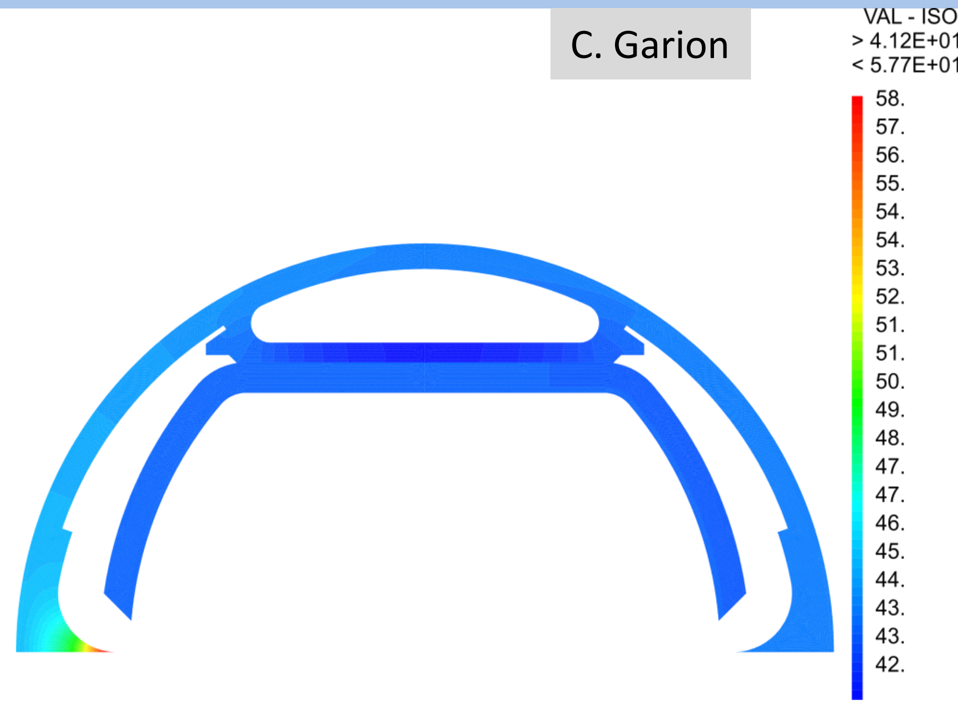
Cryo absorbers required for 4K cold bore

FCC Beam Screen Mechanical Design

$$\mathcal{L} = \xi \frac{1}{\beta} \frac{N}{\Delta t} \eta_{fill}$$



C. Garion



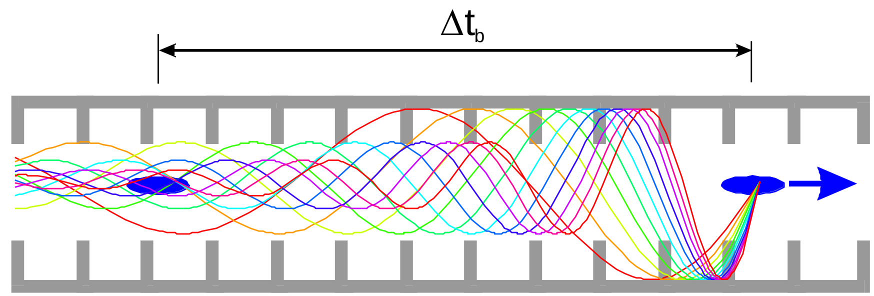
Beam screen remains relatively cool

Stress is acceptable from heat

Worry about sheer stress in quench
- attachment copper steel

Low Frequency Impedances

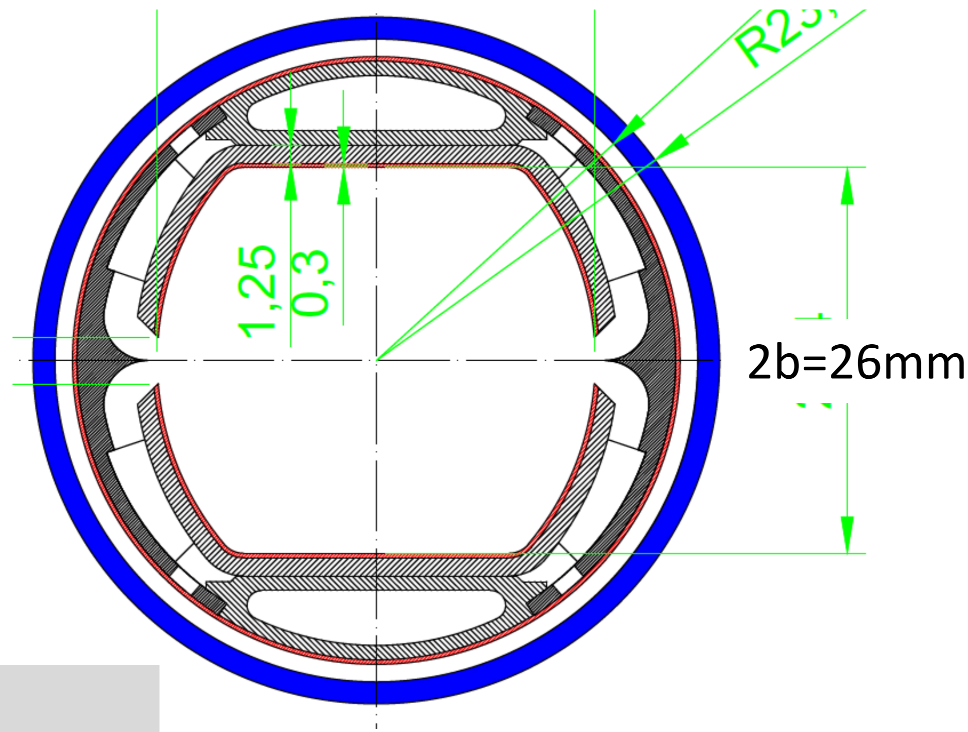
At injection multi-bunch instability is driven by resistivity of arc beam screen



Resistivity increases with temperature

Minimium radius is defined by strong dependence of impedance

$$Z_\perp \propto \frac{\sqrt{r}}{b^3}$$



⇒ Multi-bunch instability O(10) worse than in LHC

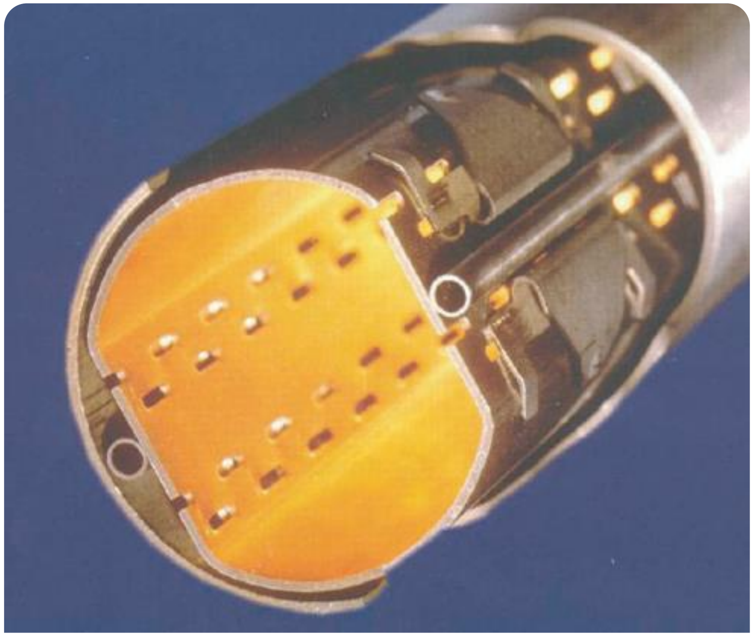
⇒ Assumes fast feedback

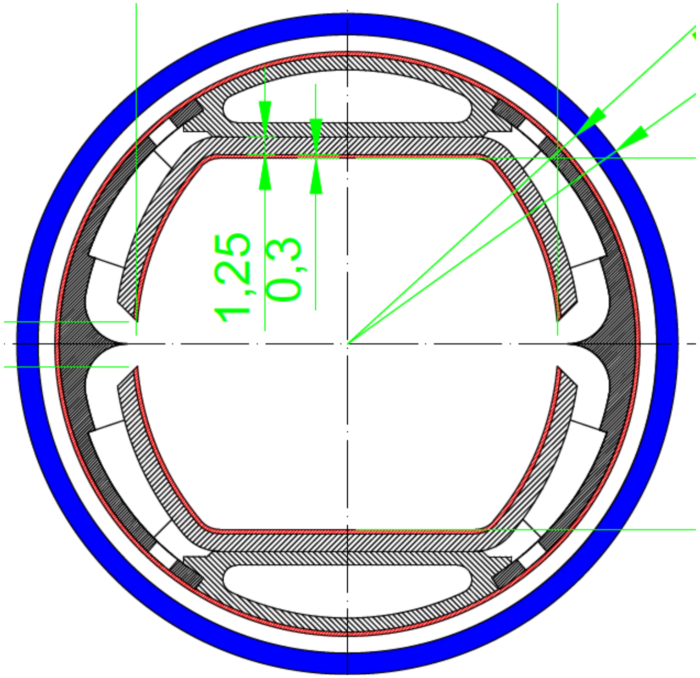
N. Mounet, G. Rumolo, O. Boine-Frankeheim, U. Niedermayer, F. Petrov, B. Salvant, X. Buffat, E. Metral, D.S.

High Frequency Impedance

In LHC pumping holes are important contribution to high frequency impedance at injection

Pumping holes in LHC-like design would lead to instability (TMCI) at 1.5×10^{11}
⇒ Way to little margin for charge of 1×10^{11}



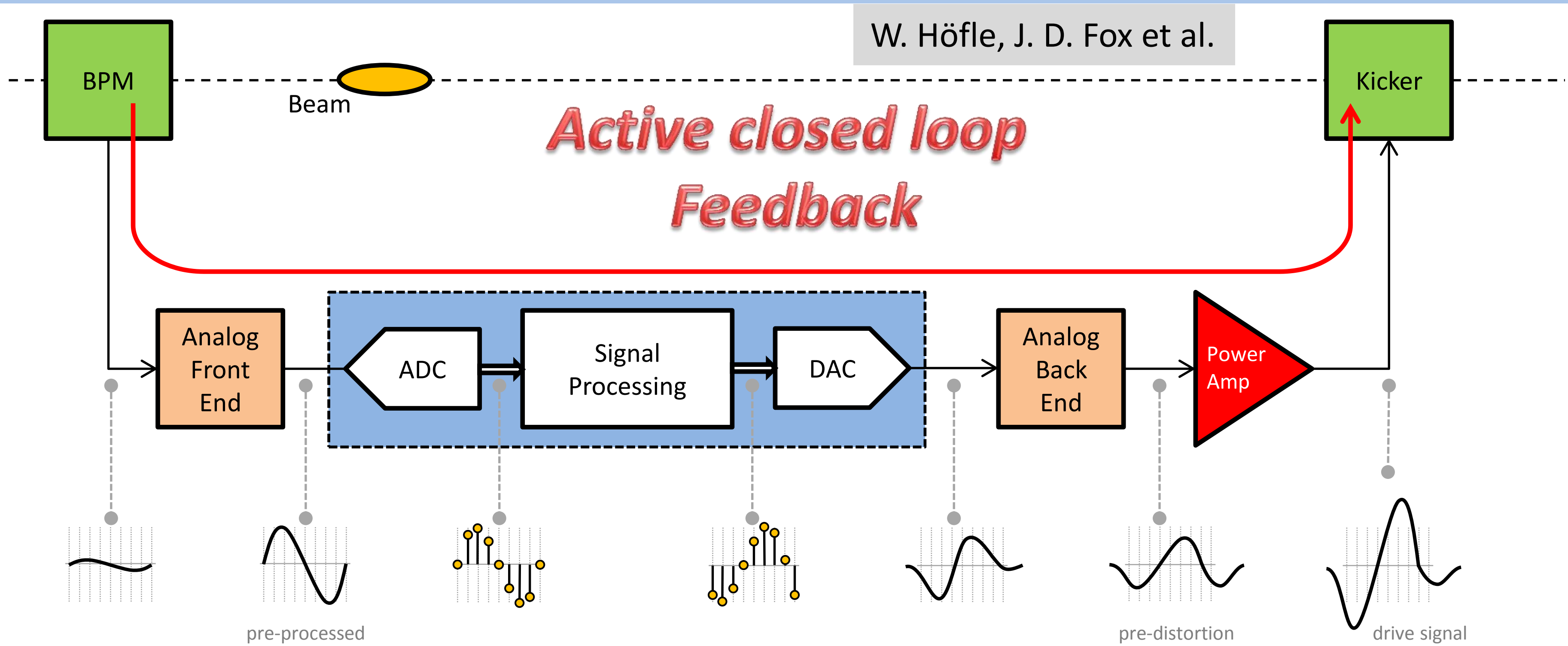


In FCC holes are shielded
⇒ Removes impedance

⇒ Other sources need to be studied (e.g. collimation system, …)

X. Buffat, O. Boine-Frankeheim, U. Niedermayer, F. Petrov, B. Salvant, D.S.

Feedback

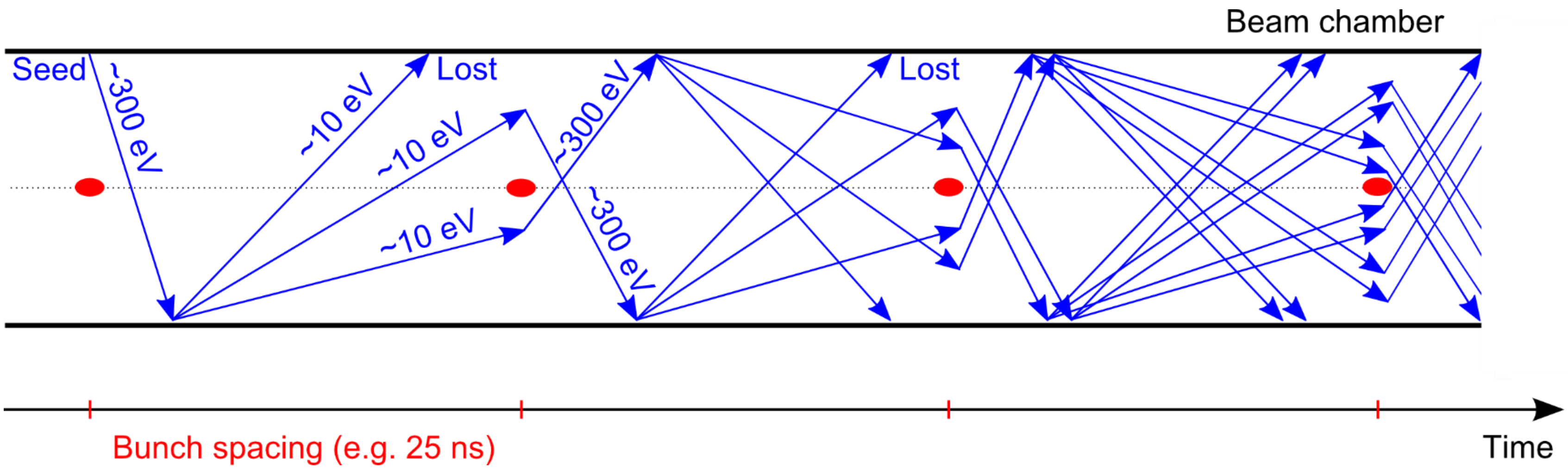


Higher bandwidth than in LHC (5ns bunch spacing)

Faster feedback allows to rise beam screen temperature

Even intra-bunch feedback is considered

Electron Cloud Effects



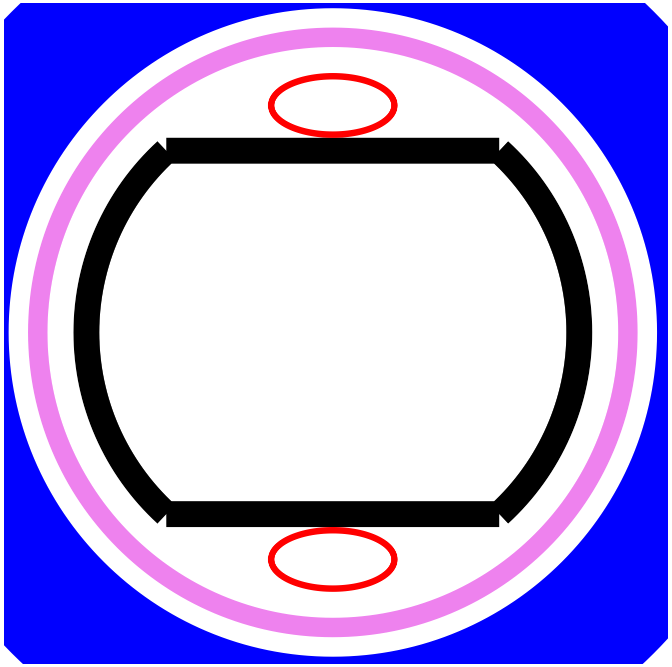
Still a potential performance limitation for LHC

- Heat load
- Beam instability

Twice as many photons as in LHC
At 100 times the energy (4.3keV vs. 44eV)

- Similar to B-factories

Surface properties important like photoelectron yield, secondary emission yield, reflectivity, …
⇒ Experimental input critical



Electron Cloud Effects

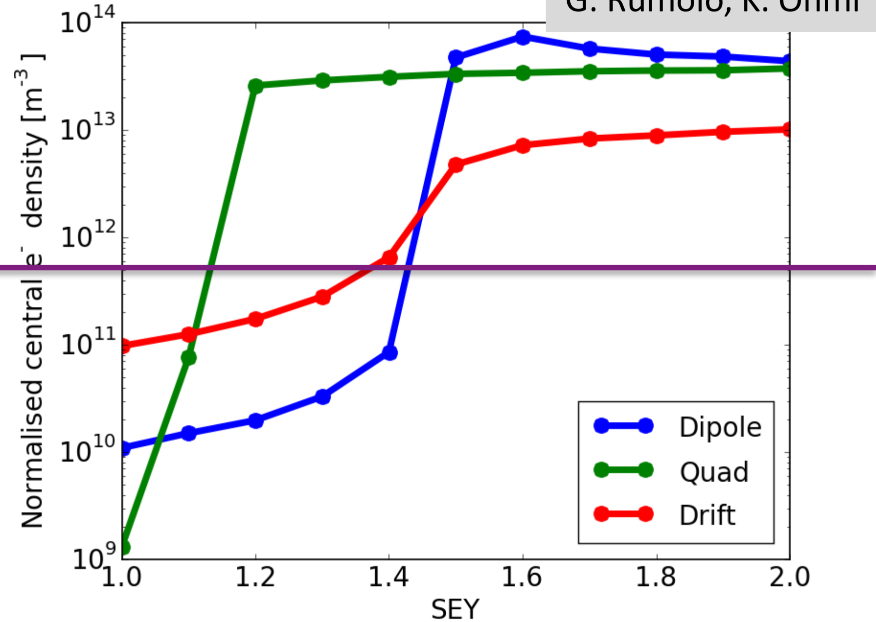
L. Mether,
G. Rumolo, K. Ohmi

Simulations (here for 5ns) show that electron cloud can be a problem

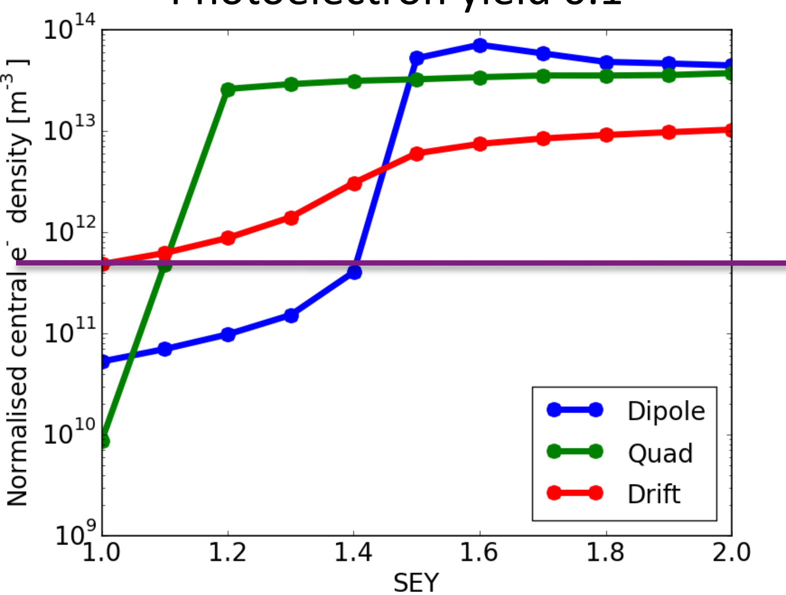
- Depends on surface properties

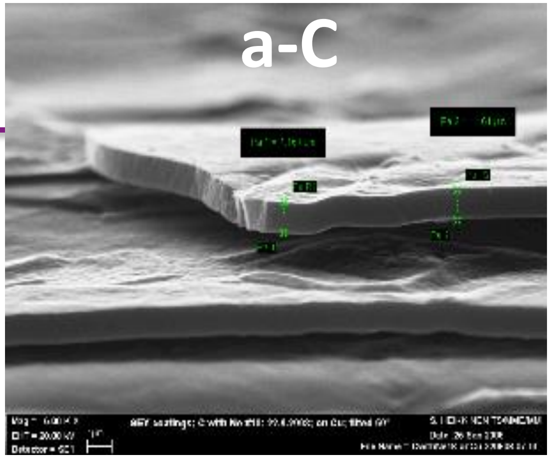
- Need to measure surface
- Use carbon coating
- Or laser treatment

