John Adams Institute for Accelerator Science

Imperial College London | Royal Holloway University of London | University of Oxford

Experimental Interaction Region

Andrei A. Seryi (JAI)

On behalf of EuroCirCol WP3 EIR design team:
CERN, CI, EPFL, INFN, JAI

FCC Week in Rome

12 April 2016

Parameters

We have two preliminary parameter sets
- Beam current is the same
- But luminosity differs

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

They have the same current but the ultimate set has more challenging collision parameters

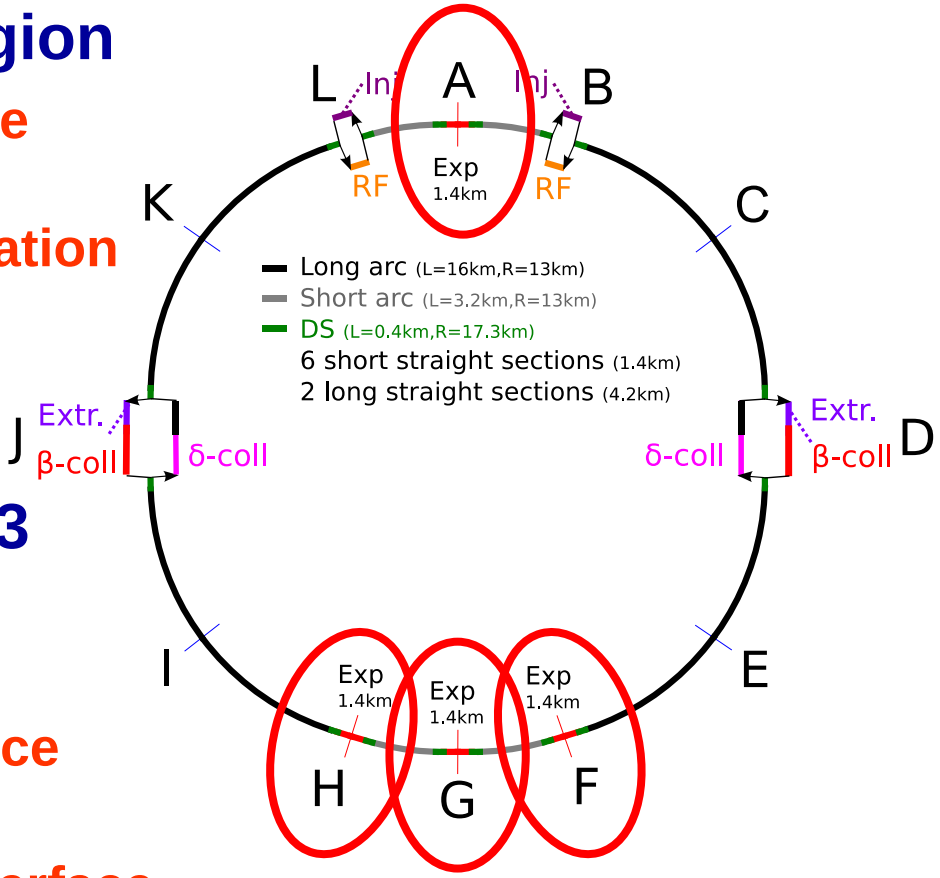
The "baseline" in EuroCirCol should be capable to run with the **ultimate** parameters

	FCC-hh Baseline	FCC-hh Ultimate
Luminosity L [10^{34}cm^{-2}s^{-1}]	5	20-30
Background events/bx	170 (34)	<1020 (204)
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

Slide from Daniel Schulte

Tasks

- **Experimental Interaction Region**
  - The main goal is to optimise the luminosity per beam current to ensure that beam induced radiation does not compromise the experiments or affect collider operation
- **Tasks of EuroCirCol EIR WP3**
  - Coordination
    - JAI/Oxford (lead), CERN, task 3.1
  - Develop interaction region lattice
    - JAI/Oxford (lead), CERN, task 3.2
  - Design of machine detector interface
    - CI/Manchester (lead), INFN, CERN, task 3.3
  - Study of beam-beam interaction
    - EPFL (lead), CERN, task 3.4



The team:

- **IR Work Package**
  - **Development of the EIR lattice**
    - JAI/Oxford (lead), CERN, task 3.2
    - PhD student started Oct 2015
    - Two PostDocs: started in Jan and Feb
      - { OPTICS }
      - { OPTICS / ENERGY DEPOSITION }
  - **Design of machine detector interface**
    - CI/Manchester (lead), INFN, CERN, task 3.3
    - One PostDoc just hired in Manchester, topic:
      - { MDI }
    - One PostDoc just hired in INFN, topic:
      - { MDI }
  - **Study of beam-beam interaction**
    - EPFL (lead), CERN, task 3.4
    - PostDoc started in Aug 2015