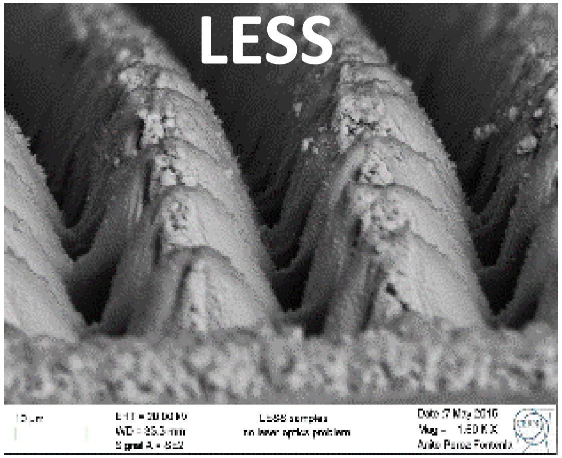
Photoelectron yield 0.02



Photoelectron yield 0.1



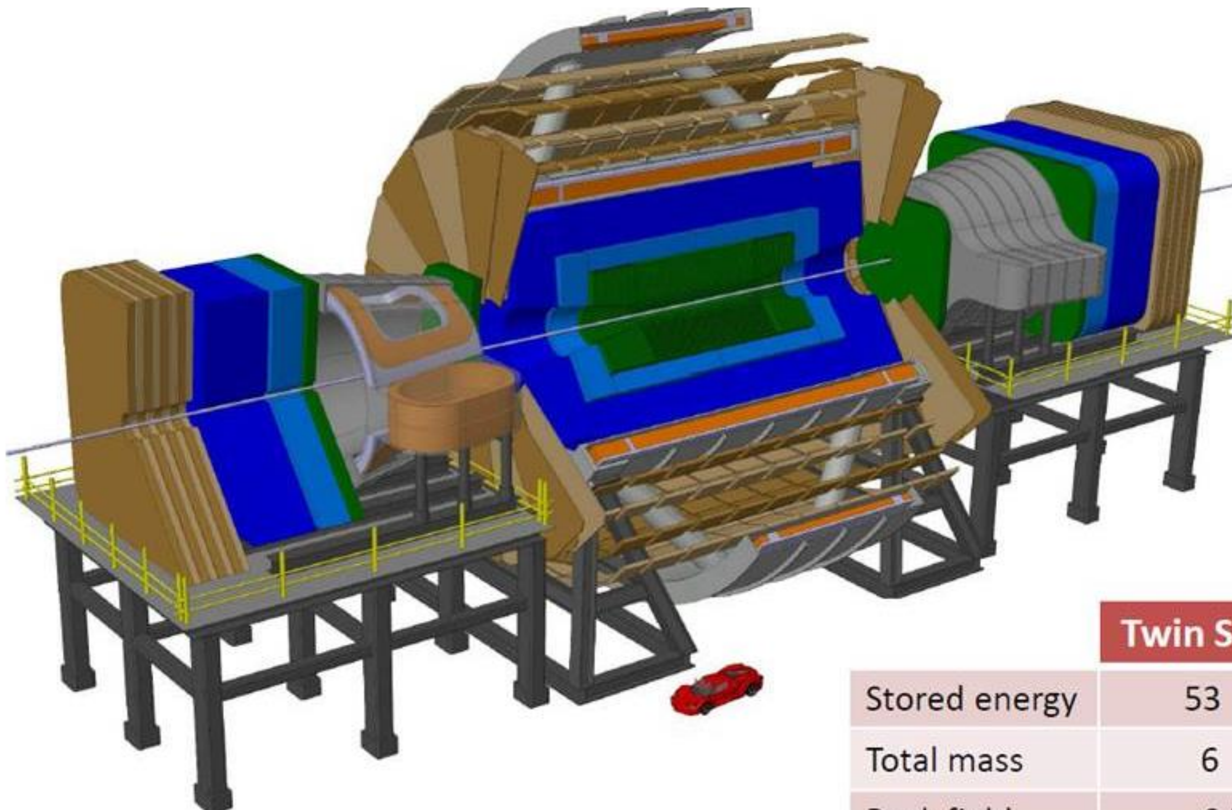




Current FCC Detector Model

W. Riegler et al.

Matthias Mentink, Alexey Dudarev, Helder Filipe Pais Da Silva, Christophe Paul Berriaud, Gabriella Rolando, Rosalinde Pots, Benoit Cure, Andrea Gaddi, Vyacheslav Klyukhin, Hubert Gerwig, Udo Wagner, and Herman ten Kate

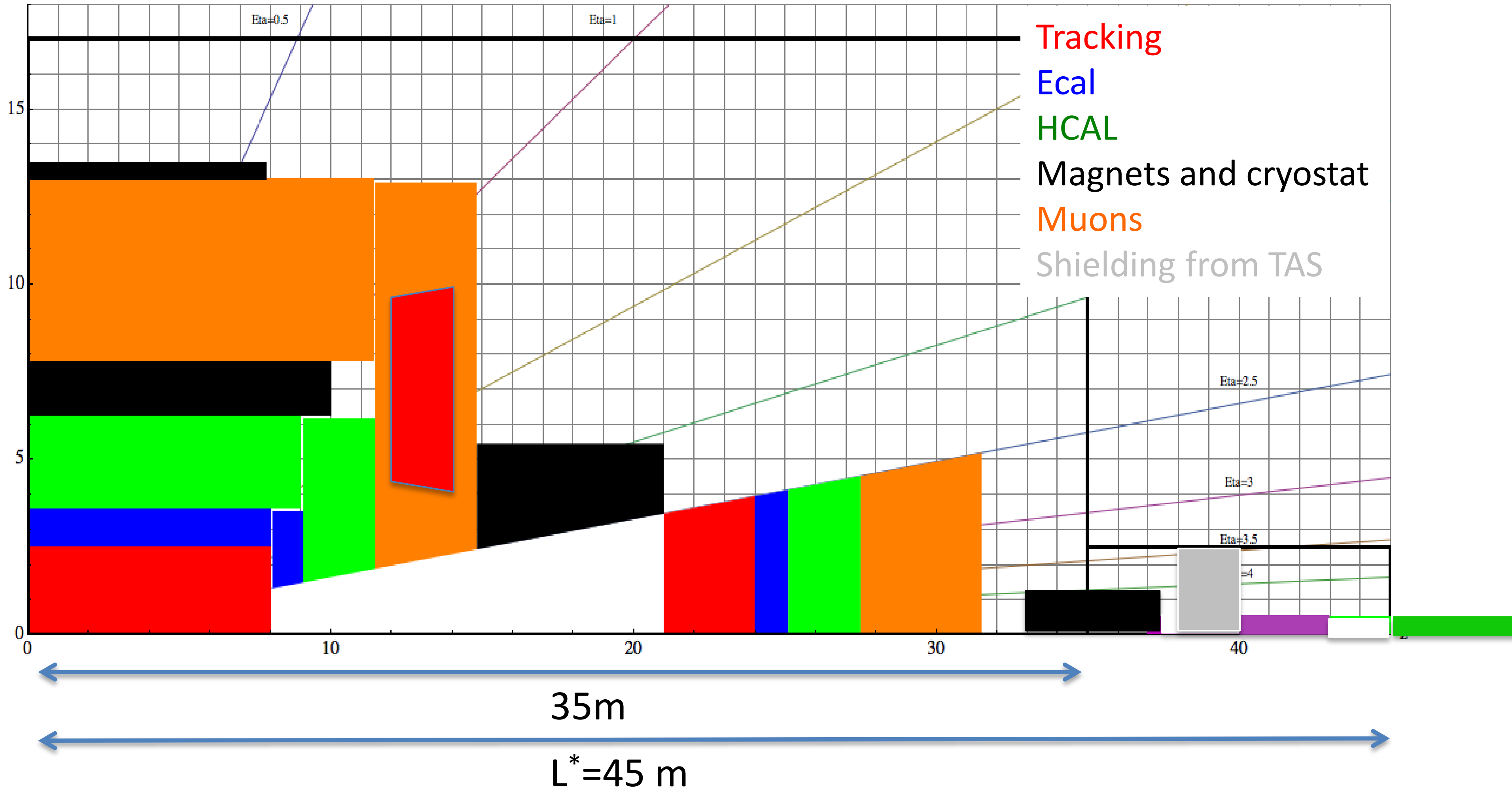


	Twin Solenoid	Dipole
Stored energy	53 GJ	2 x 1.5 GJ
Total mass	6 kt	0.5 kt
Peak field	6.5 T	6.0 T
Current	80 kA	20 kA
Conductor	102 km	2 x 37 km
Bore x Length	12 m x 20 m	6 m x 6 m

FCC Air core Twin solenoid and Dipoles

State of the art high stress / low mass design.

Modified from W. Riegler et al.

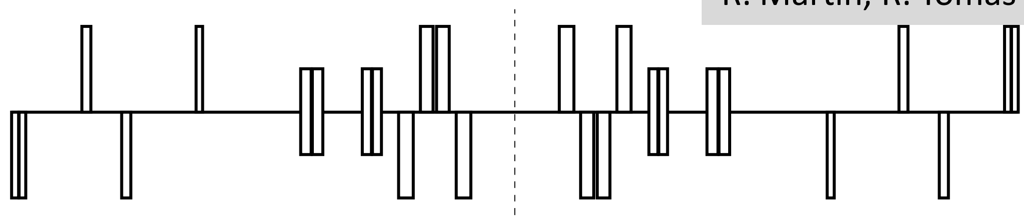


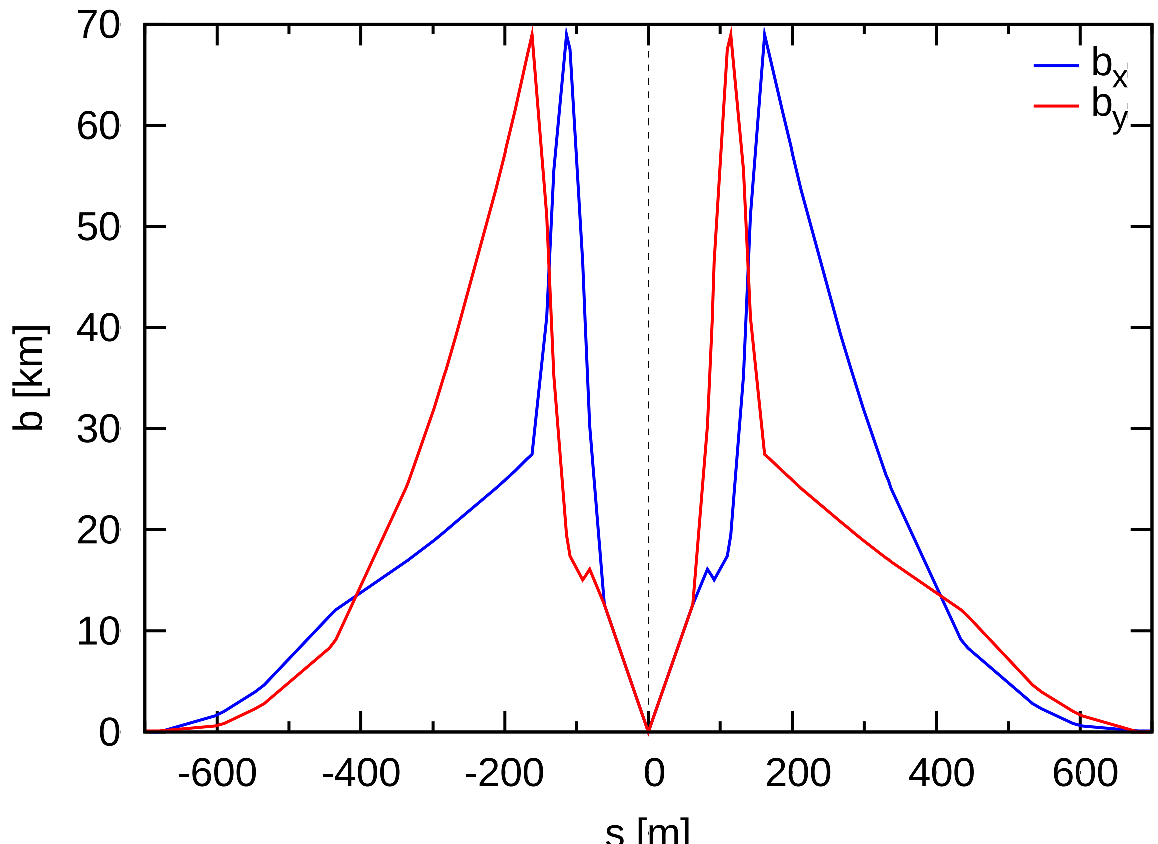
Have iterated on L*

High-luminosity Insertions

R. Martin, R. Tomas et al.

$$\mathcal{L} \propto \xi \frac{1}{\beta} N n_b f_r$$





Squeezes the beam to few microns

Have designs for L^*=36m and L^*=61m to explore

Now will go for L^*=45m

High-luminosity Insertions

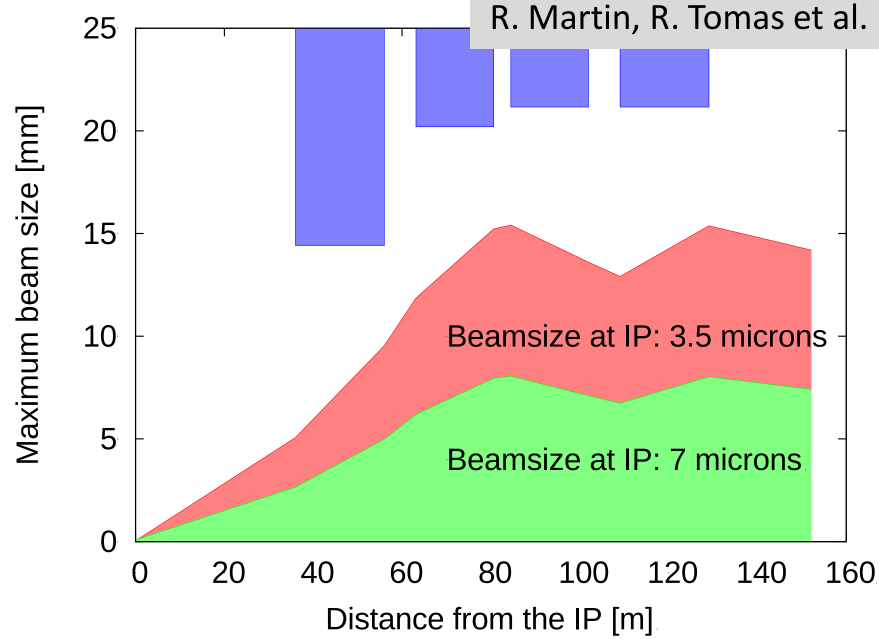
Small beam in interaction point leads

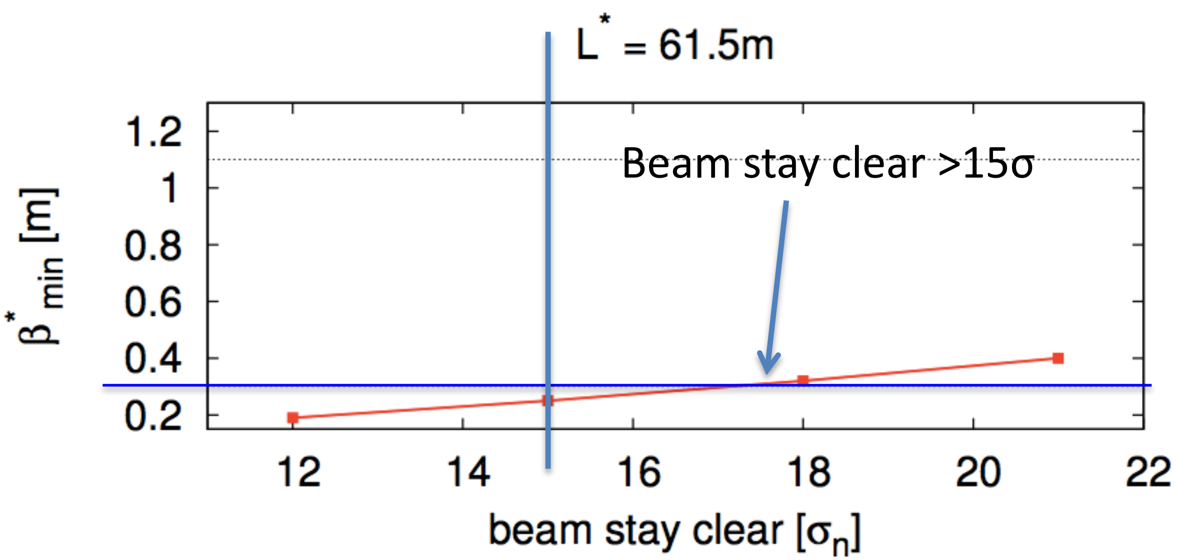
to large beam in triplets

For given triplet, aperture is limited

due to required field gradient

R. Martin, R. Tomas et al.





Can reach enough beam stay clear for target beta-function

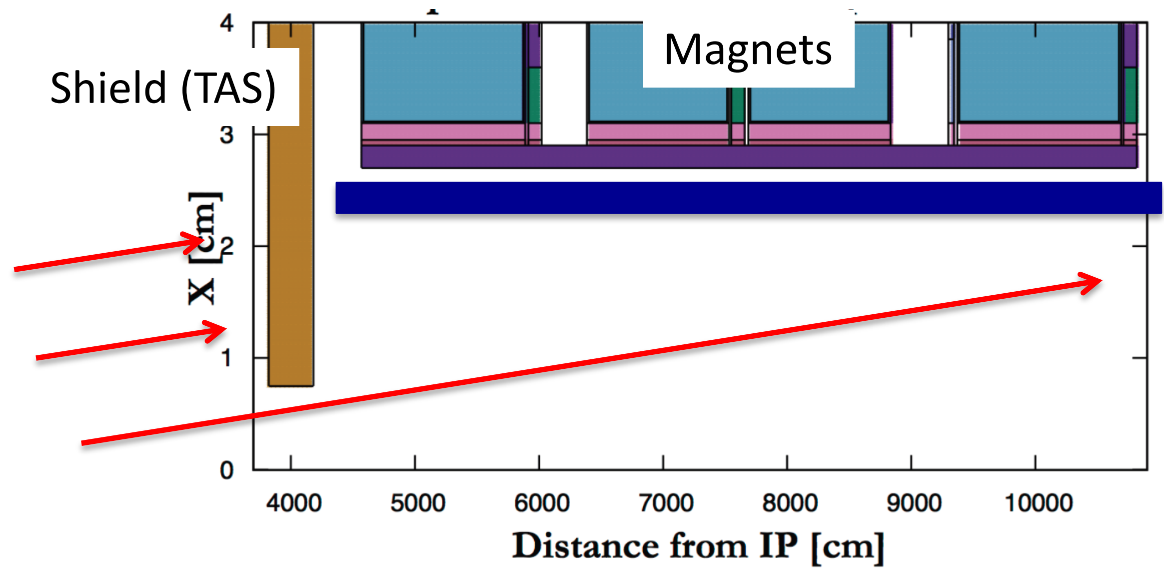
Radiation from Beam-beam

Total power of background events 100-500kW per experiment

- Car or truck engine

Already limit in LHC and HL-LHC

- Magnet lifetime, heat load



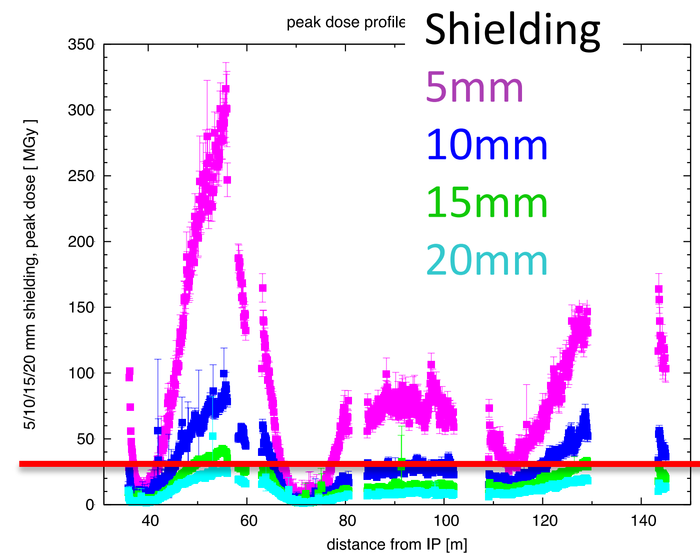
Study of $3000 fb^{-1}$ in older FCC-hh detector design

Goal: survive at least $5000 fb^{-1}$

- One 5-year run

Dose for $3000 fb^{-1}$

30MGy= Current limit

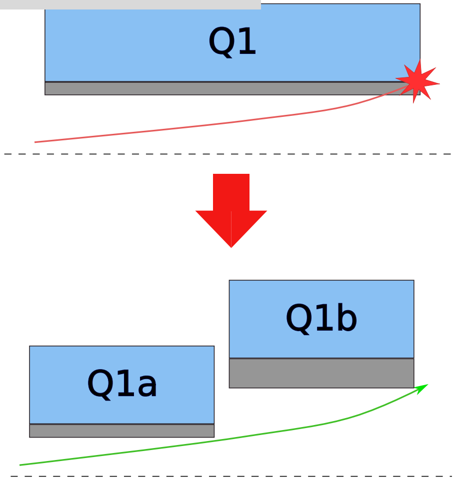


M. I. Besana, F. Cerutti, et al.

Countermeasures

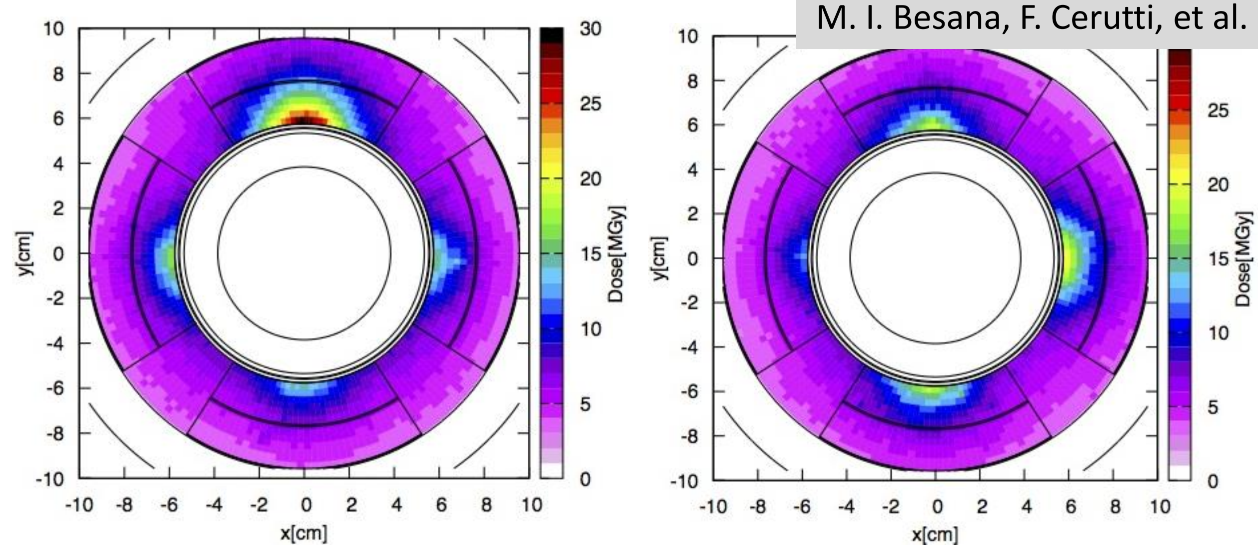
Split magnets

R. Martin et al.

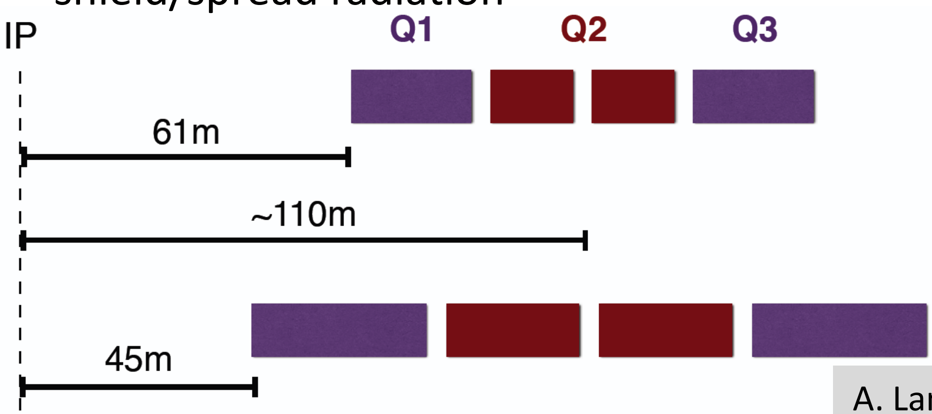


Vary crossing scheme to distribute damage (S. Fartoukh)

M. I. Besana, F. Cerutti, et al.



Longer triplet with more aperture to better shield/spread radiation

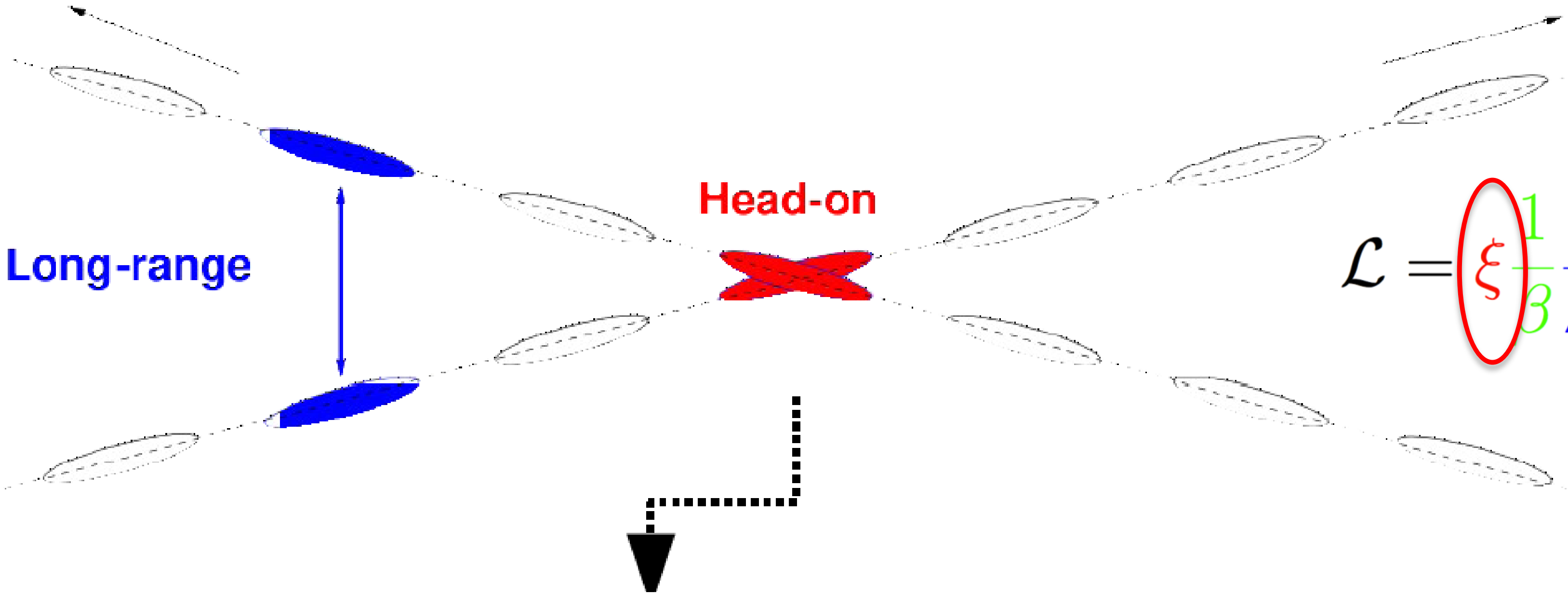


A. Langner et al.

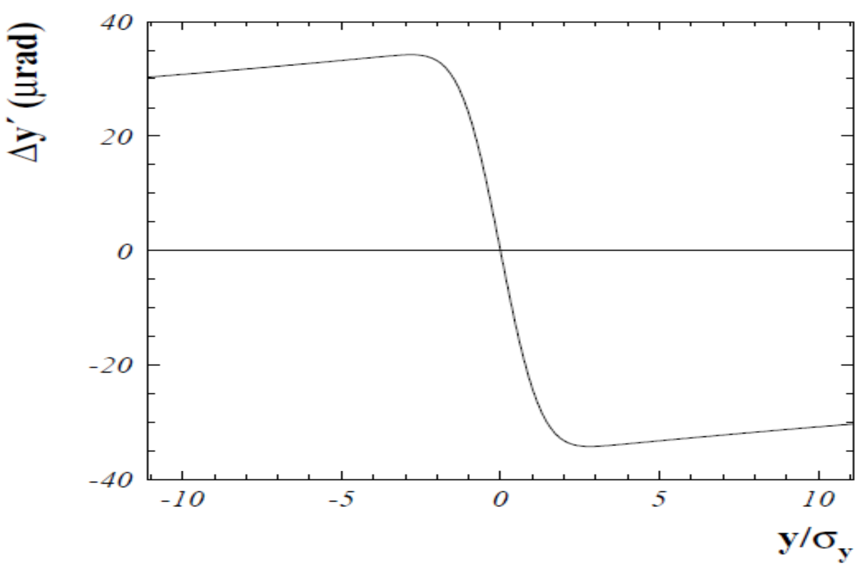
Improvements in radiation hardness

Need to push hard to gain small factors

Beam-beam Effects



$$\mathcal{L} = \xi \frac{1}{\beta} \frac{N}{\Delta t} \eta_{fill}$$

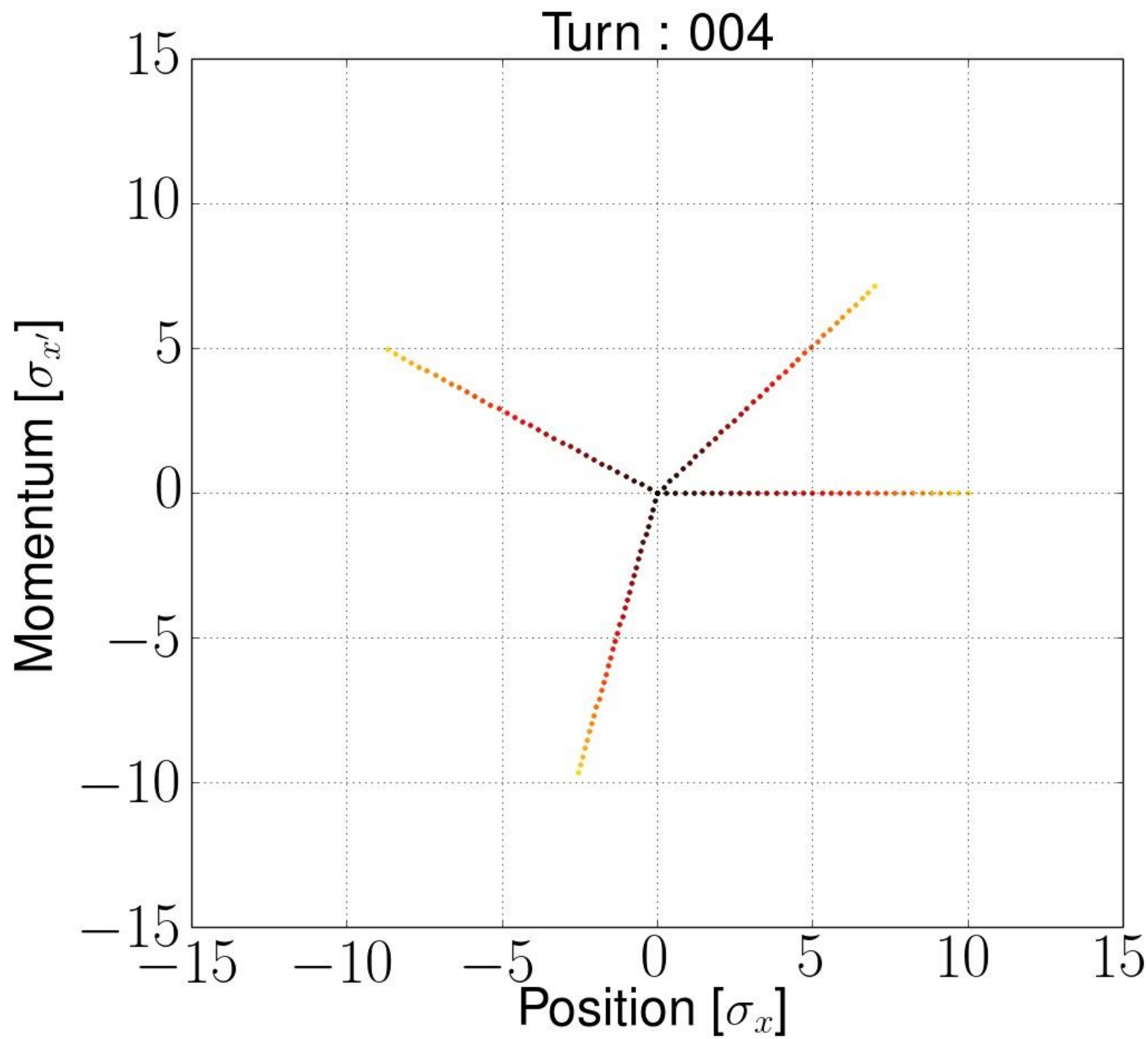


Emittance growth

Beam loss

Beam-beam Effects

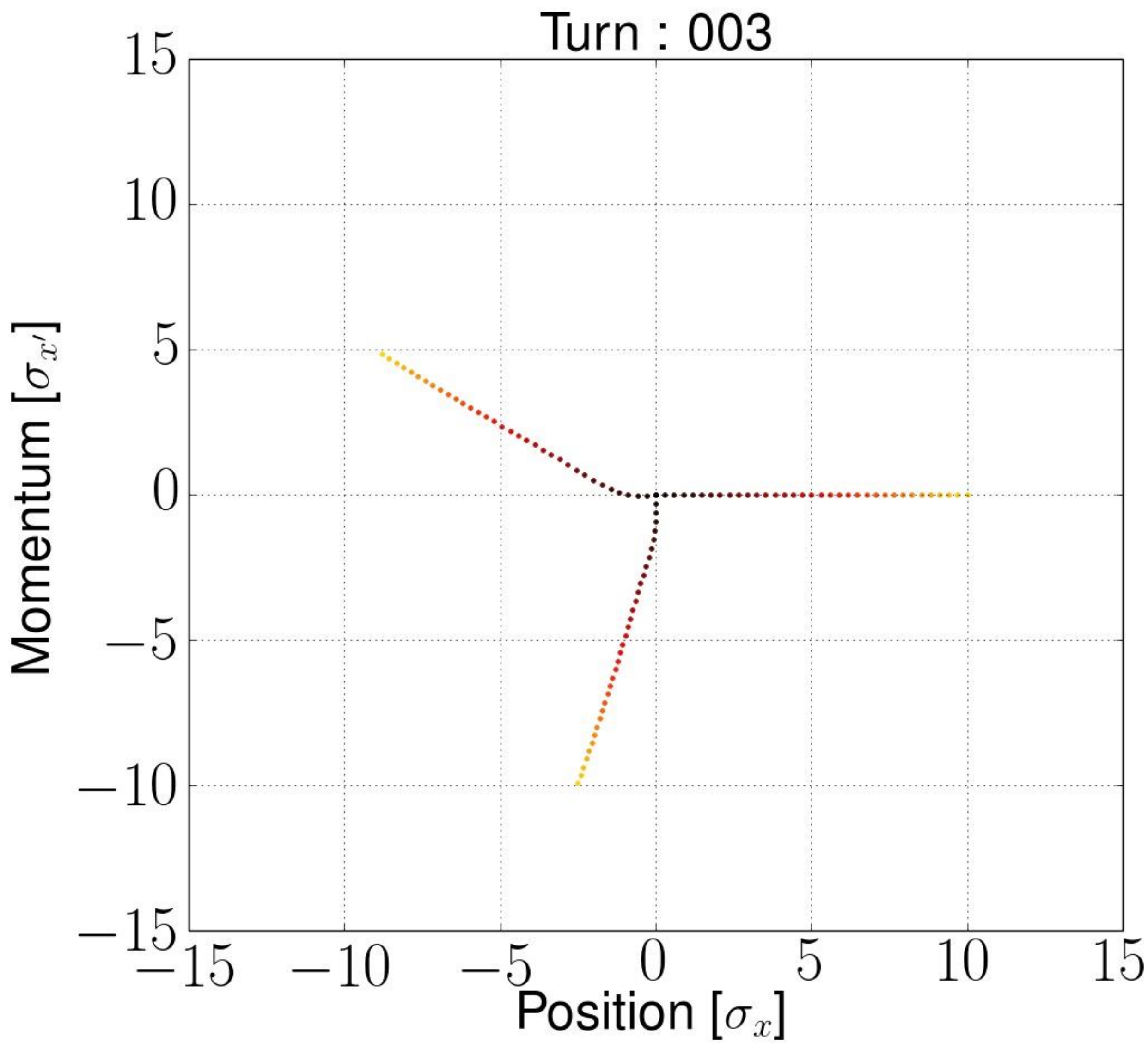
X. Buffat



Beam-beam Effects

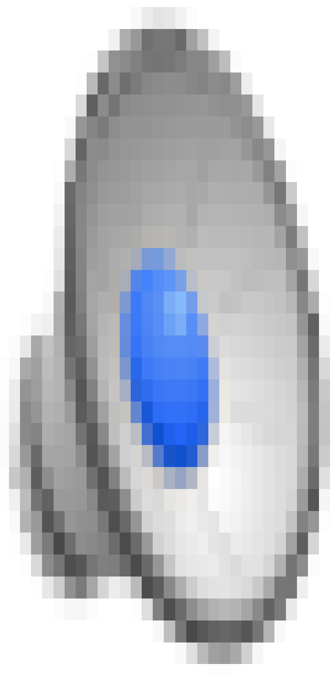
X. Buffat

X. Buffat

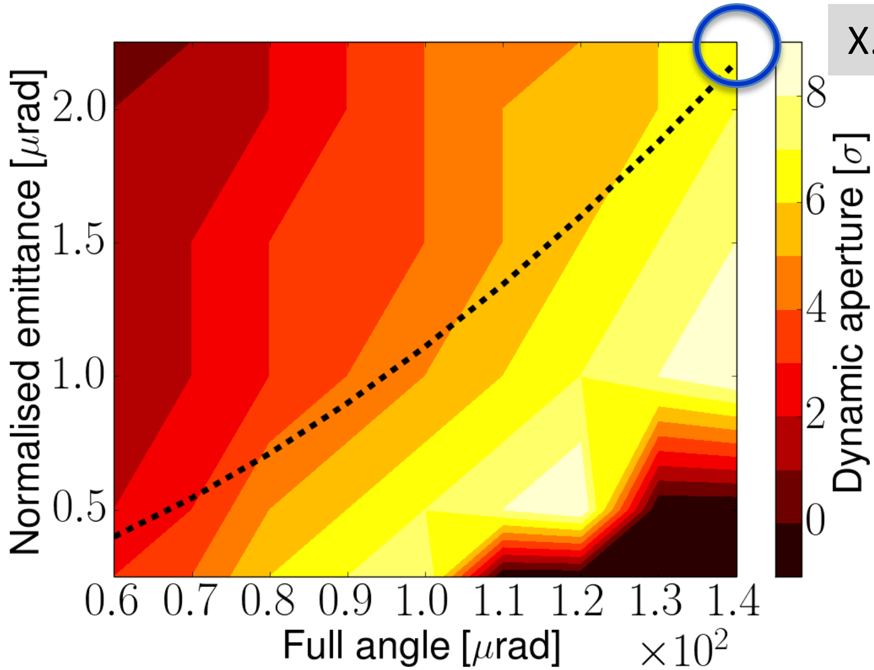


Beam-beam Effects

X. Buffat



Limit and Mitigation



X. Buffat

Crossing scheme and angle determined by beam-beam

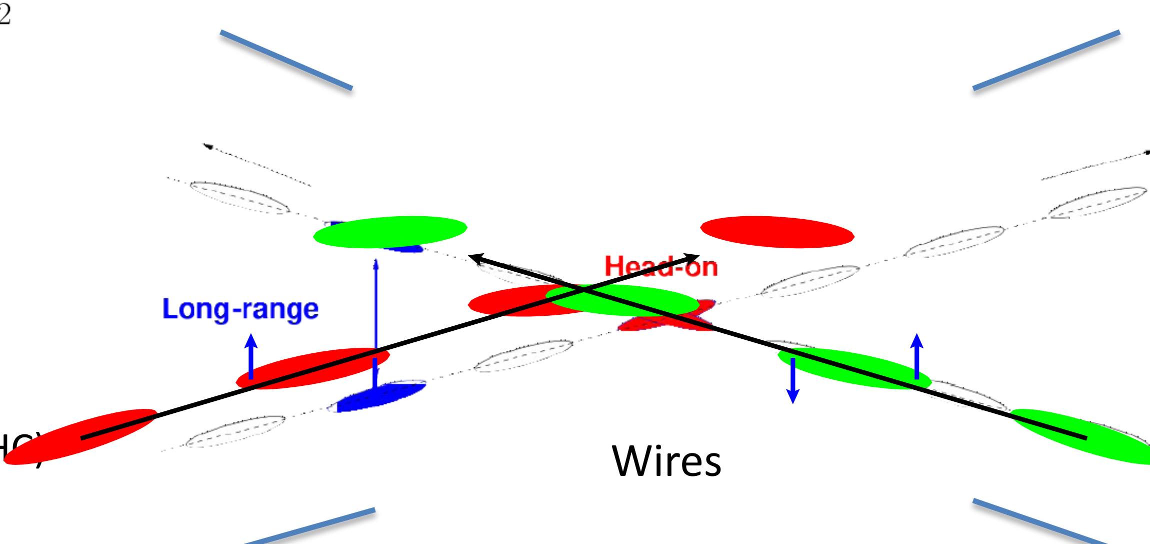
Effect is about OK for baseline

But would like to have margin and to push further

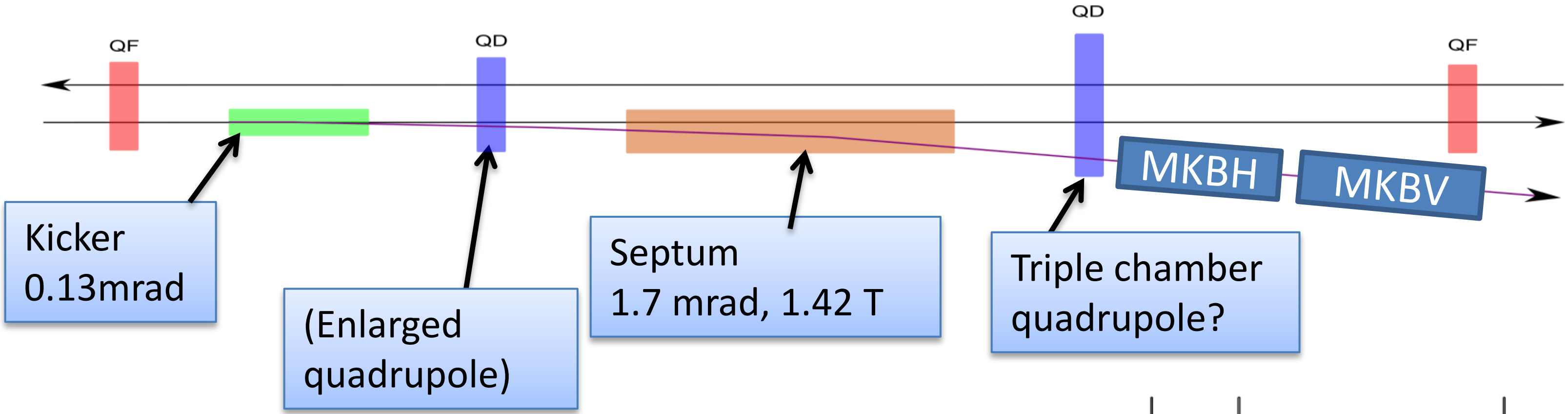
Mitigation technique examples:

Larger crossing angle (and crab crossing)

Compensating wire (to be tested for HL-LHC)

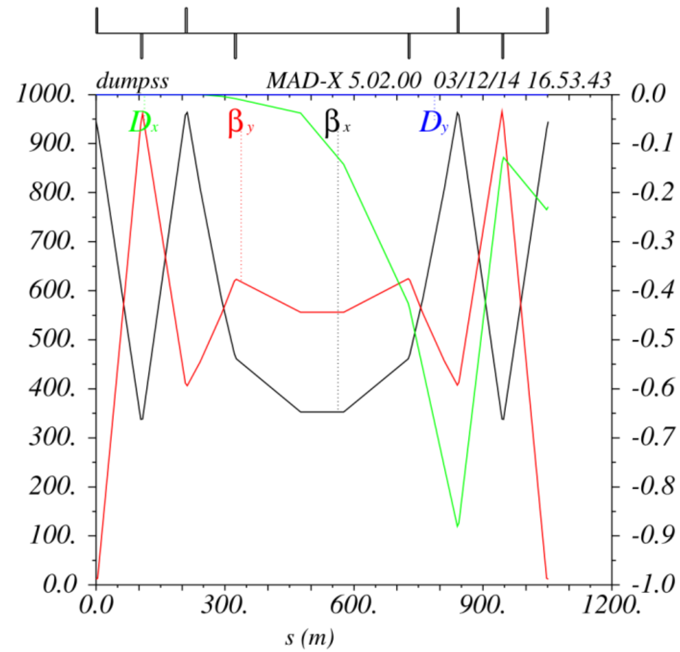


Extraction



Normally fire kickers in the abort gap of the beam

But kicker can fire on its own
⇒ In LHC fire all and sweep beam out
⇒ Does the extraction line survive?
⇒ Can we segment kicker such that we can leave beam circulating until abort gap?
⇒ Is this safe?