CERN: Rogelio Tomas, Roman Martin, Andy Langner

JAI/OX: Andrei Seryi, Emilia Cruz Alaniz, Jose Abelleira Fernandez, Leon van Riesen-Haupt

JAI/RHUL: Laurie Nevay (BDSIM expertise liaison)

CI/Manchester: Rob Appleby, PDRA just hired

CERN: Francesco Cerutti, Maria Ilaria Besana, Helmut Burkhardt

INFN: Manuela Boscolo, Francesco Collamati

EPFL: Javier Barranco, Jorge Patrik Gonçalves

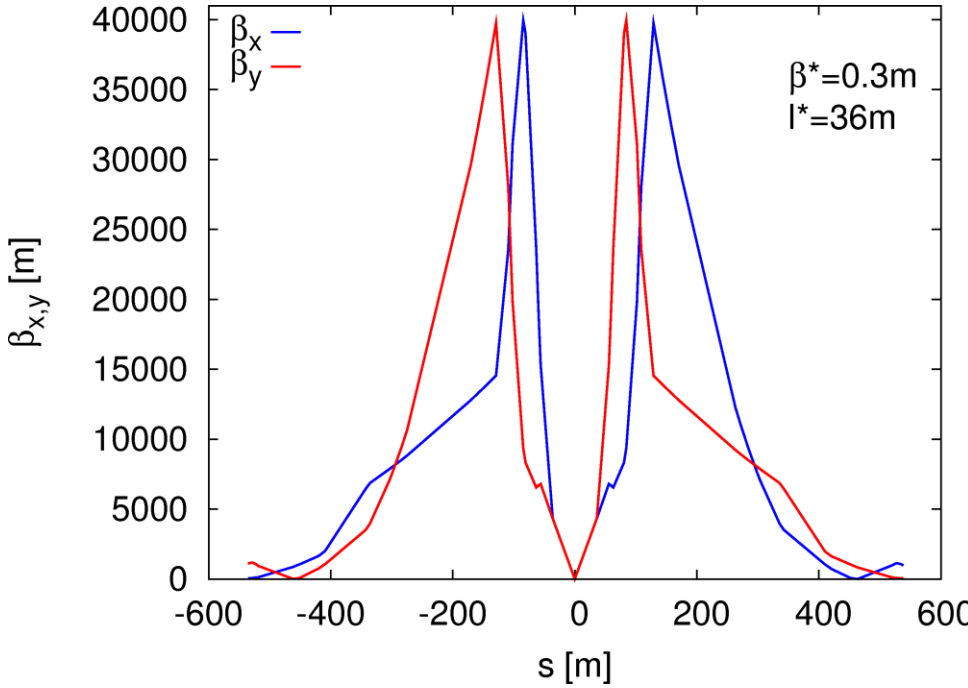
CERN: Tatiana Pieloni, Xavier Buffat

Recent design updates

- **EIR optics**
  - **Explored L* of 36 and 61m**
    - **Examples on the design process on next slides**
  - **Iterating with Detector team => L* of 45m**
    - **New optics created and being studied**

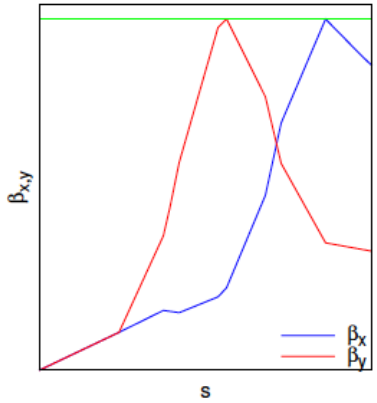
Examples of design approach – β* reach

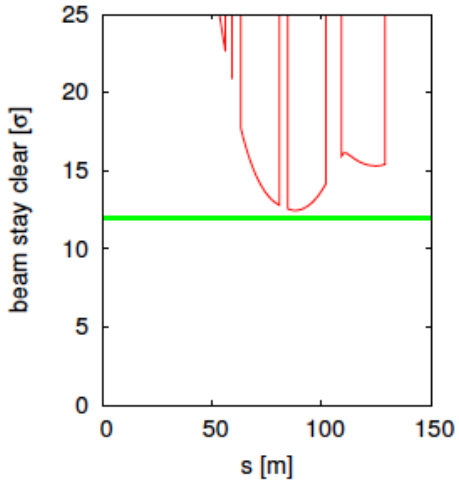
- **Starting from upscale HL-LHC IR optics**
- **For given beta*, rematch triplet so that max betas in x and y are equal**
- **Then recalculate max aperture from quadrupole gradients and Bmax, and check beam stay clear**



Upscale HL-LHC design,
R. Martin, R. Tomas, E. Todesco, L. Bottura

Beta* reach studies



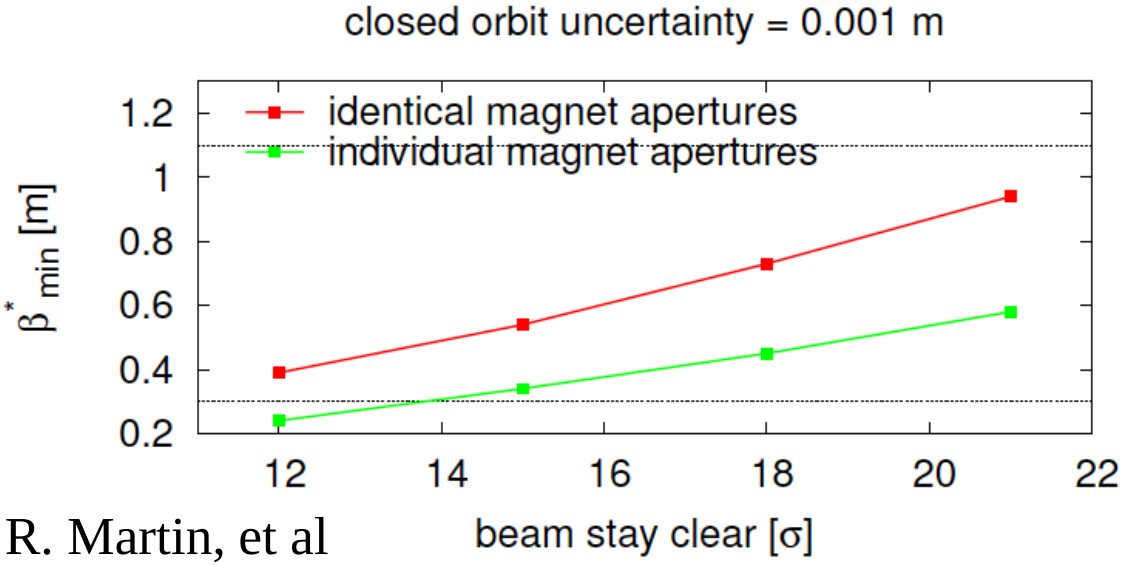


Checking beam stay clear

Re-matched triplet

- $B_{max} = 11\,T$
- $L^* = 36\,m$
- $L_{Q1} = 20\,m$
- Beam stay clear $= 12\,\sigma$
- Beam separation $= 12\,\sigma$
- Shielding $= 15\,mm$
- Further layers:
  - Cold bore: 2.0 mm
  - Kapton insulator: 0.5 mm
  - LHe: 1.5 mm
  - Beam screen: 2.05 mm
  - Beam screen insulator: 2.0 mm

Initial results for stay clear vs beta*



R. Martin, et al

β* reach study

- **Scaling study conclusion**
  - **L* and/or triplet length can easily be increased until chromaticity and DA become the main issues**
  - **Triplet length has larger impact on β* reach than L***
- **=> strategy:**
  - **Select shortest L* that does not restrict detector, and then increase the length of the triplet until hit the limit due to DA**

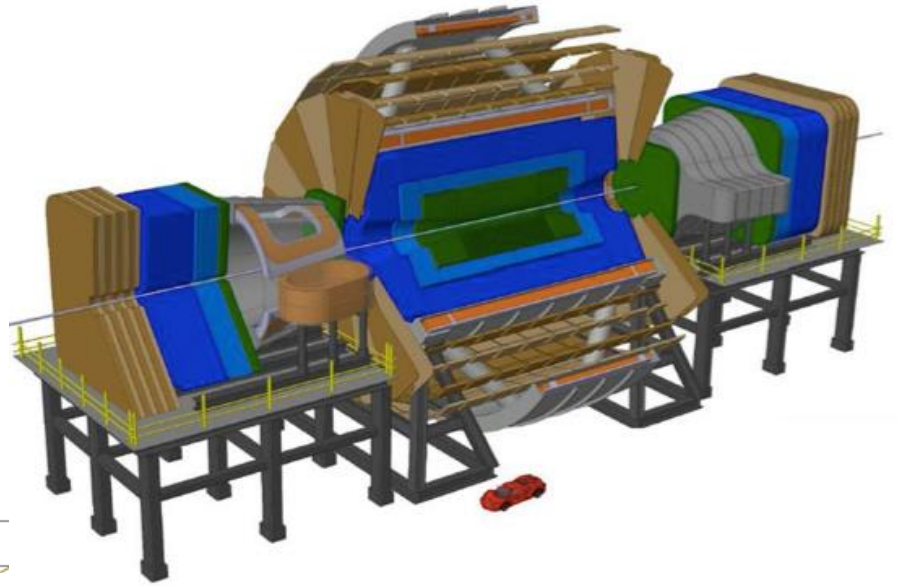
More details in the talk of Roman Martin