Design based on LHC design
Alternatives studied

W. Bartmann, B. Goddard, F. Burkart, …

Beam Dump Considerations

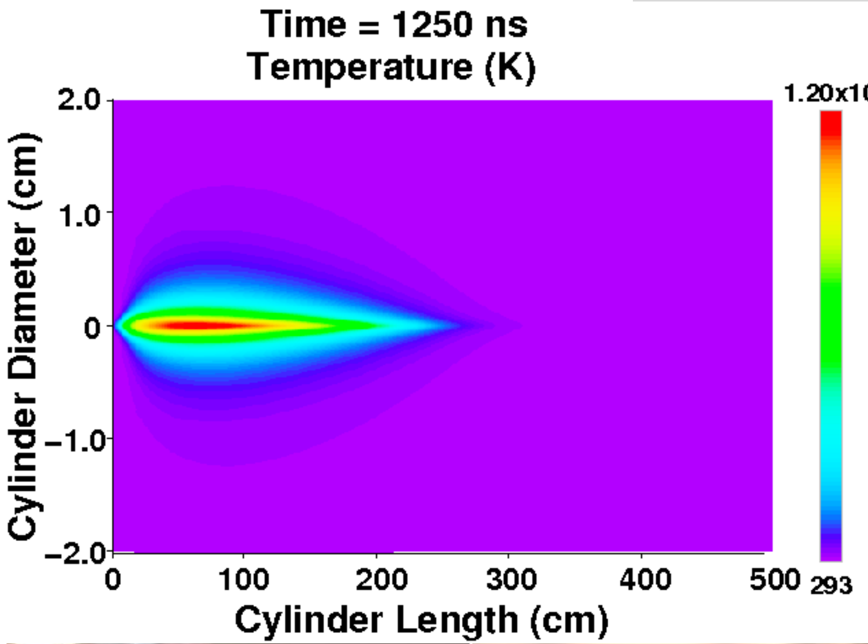
F. Burkart et al.

8GJ kinetic energy per beam

- Airbus A380 at 720km/h
- 2000kg TNT
- 400kg of chocolate
  - Run 25,000km to spent calories
- O(20) times LHC

Simulation show beam will penetrate ~ **300 m** in Copper, assuming no dilution.
→ **Dilution required!**

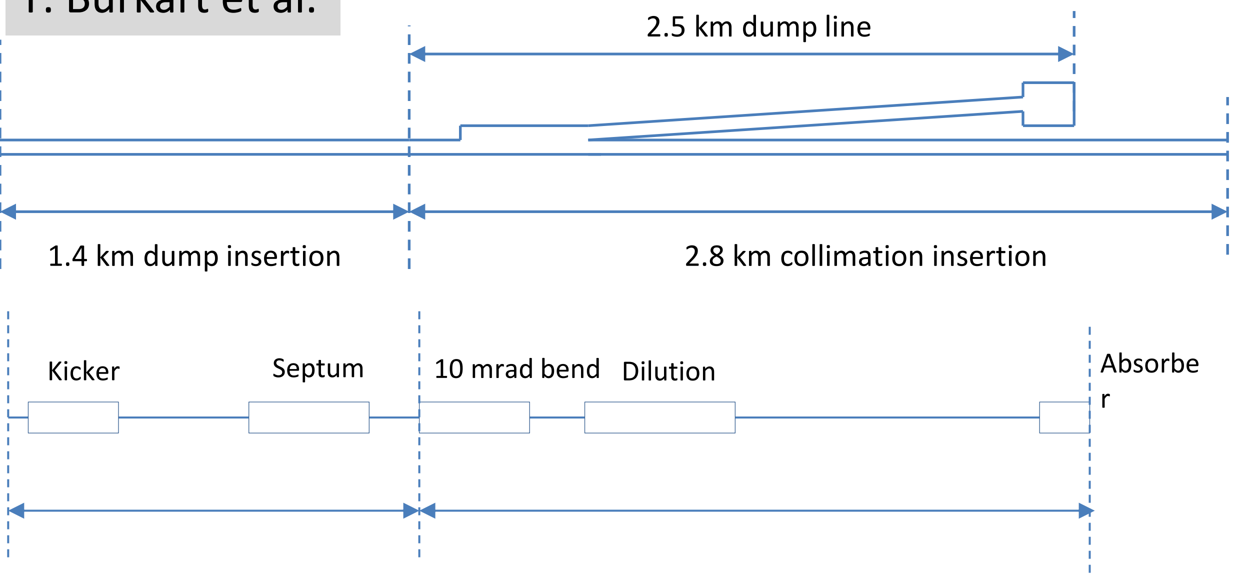
Hydrodynamic tunneling

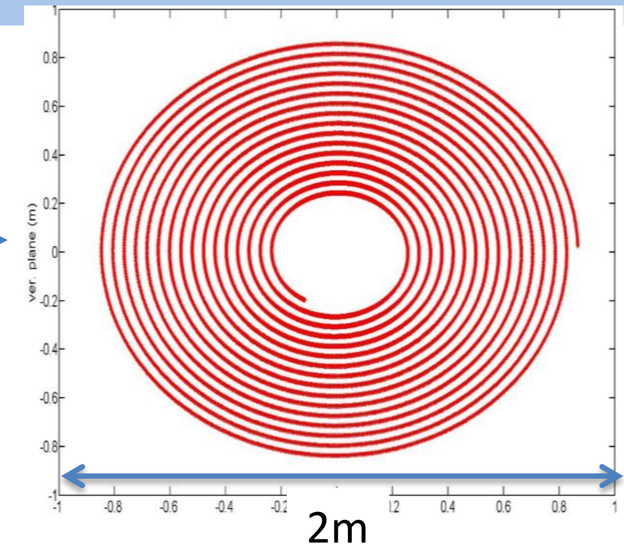


![CERN logo] ![FCC logo]

Dilution System

F. Burkart et al.





A. Lechner, P. Garcia

Horizontal and vertical kicker system as in the LHC

- **~ 300 m, ~150kickers,** to be optimized
- Large magnet apertures required towards dump

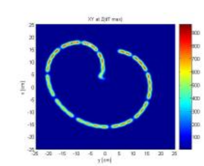
Fluka studies of required pattern:

- Bunch separation > 1.8 mm
- Branch separation: 4 cm
- Keeps T<1500°C

Different solutions studied

- Require up to 80cm radius

LHC pattern (same scale)



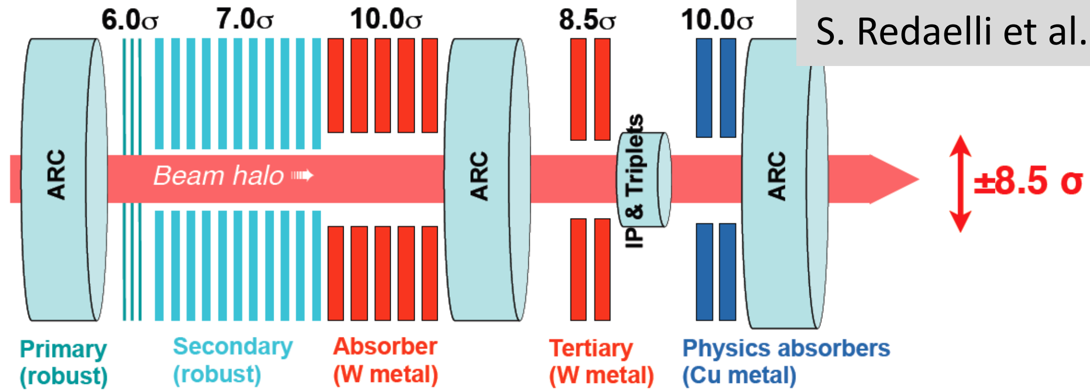
Collimation

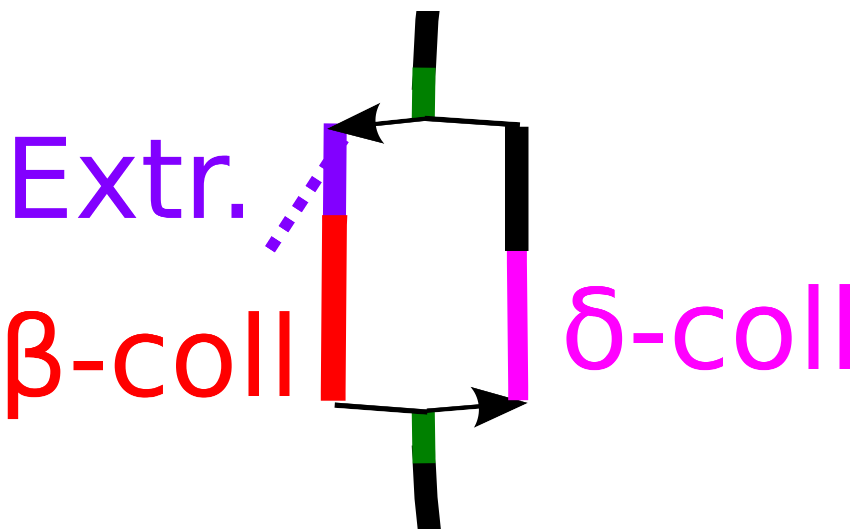
To protect machine and experiments

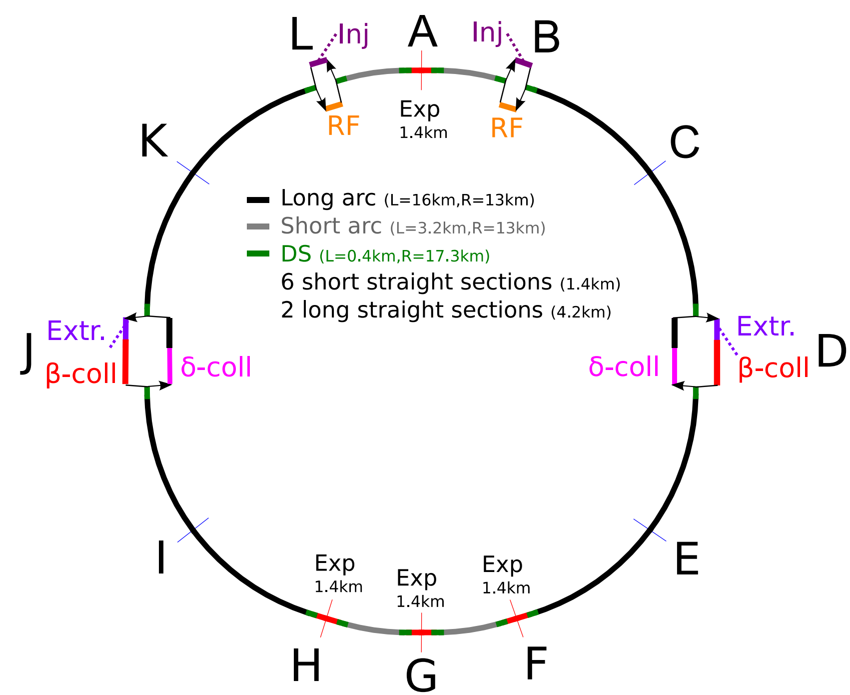
At injection tightest part is arcs

At collision energy triplets at experiments

S. Redaelli et al.







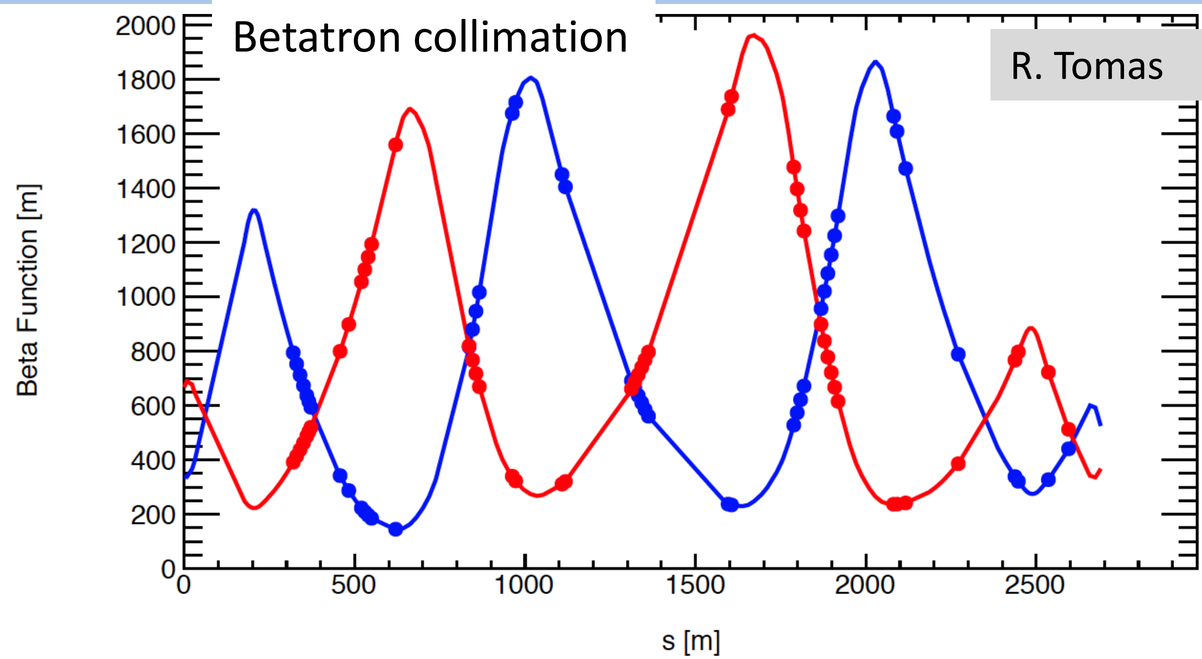
First Collimation Studies

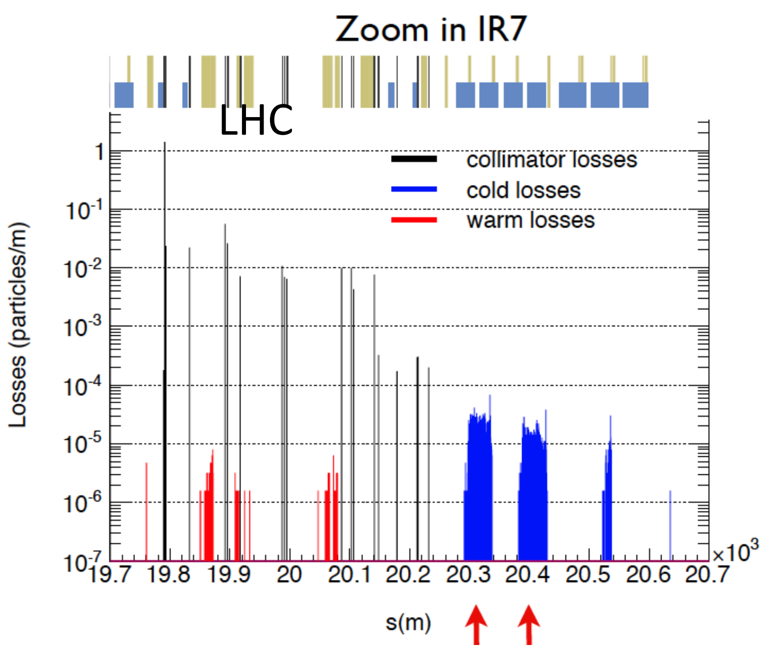
First collimation system lattice designs exist

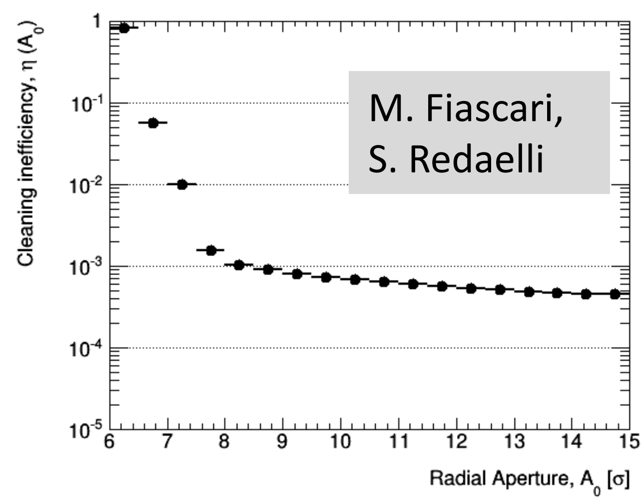
- Based on LHC designs

⇒ Starting point for exploration

⇒ Fix issues from LHC design







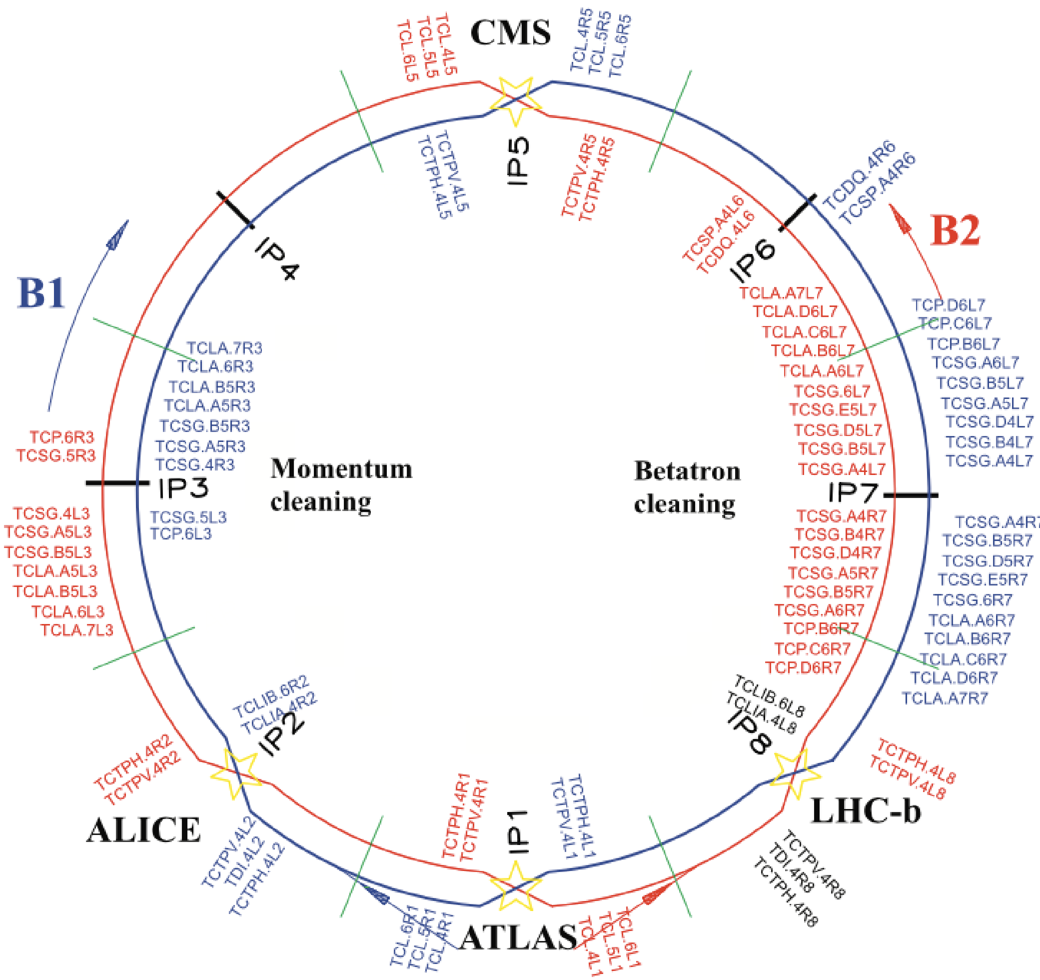
Collimation

First performance studies are ongoing
- Collimation efficiency
- Power losses

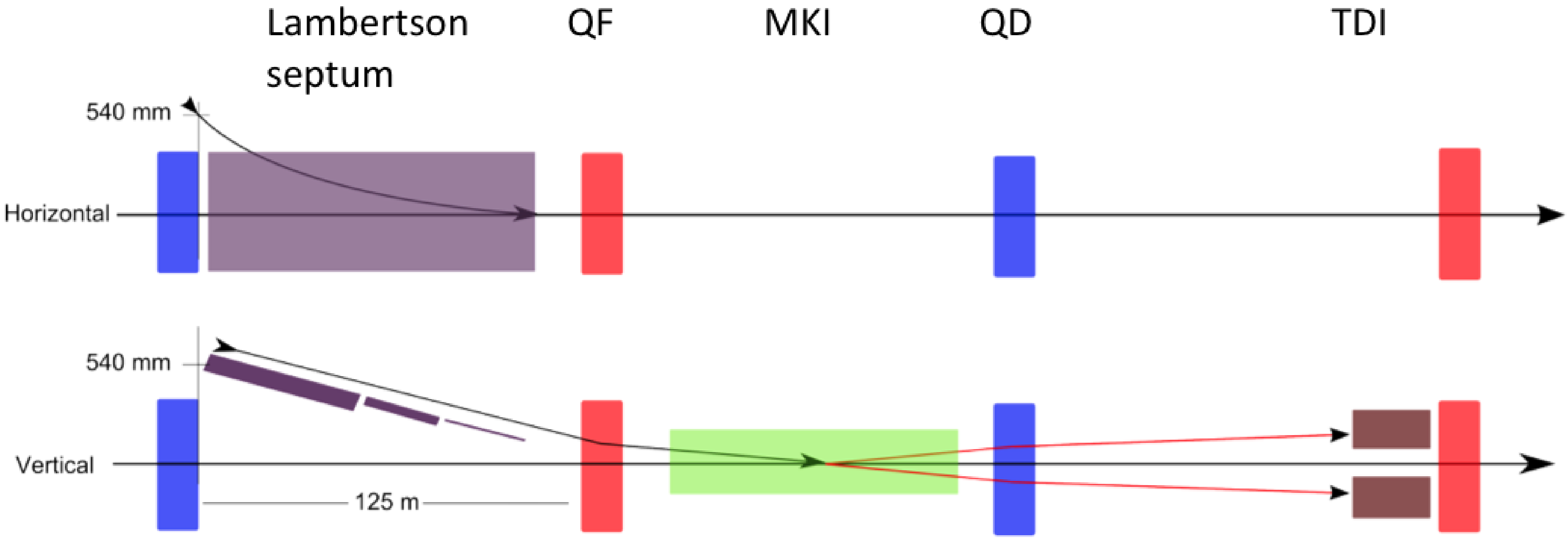
Many studies to be performed
- Protection of machine from experiments
- Background from one experiment to the next
- …

Have to review FLUKA at FCC energies

A complex long-term optimisation



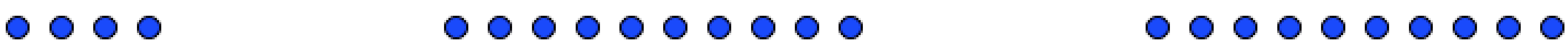
Injection Insertion



Have to limit injected batch

⇒ With LHC limits can inject O(100) bunches

⇒ Very fast kicker (O(300ns)) for beam filling factor of 80%

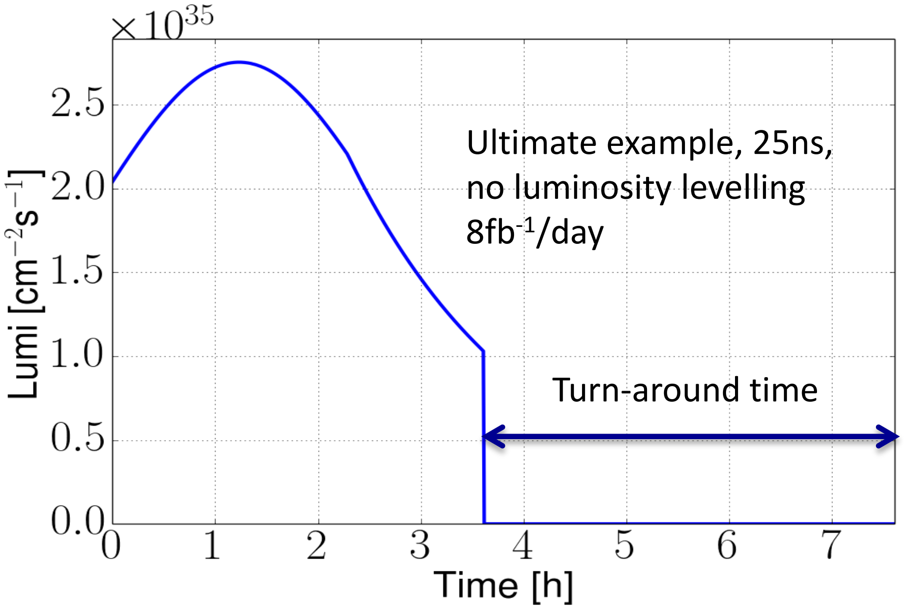


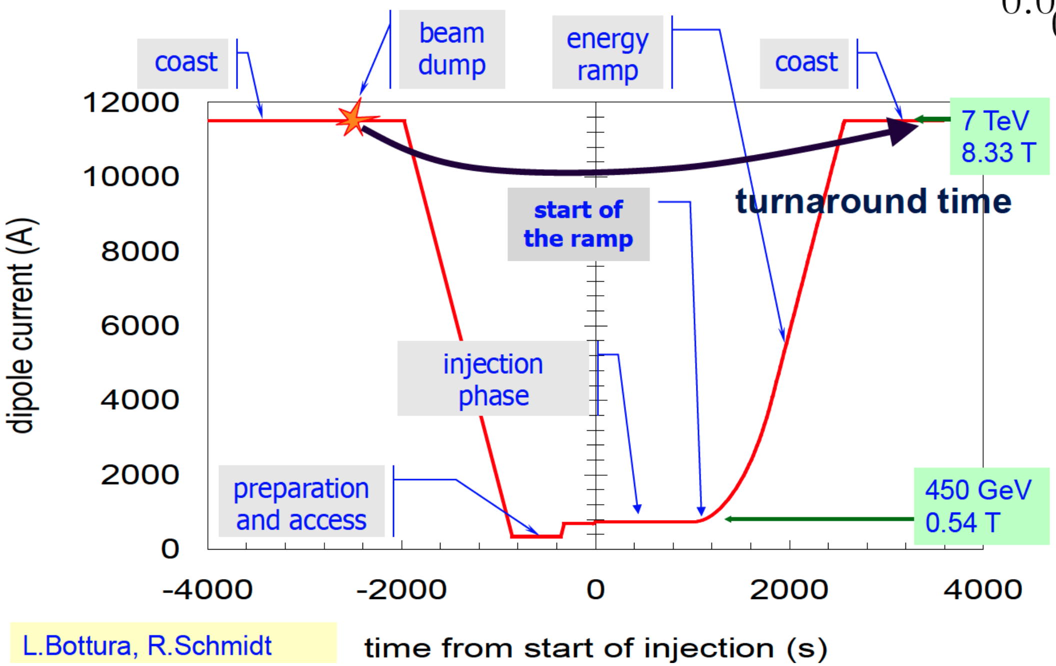
W. Bartmann, B. Goddard, F. Burkart, …

Turn-around Time

Integrated luminosity is strong affected by turn-around time
$\Rightarrow$ Higher luminosity would not help a lot

Turn-around time in LHC larger than theoretical limit
$\Rightarrow$ Need to understand in more detail





Ensure we are not too optimistic

Explore options to speed it up

Magnets need >600s (linear ramp)

Dynamic Aperture

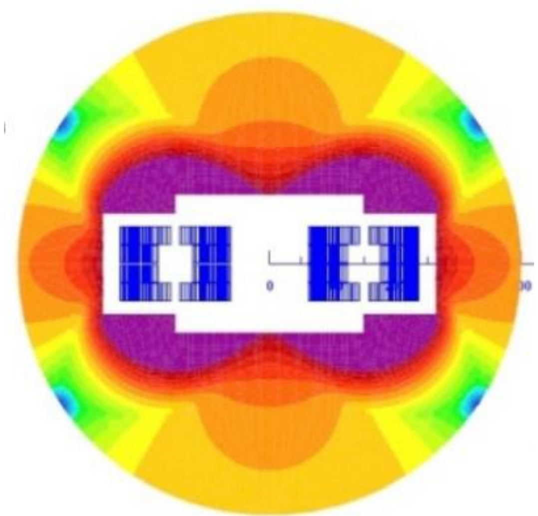
Magnets have field errors

Random and systematic

Non-linear fields can lead to chaotic motion
$\Rightarrow$ particle loss over many turns

Need to also work at low field at injection

Critical limit for magnet design



Example table: Need to consider many errors

			Uncertainty		Random	
Normal	Injection	High Field	Injection	High Field	Injection	High Field
2	0.000	0.000	0.484	0.484	0.484	0.484
3	-5.000	20.000	0.781	0.781	0.781	0.781
4	0.000	0.000	0.065	0.065	0.065	0.065
5	-1.000	-1.500	0.074	0.074	0.074	0.074
6	0.000	0.000	0.009	0.009	0.009	0.009
7	-0.500	1.300	0.016	0.016	0.016	0.016
8	0.000	0.000	0.001	0.001	0.001	0.001
9	-0.100	0.050	0.002	0.002	0.002	0.002
10	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000
Skew						
2	0.000	0.000	1.108	1.108	1.108	1.108
3	0.000	0.000	0.256	0.256	0.256	0.256
4	0.000	0.000	0.252	0.252	0.252	0.252
5	0.000	0.000	0.050	0.050	0.050	0.050
6	0.000	0.000	0.040	0.040	0.040	0.040
7	0.000	0.000	0.007	0.007	0.007	0.007
8	0.000	0.000	0.007	0.007	0.007	0.007
9	0.000	0.000	0.002	0.002	0.002	0.002
10	0.000	0.000	0.001	0.001	0.001	0.001
11	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000
15	0.00					

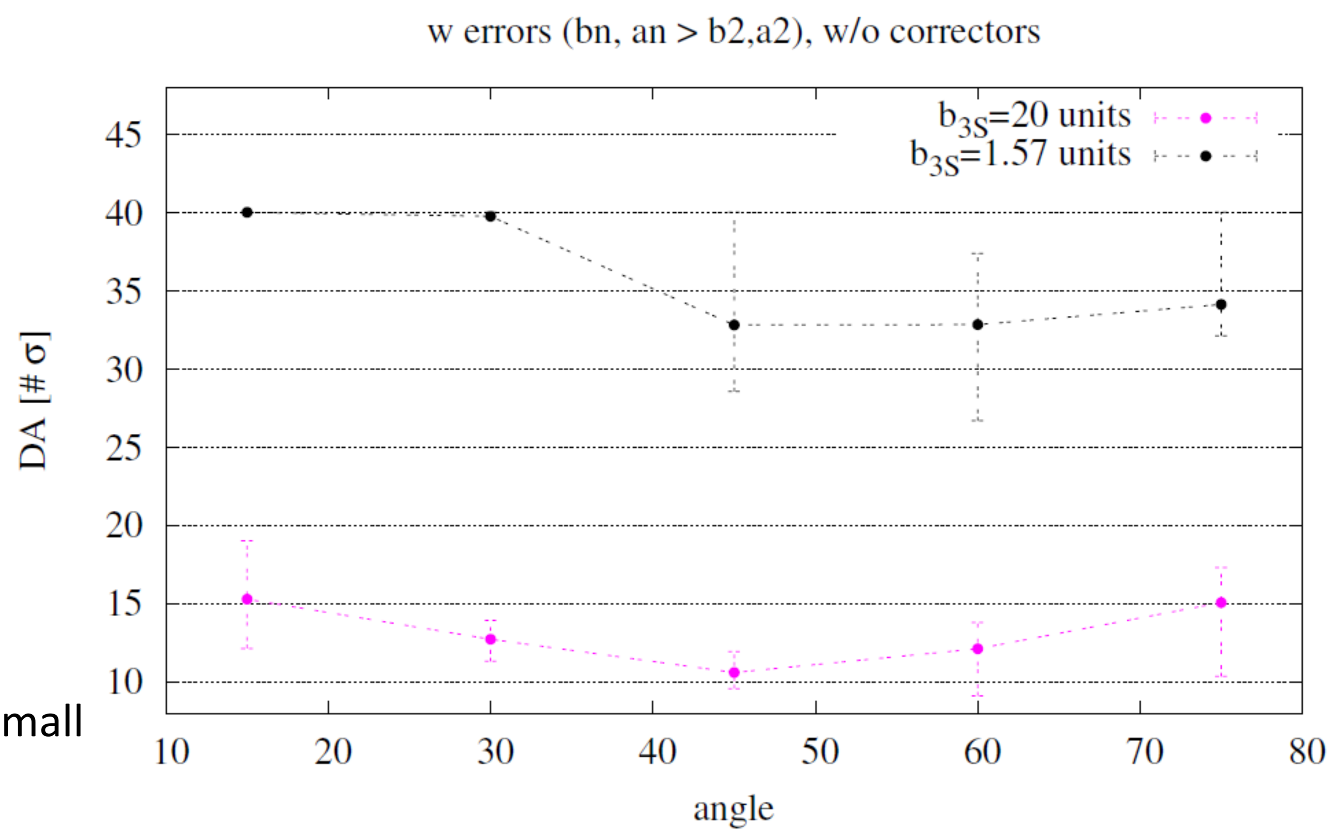
E. Todesco, S. I. Bermudez et al.

Example Estimate

Collision energy

1) Design to have B3 mainly at full energy

2) Design to have B3 mainly at injection



Conclusion:

1) Dynamic aperture too small
- Would need very strong correctors (10xLHC)

2) Dynamic aperture looks fine
- Need to work on dynamic aperture at injection

B. Dalena, A. Chance, D. Boutin, J. Payet,

LHC Experiments

Field error depends on injection energy

Uncertain about reproducibility and stability at low fields

Experiment is important

Inject beam into LHC at 225GeV

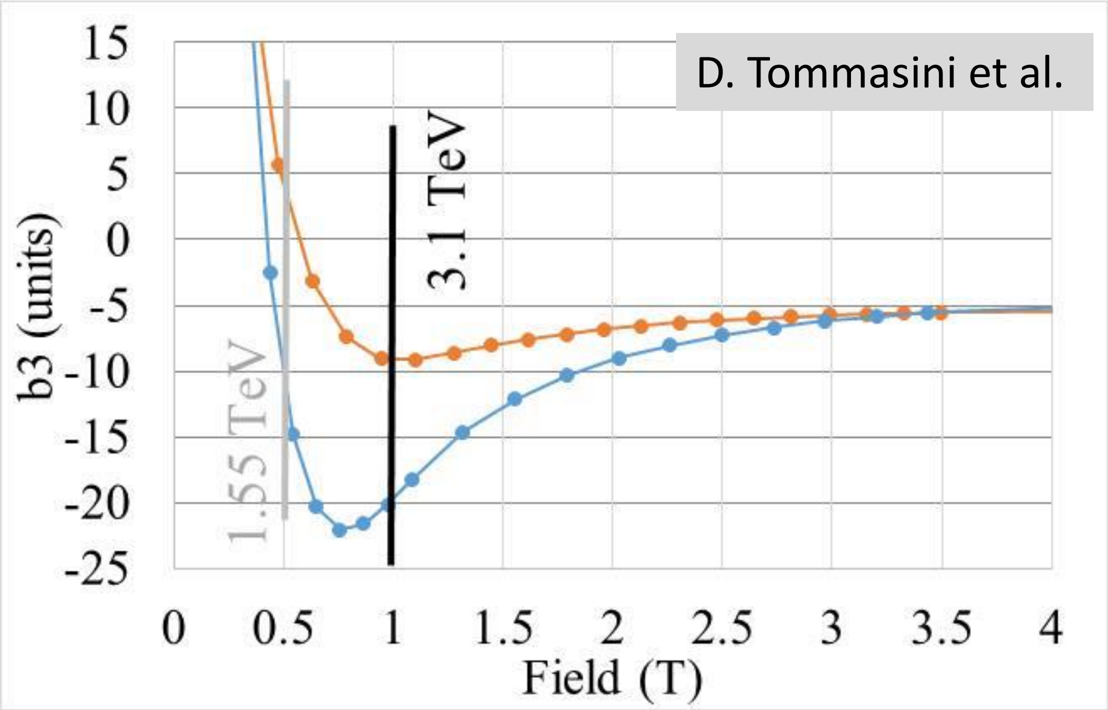
- Or decelerate injected beam to 225GeV

Many changes are required and need to be undone

⇒ Best at the end of a run

http://indico.cern.ch/event/469656/

B. Goddard et al.



Important for FCC as well:

- Faster ramping

Profit from LHC and HL-LHC MDs

- Impedances
- Beam-beam
- …

If You Want to Contribute

Work/meeting structures established based on INDICO, see:

- **FCC Study:** https://indico.cern.ch/category/5153/

In particular:

- **FCC-hh Hadron Collider VIDYO meetings**
  - https://indico.cern.ch/category/5263/
  - **Contacts:** daniel.schulte@cern.ch

- **FCC-hadron injector meetings**
  - https://indico.cern.ch/category/5262/
  - **Contacts:** brennan.goddard@cern.ch

Conclusion

- FCC-hh developed as option for future flagship project at CERN
  - Goal is to have CDR ready for European strategy update (2018)
  - https://indico.cern.ch/category/5153/
  - Workshop in Rome April 11-15, 2016
- Work is progressing
- More work to be done
  - Exciting technological challenges
  - Exciting beam physics
  - Exciting physics
- Your contributions are most welcome