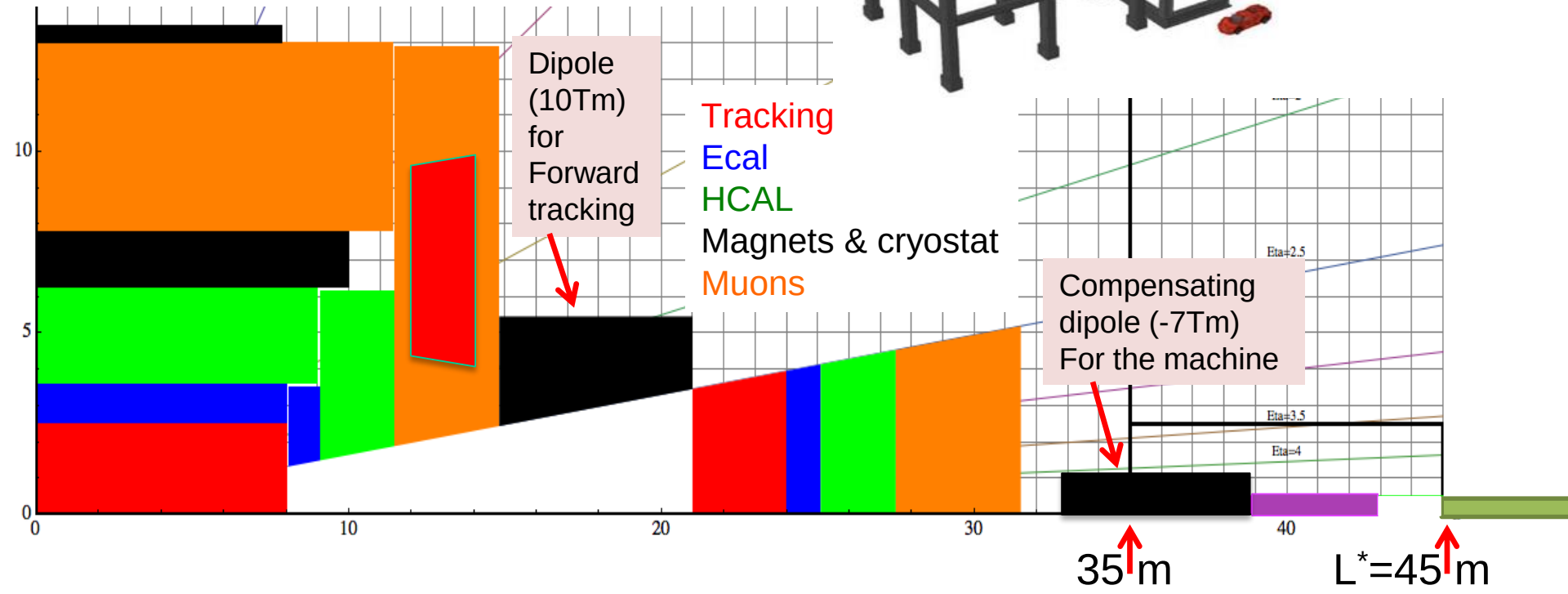
Detector design and L*

FCC detector with Air core Twin solenoid and Dipoles

Minimum L* that does not restrict detector design is 45 m

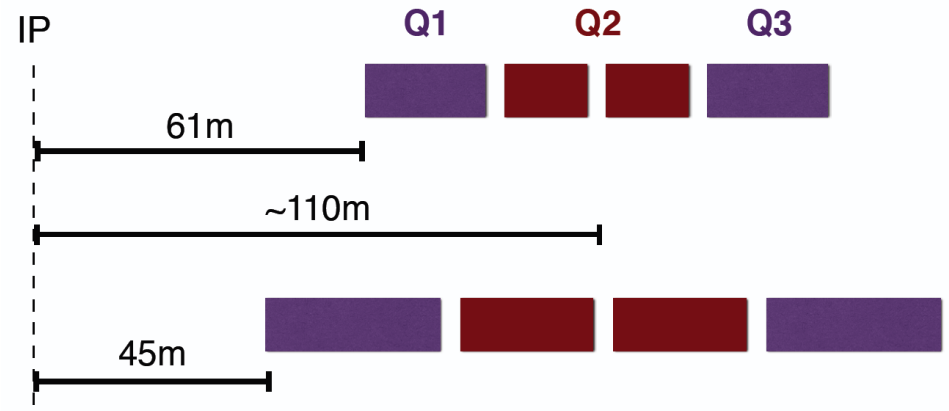
Werner Riegler et al.

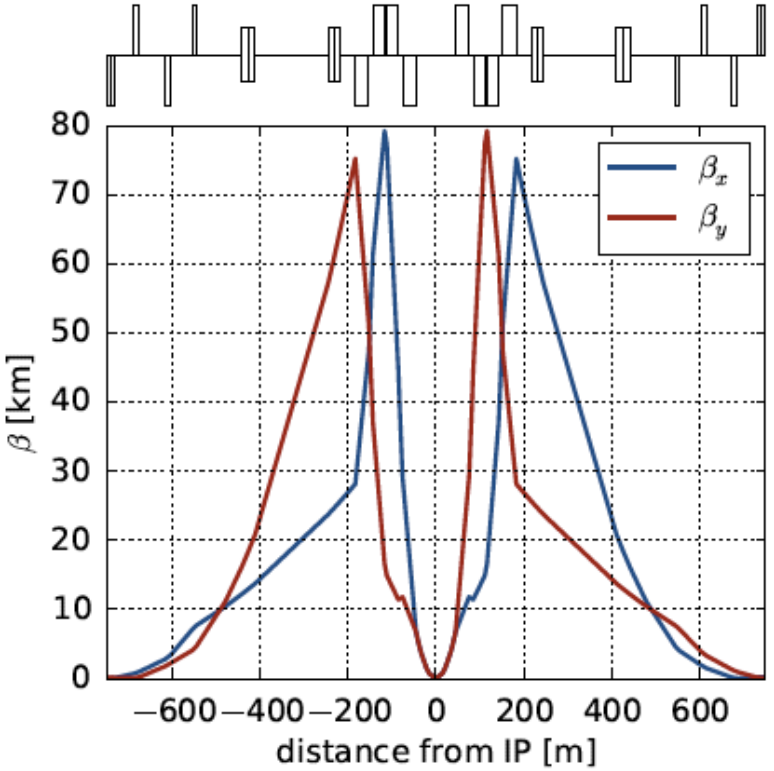




Latest optics with L* of 45m

- **L* 61m => 45m**
  - **Following the selected strategy increase triplet length by ~50%**



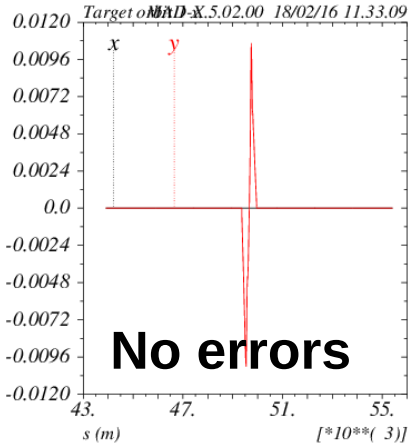


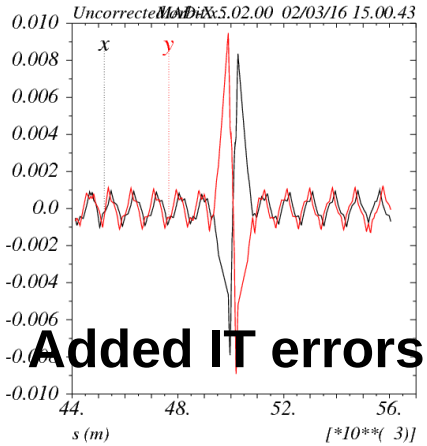
- **Further optics optimization needed (system length longer by 50m per side and per IP then desired)**

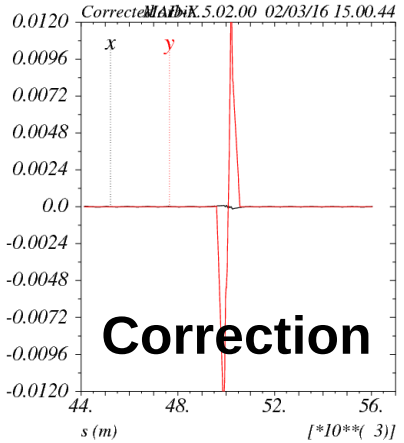
Optics for $\beta^* = 0.3\,\mathrm{m}$

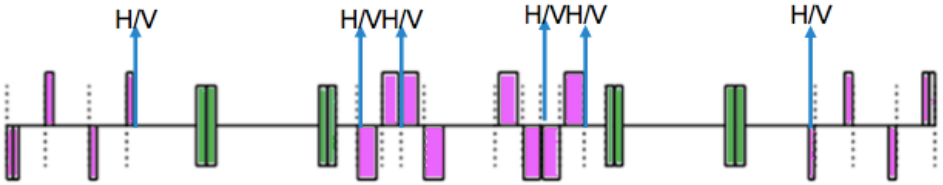
More details in the talk of Roman Martin