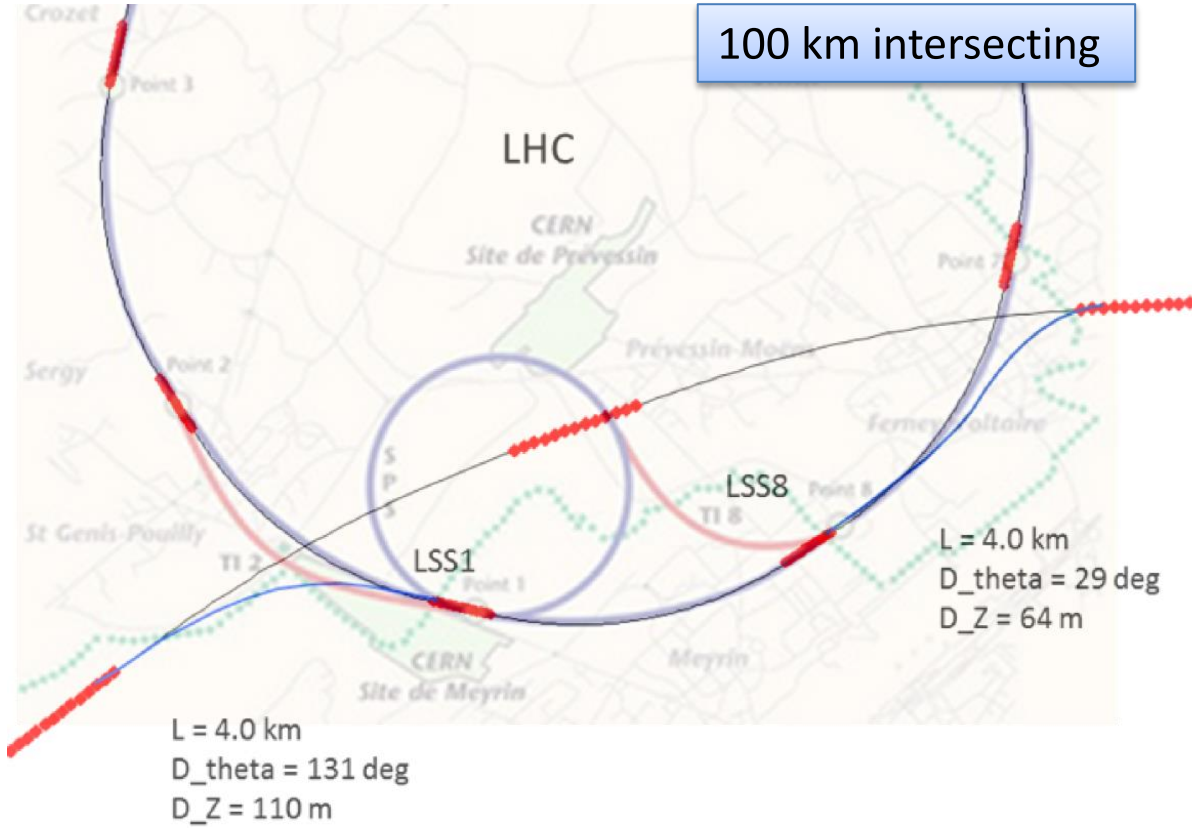
Reserve Slides

Injector Considerations

Many choices

- SPS -> LHC -> FCC
- SPS -> FCC
- SPS -> FCC booster -> FCC

Current baseline injection energy is 3.3TeV



B. Goddard at al.

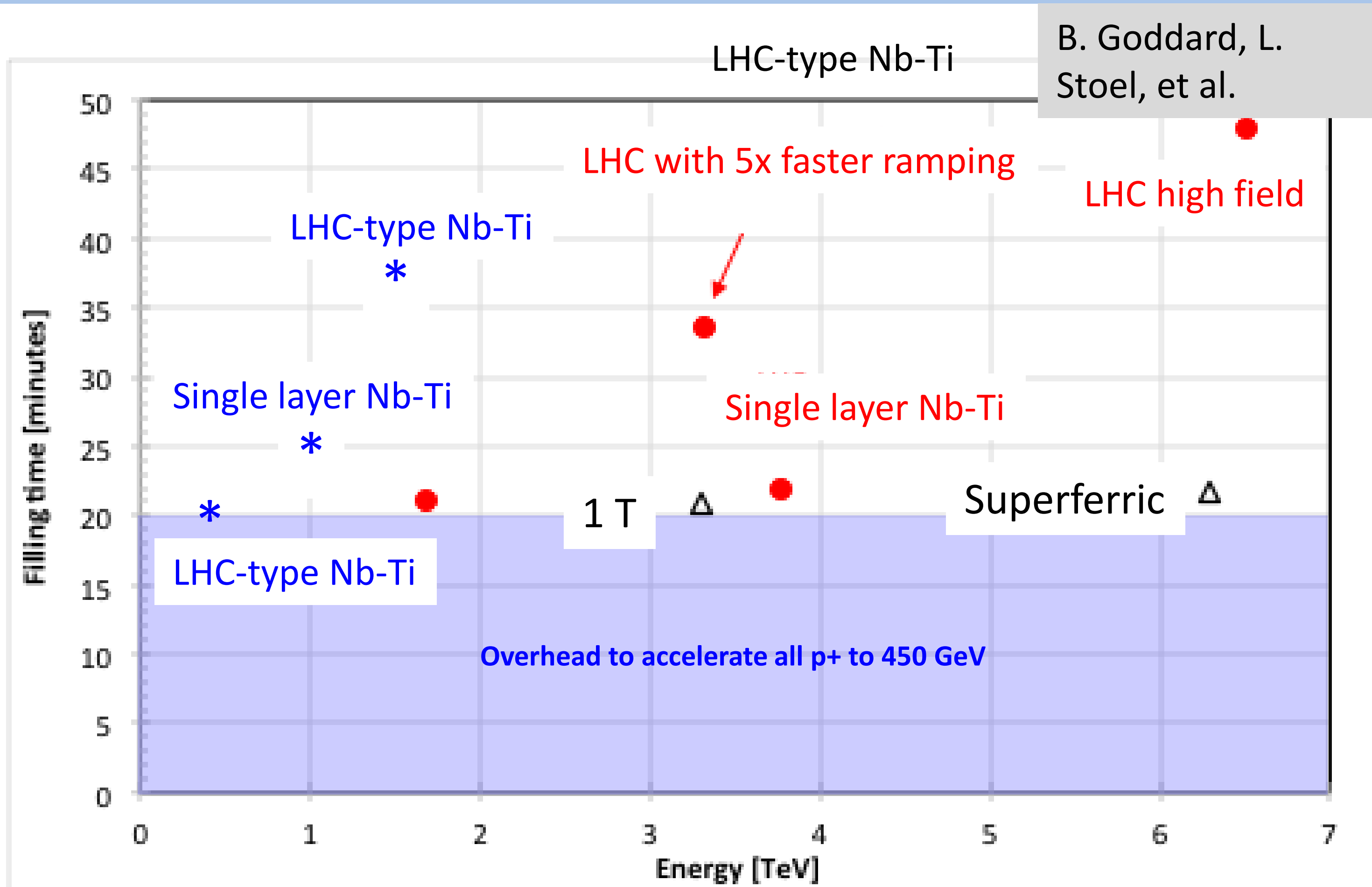
Filling Time

SPS -> FCC

Higher fields lead to long ramp times

SPS -> LHC -> FCC

SPS -> FCC booster -> FCC



LHC would work as injector

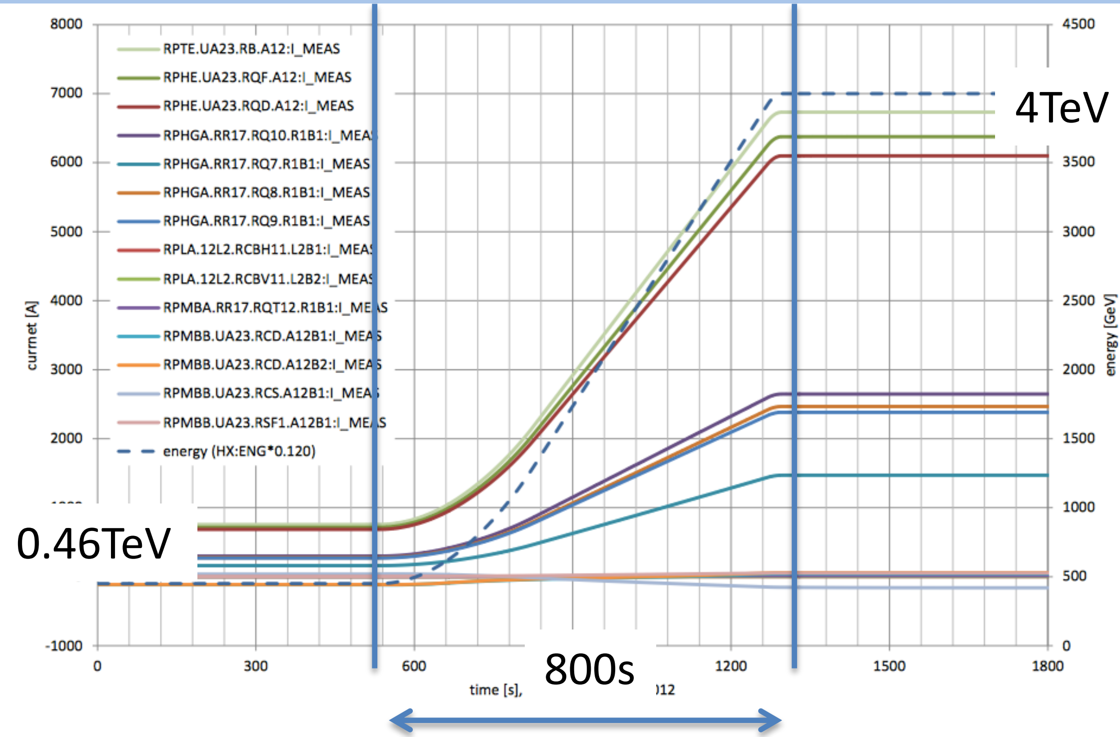
Will study other options in more detail

Study effects of lower energy in collider ring

LHC as Injector

The LHC is basically suited as injector

- Some modifications required



Faster ramping of magnets is required

- Need four fillings into FCC
- In total roughly 1.5h ramping up and down
- Realistic goal seems a factor 5 improvement
  - Better ramp shape
  - Upgrade of power converters

Many studies to come

- 5ns bunch spacing
- Injection into LHC
- …
- Develop the other options

B. Goddard, A. Milanese et al.

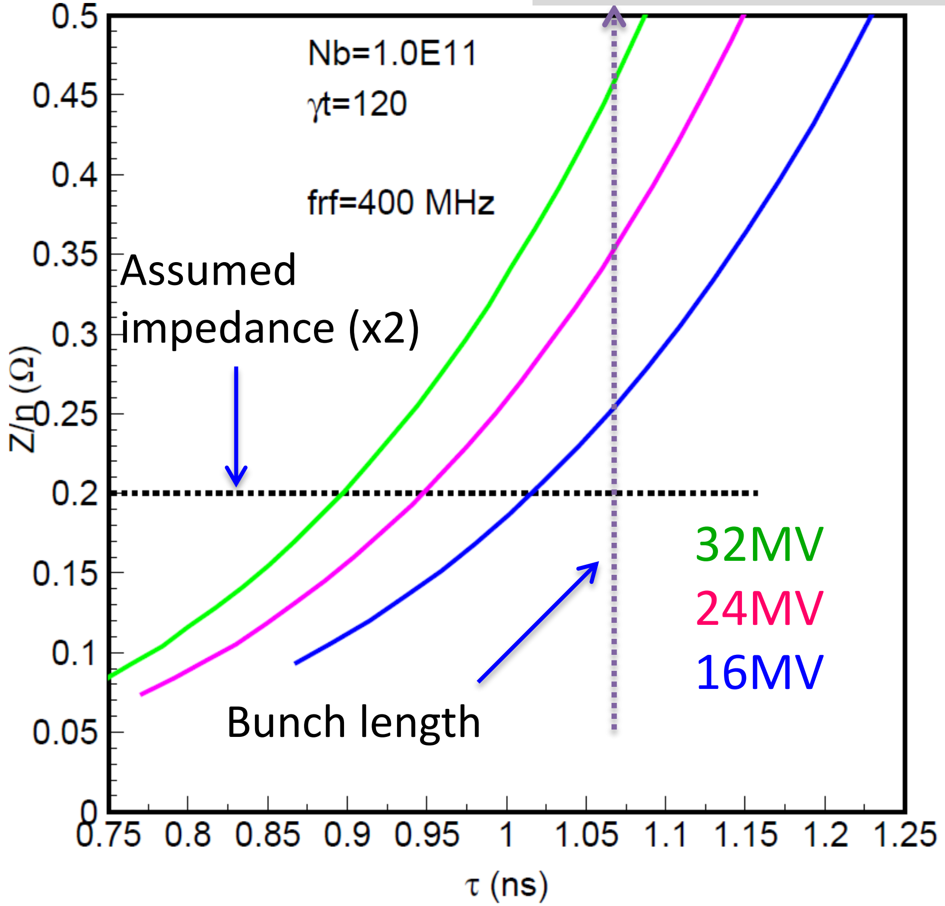
RF Design Considerations

RF integrated in injection insertion
- Limited radiation

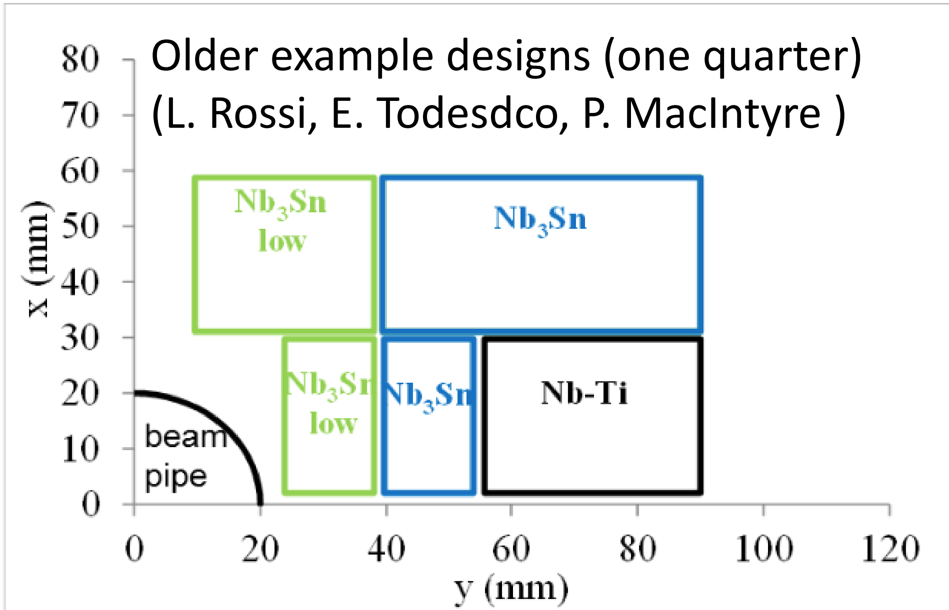
400.8 MHz seems a good baseline
- 16MV minimum with no margin
- 32MV seems fine
- Higher voltage helps for other instabilities as well

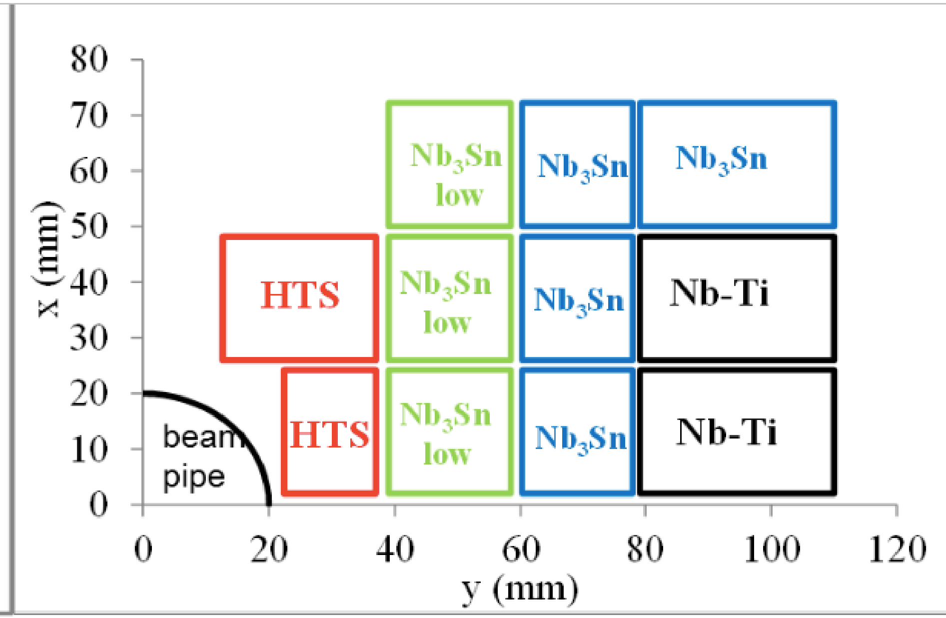
- To accelerate beam in 1000s require 16MV and 8MW

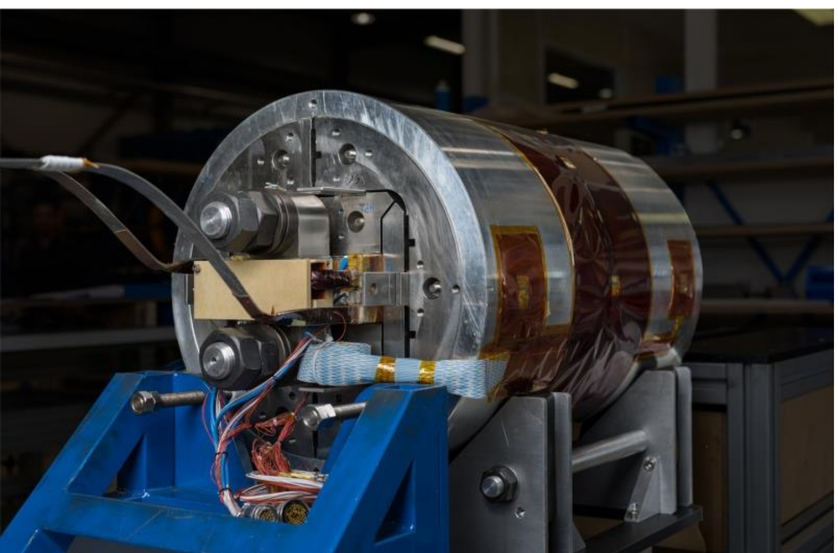
E. Shaposhnikova



Magnets







Combination of materials used to reduce cost

Different designs are being explored for FCC

A recent test AT CERN has achieved world record of 16.2T

- But a short racetrack magnet

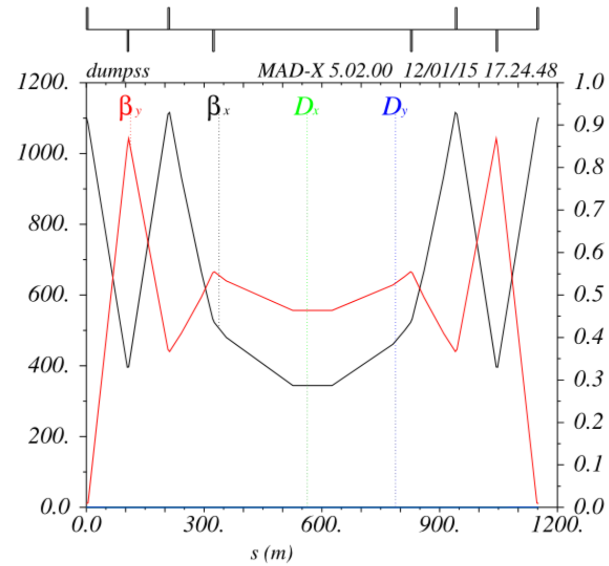
Dump Insertion Alternatives

SSC like

Septum is part of extraction bump

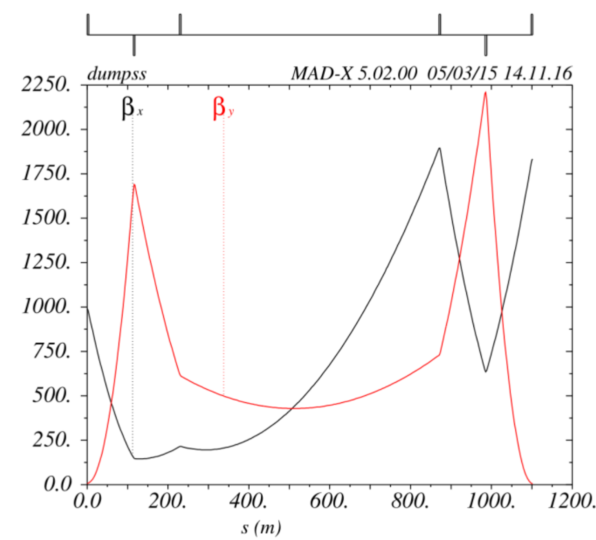
Use field free channel of septum to extract

Need strong, good field quality septum



Asymmetric insertion optics

- Avoid asynchronous dumps by accepting single kicker erratic
- High segmentation of kicker system (200-300 modules)
- Asymmetric optics
  - to reduce oscillation from single kicker failure (small hor beta)
  - to reduce kicker strength and dilute beam at absorbers (high betas at septum)



Beam Dump Dilution

Dilution pattern was evaluated as a function of dilution kicker magnet **MKB parameters** and **energy deposition** on the TDE.

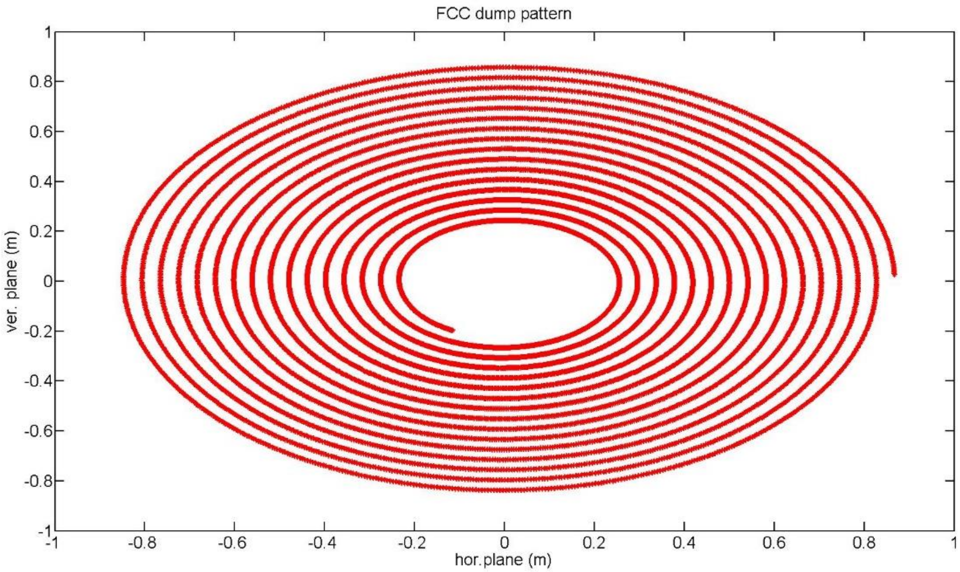
Energy deposition studies by FLUKA (A.Lechner & P. Garcia)
Max. temperature below ~ 1500 °C.

<u>Fixed dilution frequency:</u>

- f = 50.9 kHz
- Maximum amplitude at the dump block: 80 cm
- Bunch separation > 1.8 mm
- Branch separation: 4 cm
- Max deflection: 0.32 mrad
- B.dl = 53 T.m

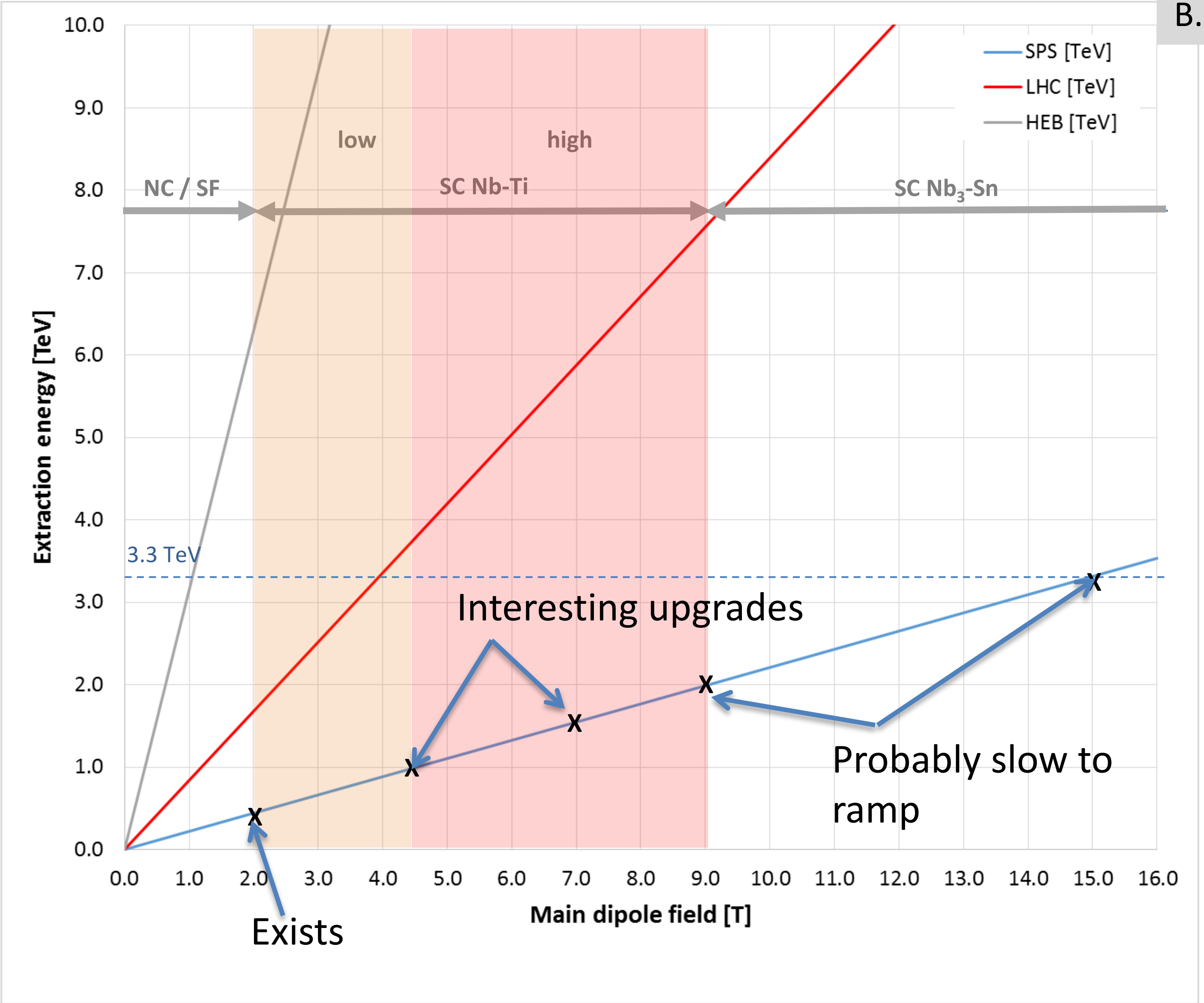
<u>Alternative with frequency change:</u>

- f = 20.4 kHz – 42.9 kHz
- Bunch separation = 1.9 mm constant
- Branch separation = 4 cm
- Max deflection = 0.24 mrad
- Max amplitude = 0.59 m
- Bdl = 39 Tm (2.5 km dump line)



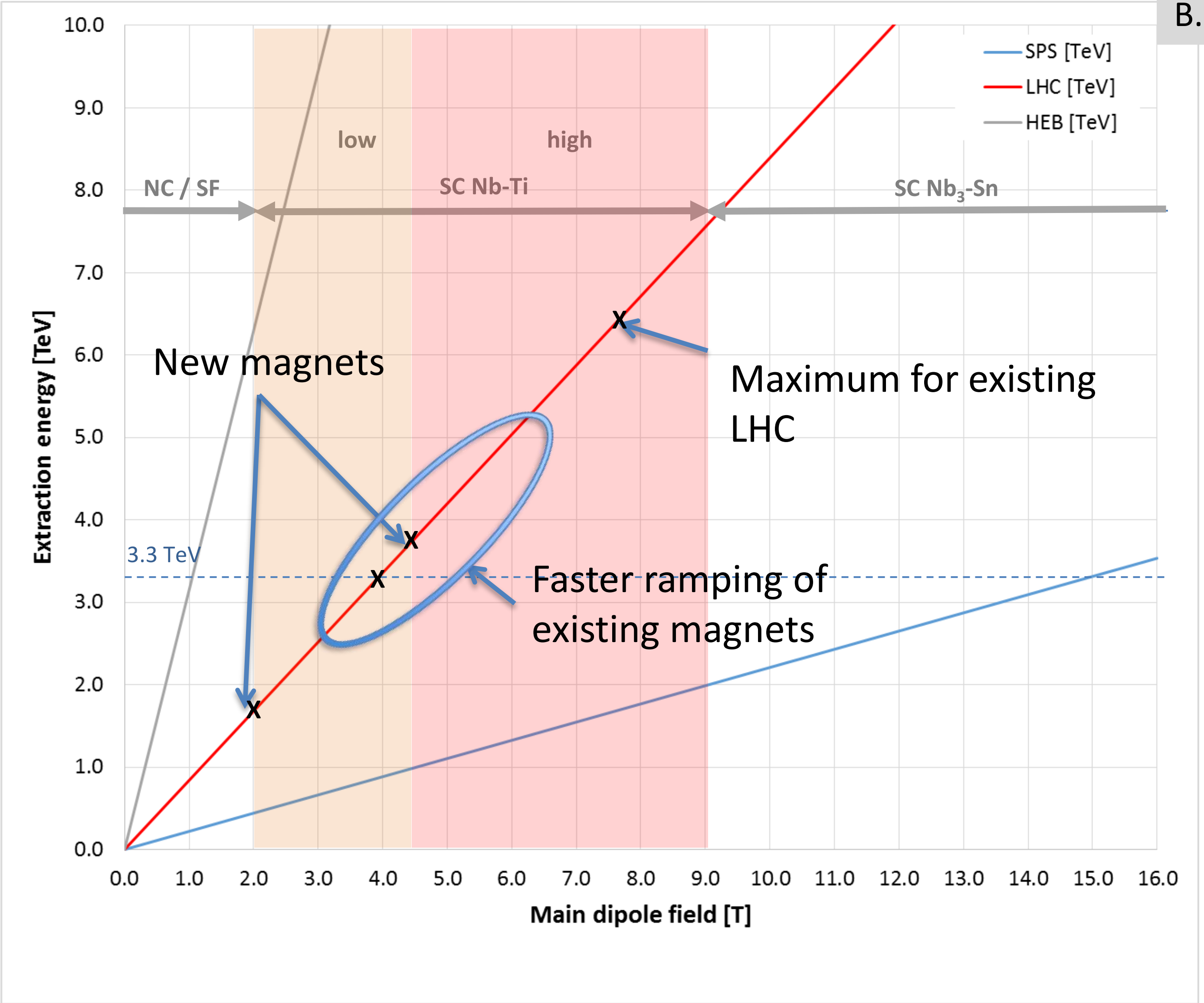
Injection from SPS Tunnel

B. Goddard at al.



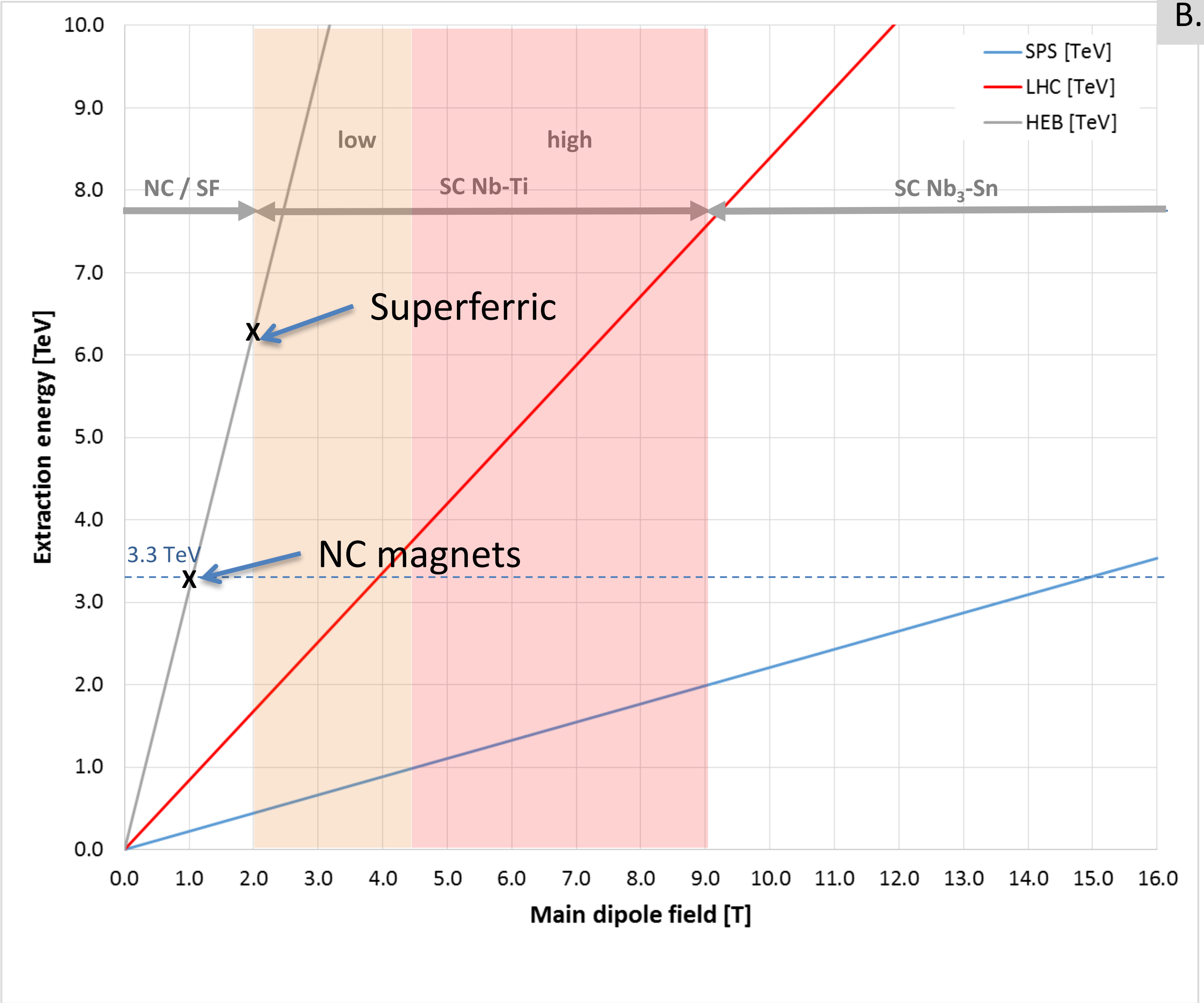
Injection from LHC Tunnel

B. Goddard at al.



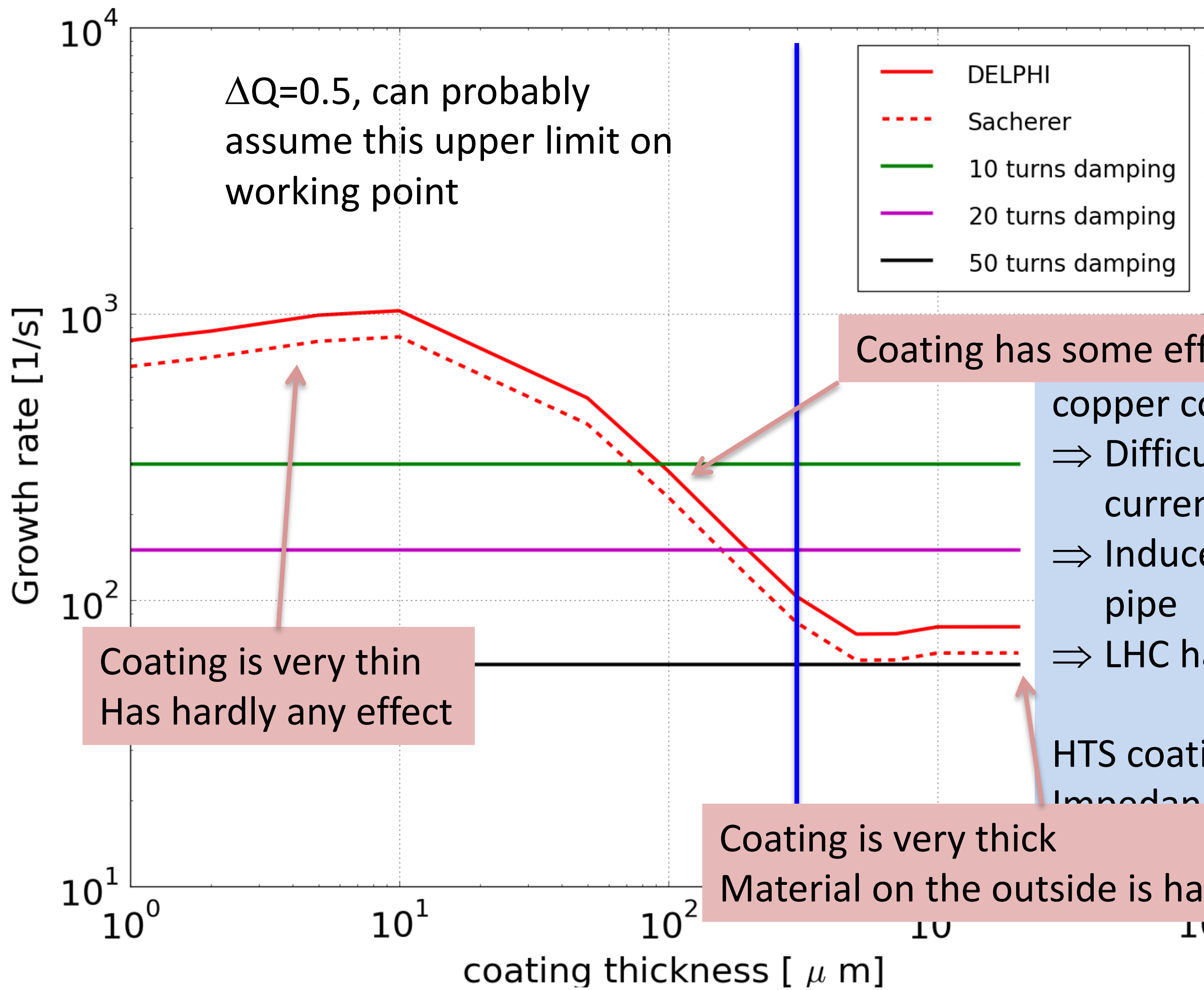
Injection from FCC Tunnel

B. Goddard at al.



Thickness of Copper Coating

N. Mounet, G. Rumolo



ΔQ=0.5, can probably assume this upper limit on working point

Coating has some effect

Coating is very thin
Has hardly any effect

Coating is very thick
Material on the outside is hardly seen

300µm of copper coating

- ⇒ Difficult because of eddy currents in quench
- ⇒ Induces stress on beam pipe
- ⇒ LHC has 50µm

HTS coating? Lots of work

…

Example for Loss Mechanism

F. Cerutti, I. Besana

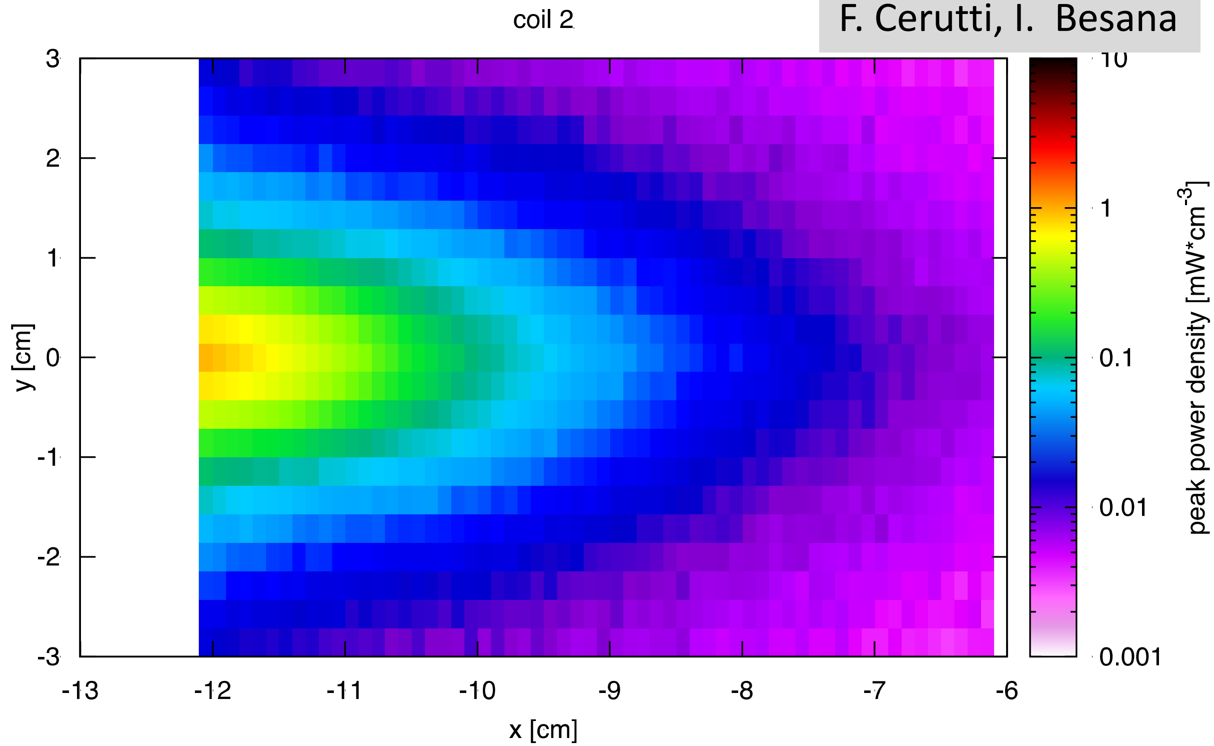
Beam-gas scattering goal >100h beam lifetime

⇒ <O(10^{15}m^{-3}) H_2 (σ≈100mb)

⇒ 45kW proton losses

⇒ power for cooling

- @2K <30MW
- @4K <15MW
- some part is lost in collimation system

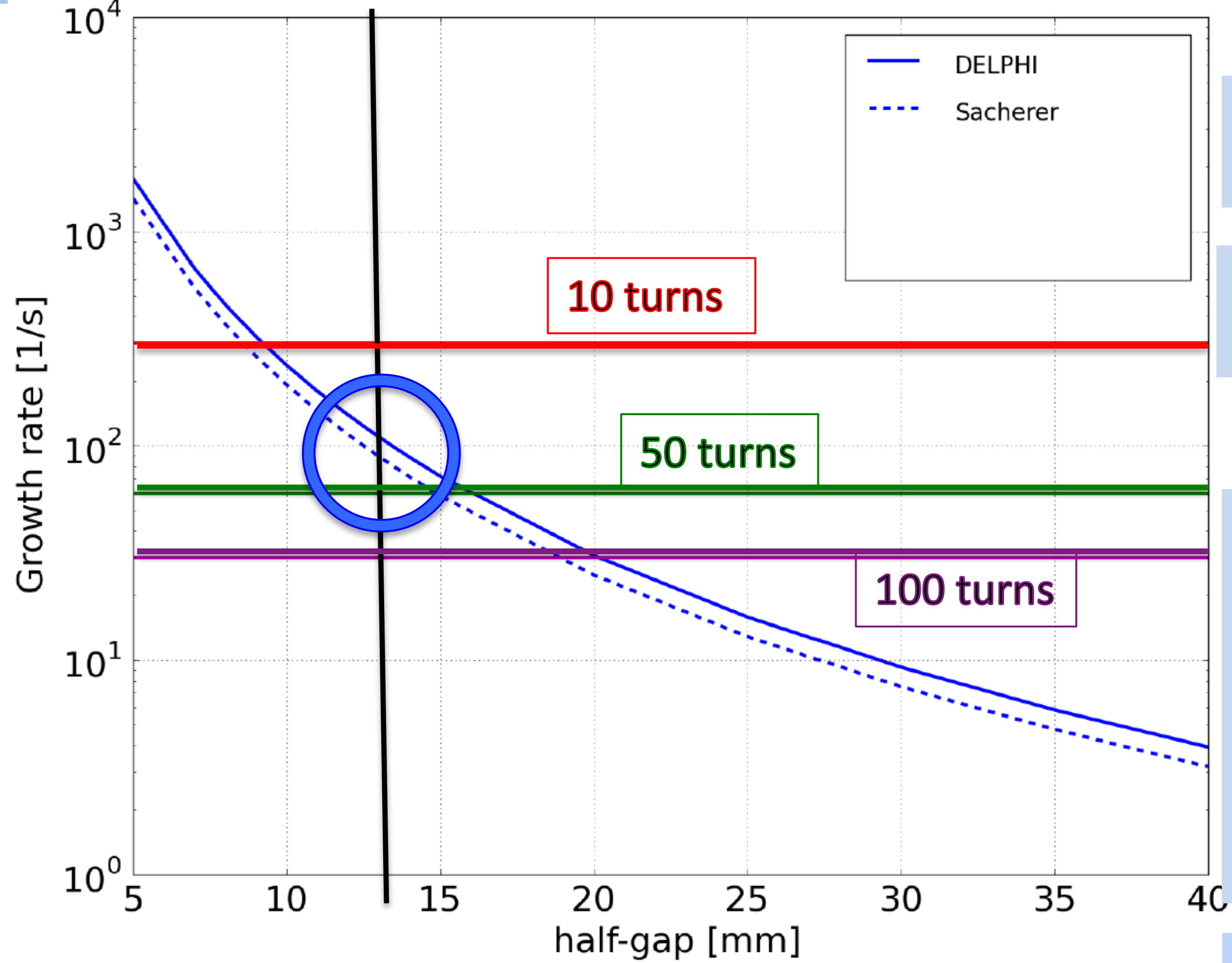


First studies indicate peak power density O(1mW/cm^{-3}) and 3.5W/beam/dipole in cold

Seems very acceptable but need to define margin

Work in progress

Estimates of Beamipe Impedance Effects



Multi-bunch effect at 50K and injection (worst case)
Only resistive wall (infinite copper layer assumed)