IR optics – orbit corrections



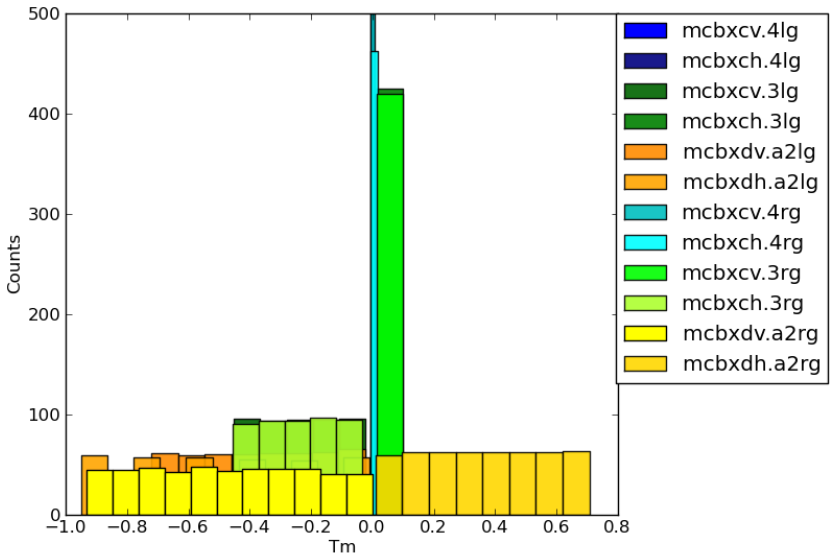






Max misalignment errors in the inner triplet of 0.5 mm

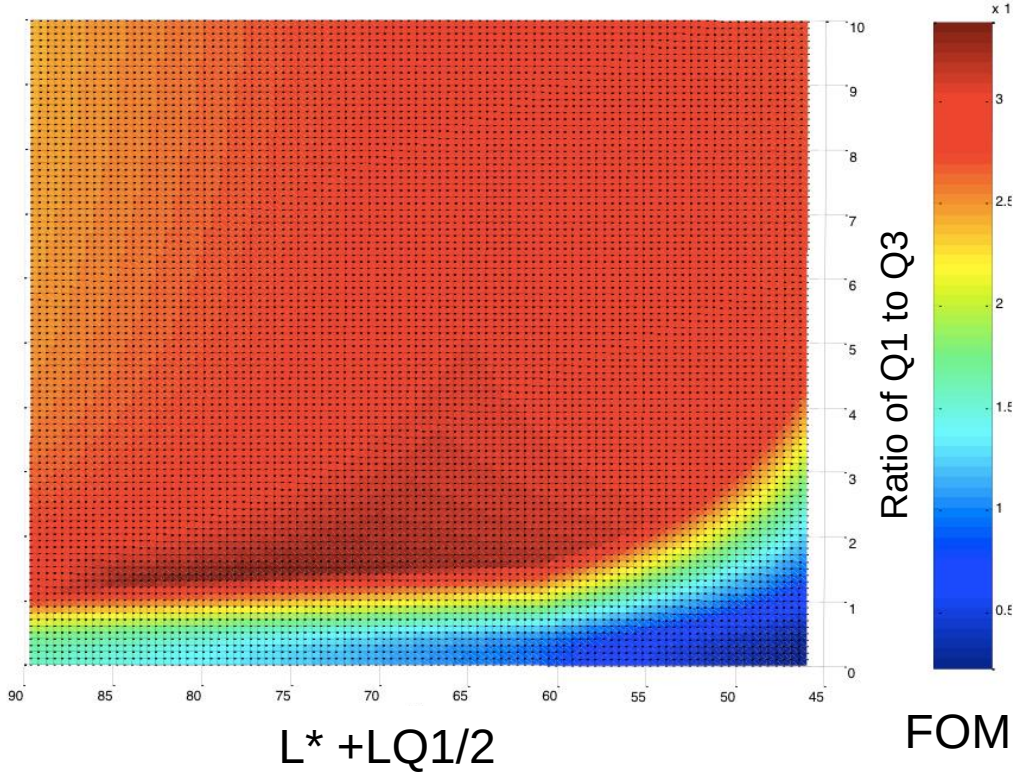
Result: successful correction and all correctors in the achievable range of -1, 1 TM