N. Mounet, G. Rumolo

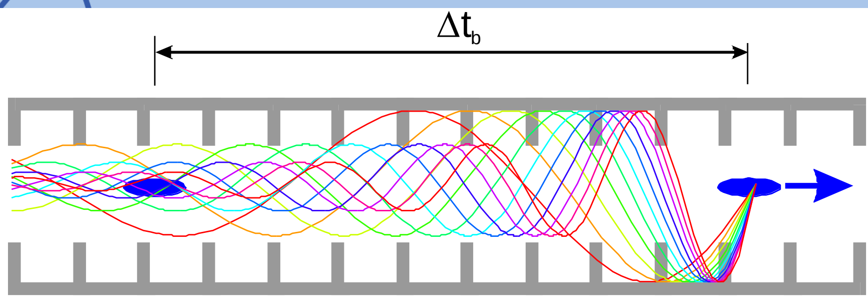
Growth rate of multi-bunch instability

Noise growths every 20-30 turns by factor e

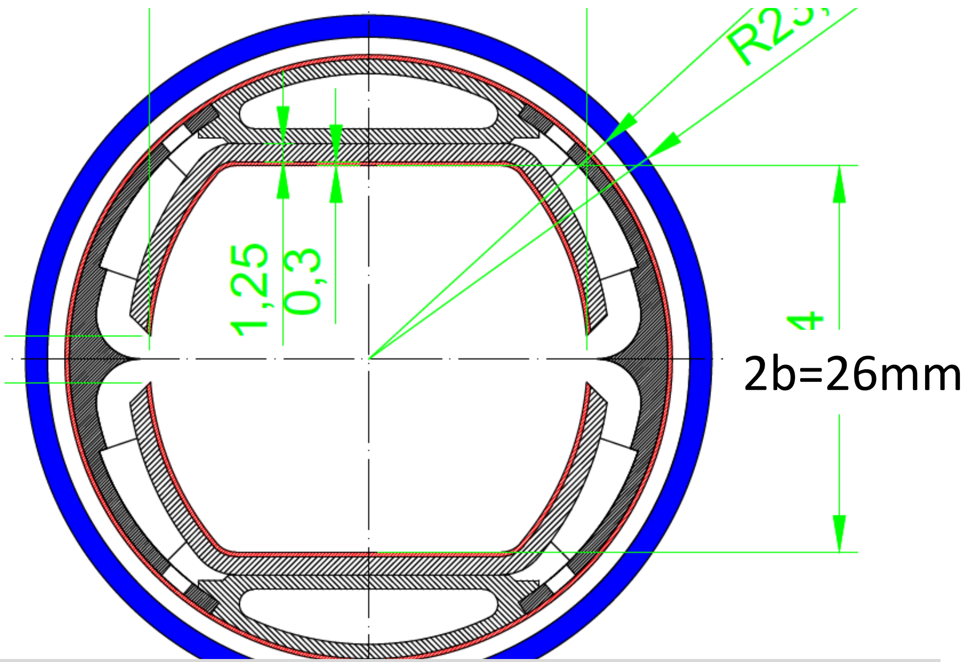
Need feedback within 10 turns

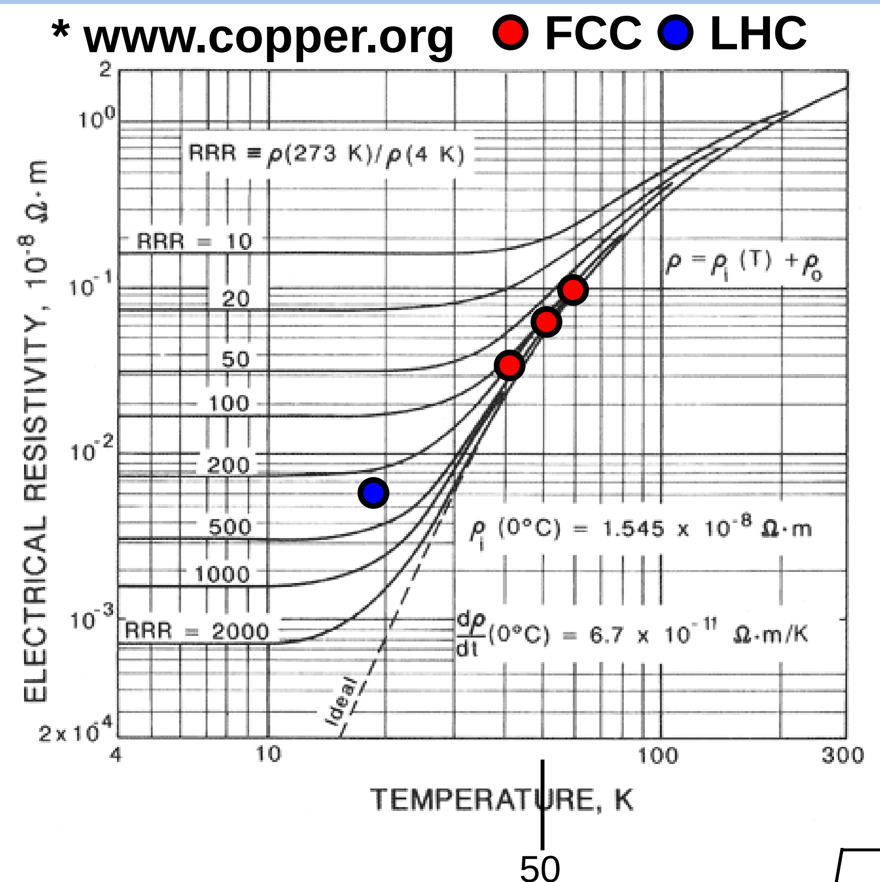
- Challenge for RF and instrumentation
- Or increase the beam screen radius
- Or decrease beam current

Many more impedance studies required



At injection multi-bunch instability is driven by resistivity of arc beam screen





Strong dependence on radius $Z_{\perp} \propto \frac{\sqrt{r}}{b^{3}}$

Defines minimum b

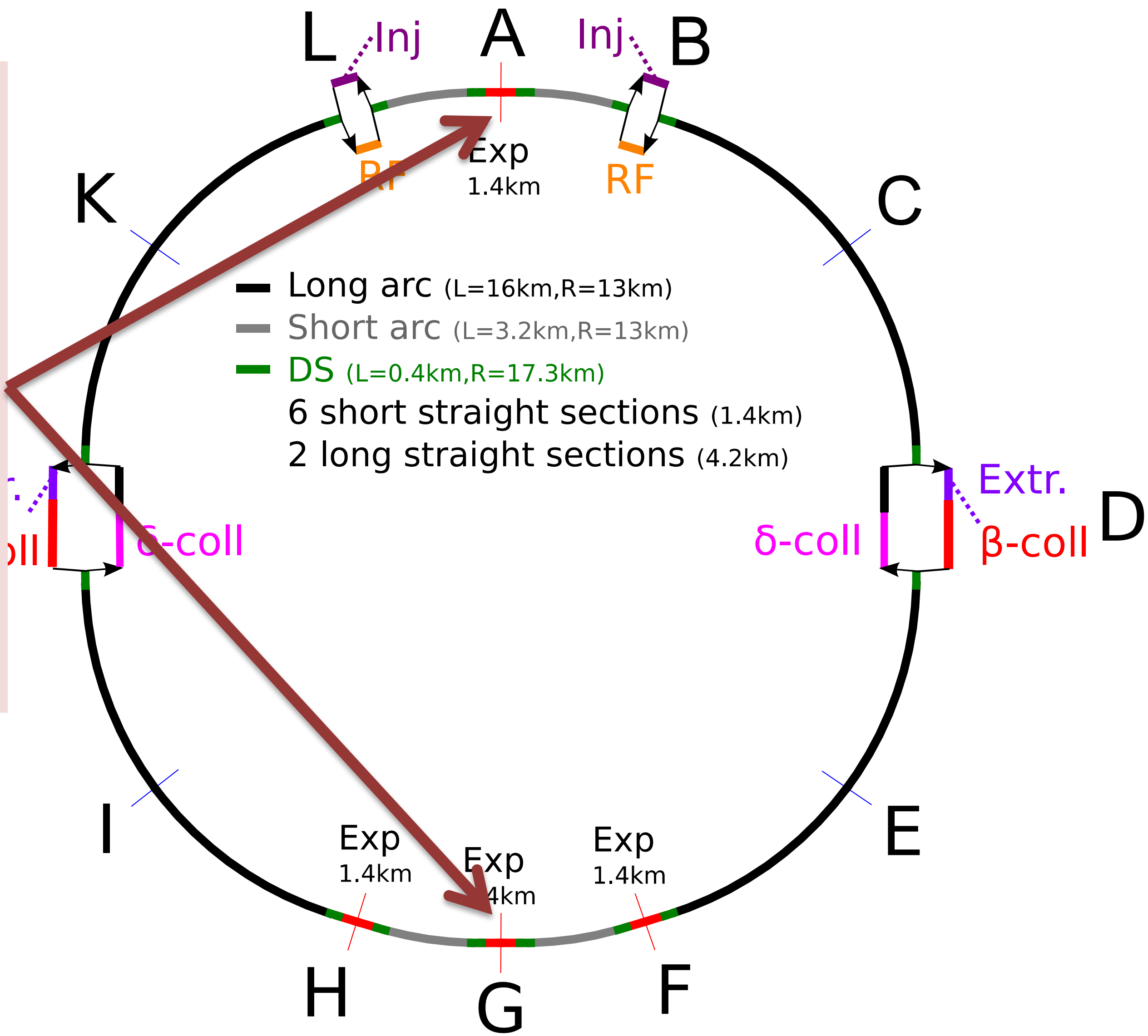
Multi-bunch instability O(10) worse than in LHC

N. Mounet, G: Rumolo, O. Boine-Frankeheim, U. Niedermayer, F. Petrov, B. Salvant, X. Buffat, D.S.

FCC-hh Layout

Two main experiments on opposite sides of the collider

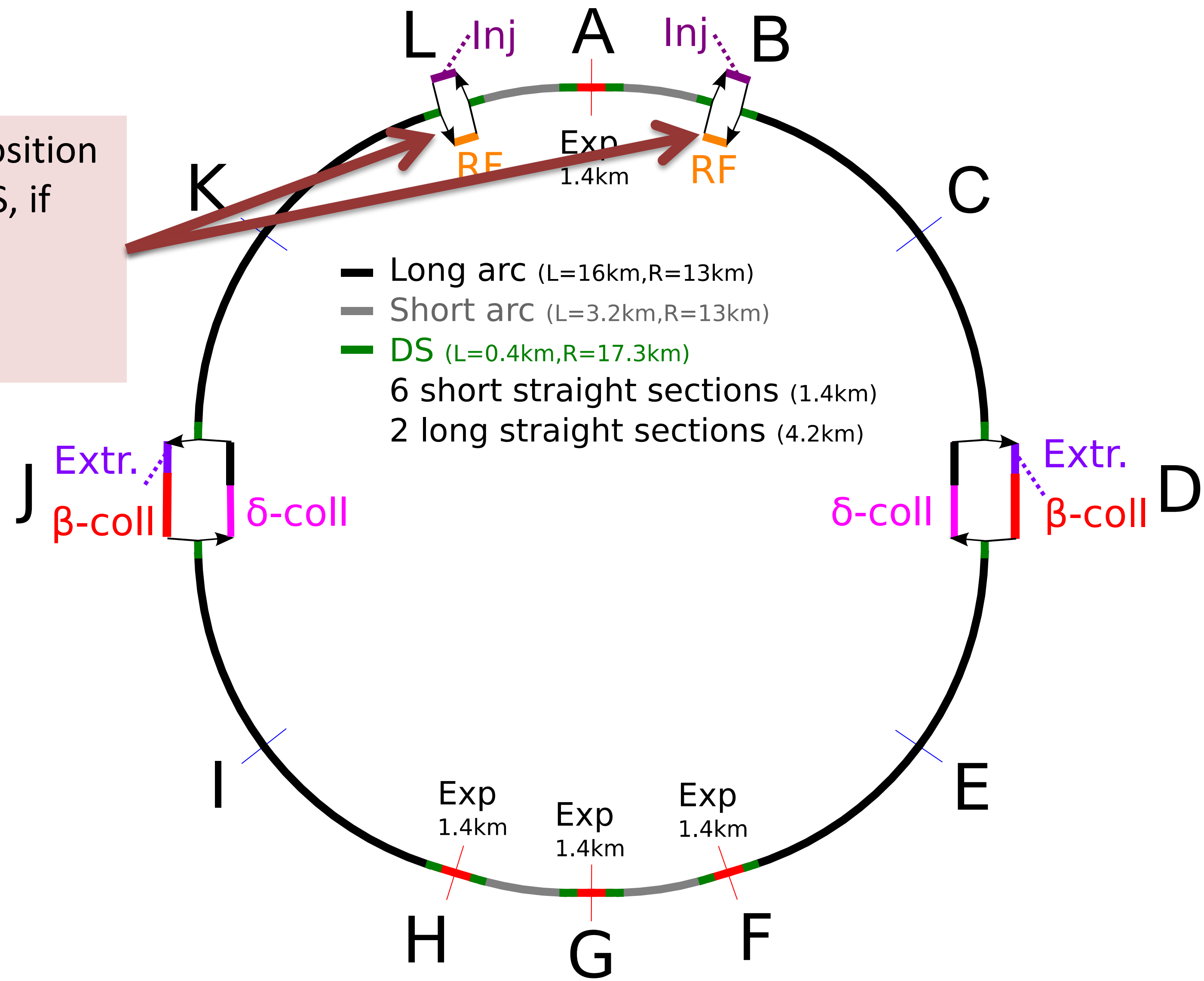
- All bunches collide in main experiments
  - independent of filling pattern
  - Highest luminosity
- Each bunch collides with the same bunch in both experiments
  - Compensation of beam-beam effects



FCC-hh Layout

The injection insertion position is determined by LHC/SPS, if used as injector

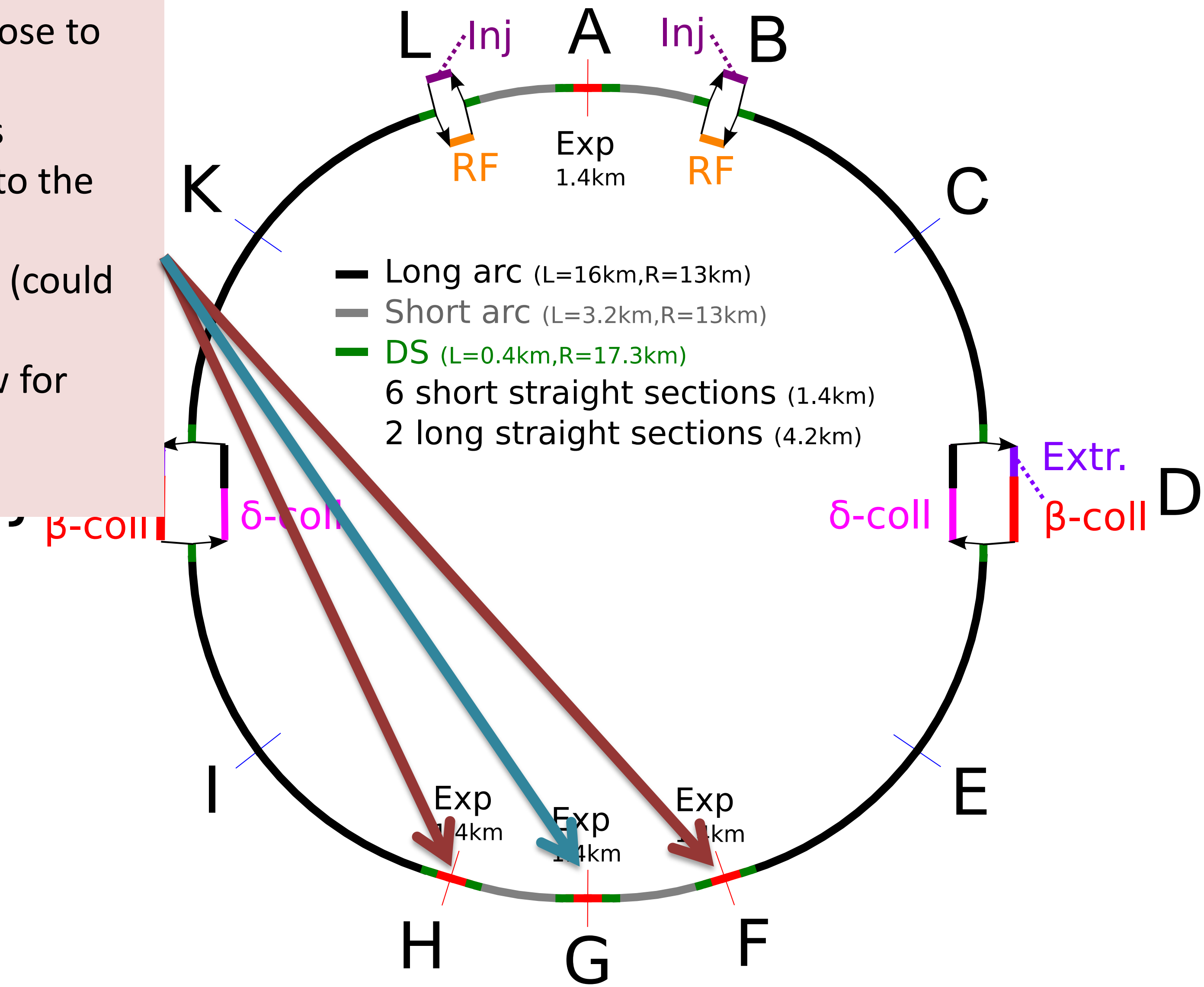
Best place for RF



FCC-hh Layout

Additional experiments close to one main experiment

- Separation to suppress background from one to the next
- Symmetric to injection (could be changed)
- Short arcs should allow for enough tuning



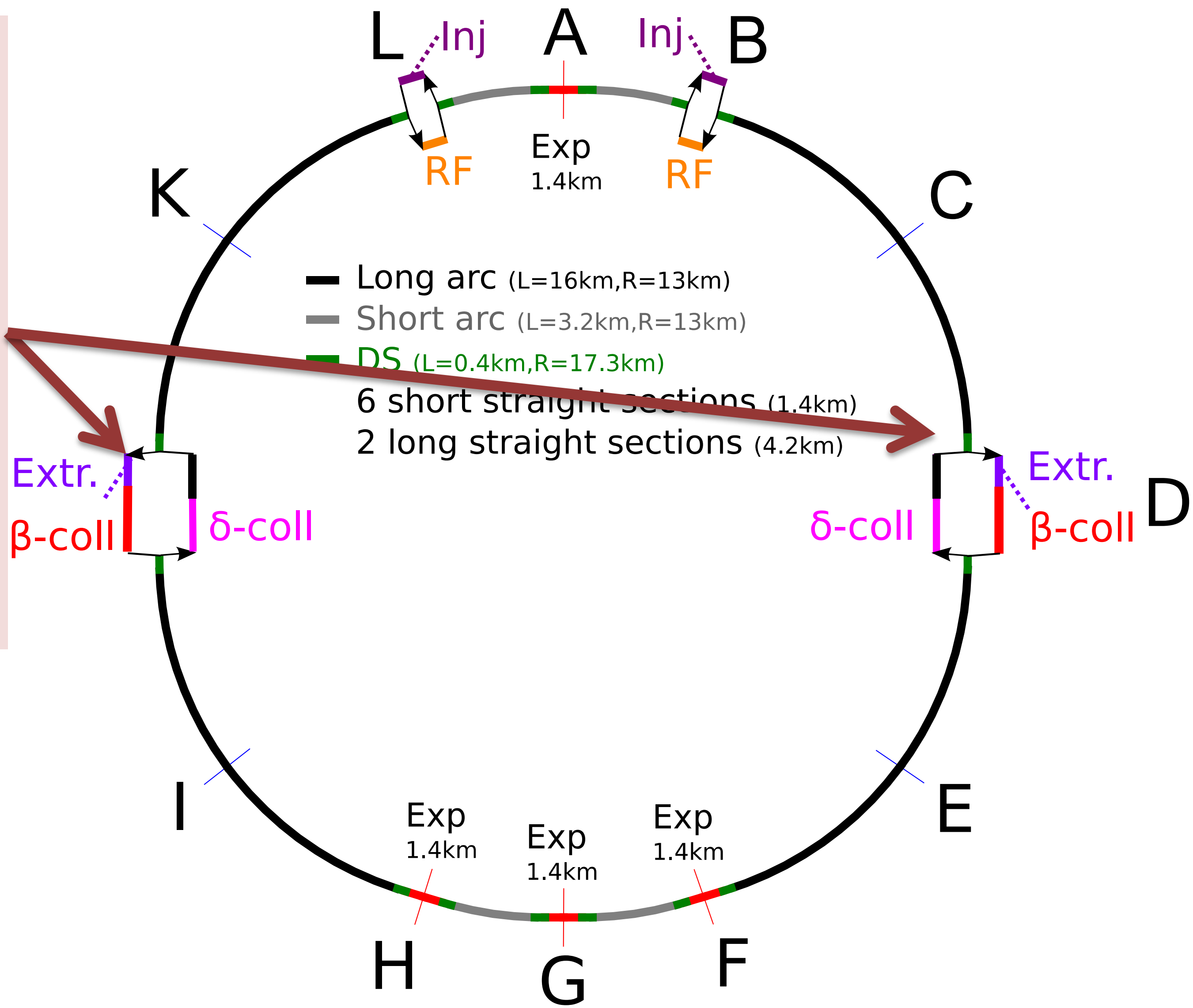
FCC-hh Layout

Foresee two collimation and extraction insertions

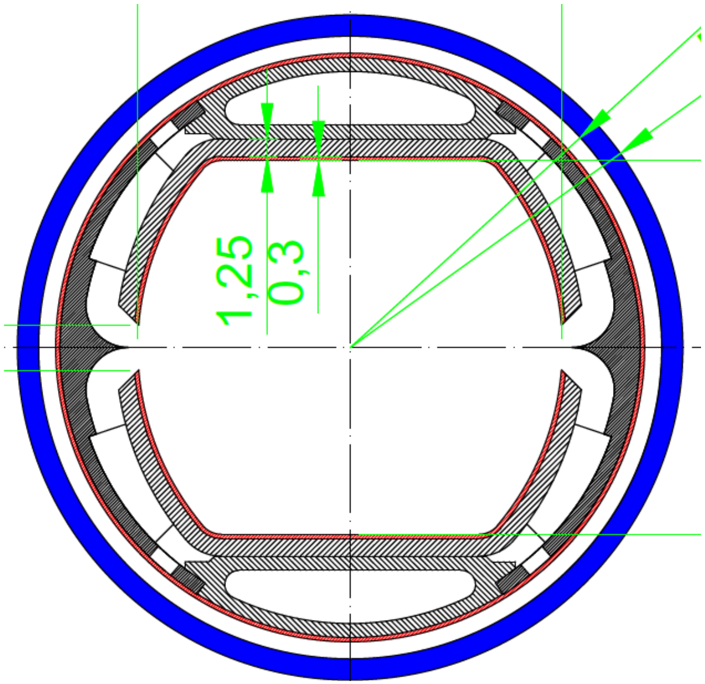
- Insertions with largest risk
- Scheme provides flexibility

Current baseline

- betatron-collimation after extract to protect machine
- Energy collimation



Alignment



Good alignment required for beam quality
- good pre-alignment
- good beam-based alignment

Alignment beam vs. slit is also important

M. Jones, N. Ibarrola Subiza

First system is based on wire and hydrostatic leveling