Emilia Cruz Alaniz

IR optics – triplet optimization

- **Procedure**
  - Model quads as thin lenses
  - Find triplet analytically
  - Estimates beam stay clear
  - Calculate Figure of Merit (FOM)
  - Vary elements to scan through parameters quickly
  - Find ideal setup and convert to thick lens
- **Plan**
  - Work in progress
  - Will use the method to optimize alternative L* and beta* configurations
- **Further plans**
  - This will be combined with detailed optics study by Emilia Cruz and Jose Abelleira

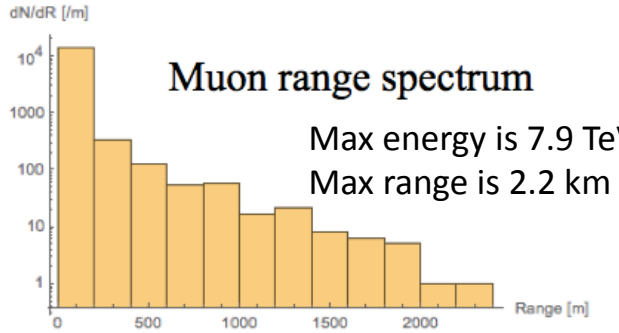


Leon van Riesen-Haupt

MDI – cross-talk between IRs

- **Preliminary study of**
  - **Inelastic protons through beam pipe vacuum (i.e. optics)**
  - **Elastic protons through beam pipe vacuum (i.e. optics)**
  - **Muons travelling through rock from IPA to IPB (analytical estimations)**

More details in the talk of Rob Appleby



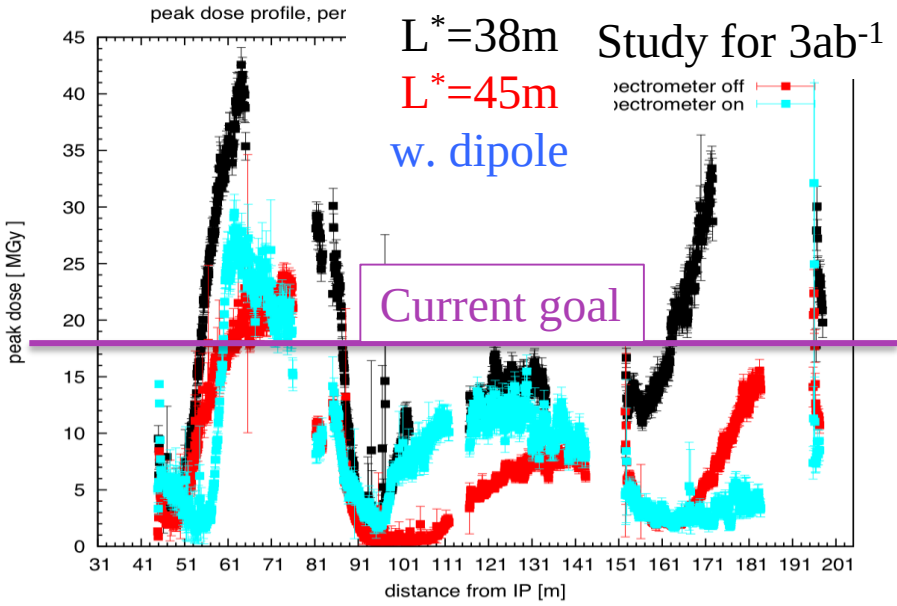
- **Preliminary conclusions (some)**
  - **Inelastic protons – around 40 protons per BX (ultimate) with 0.1mm spot size from IPA to IPB – may cause some background**
  - **Elastic protons – lead to some emittance growth**
  - **Muons – do not expect much muons arriving through rock**
    - **Can muons be guided by tunnel walls?**
    - **need to check by FLUKA or similar code**
- **Ongoing study of SR in IR**
  - **Tools developed, results to be presented soon**

H. Burkhardt, M. Boscolo, F. Collamati

MDI – triplet shielding

Minimum goal: survive 5000fb^{-1} (<30MGy)

- Gain almost factor 2 with new design
- Lose a bit due to dipole
- Still need to improve

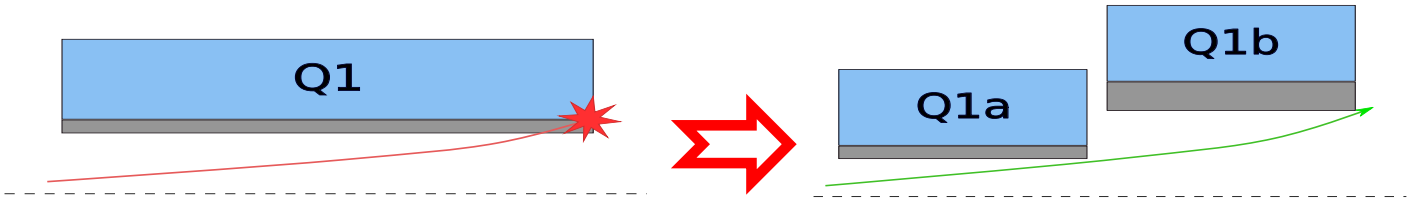


M. I. Besana, F. Cerutti, et al.

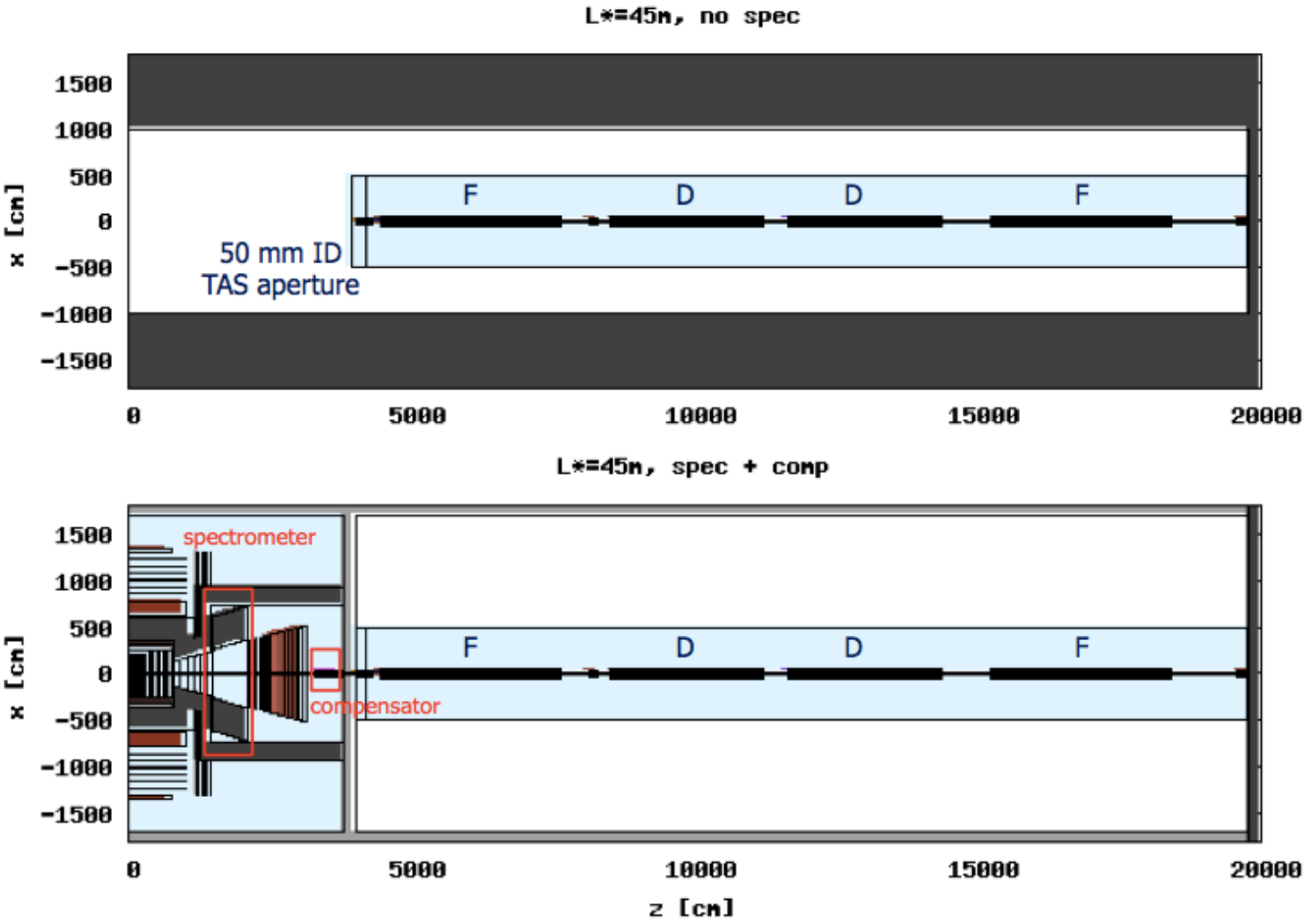
Ideas to (re-)explore for further improvement

- More shielding
- Elliptical apertures?
- Improved radiation hardness
- Split magnets
- Vary crossing scheme to distribute damage (S. Fartoukh)

More details in the talk of Francesco Cerutti



MDI – collision debris on the triplet



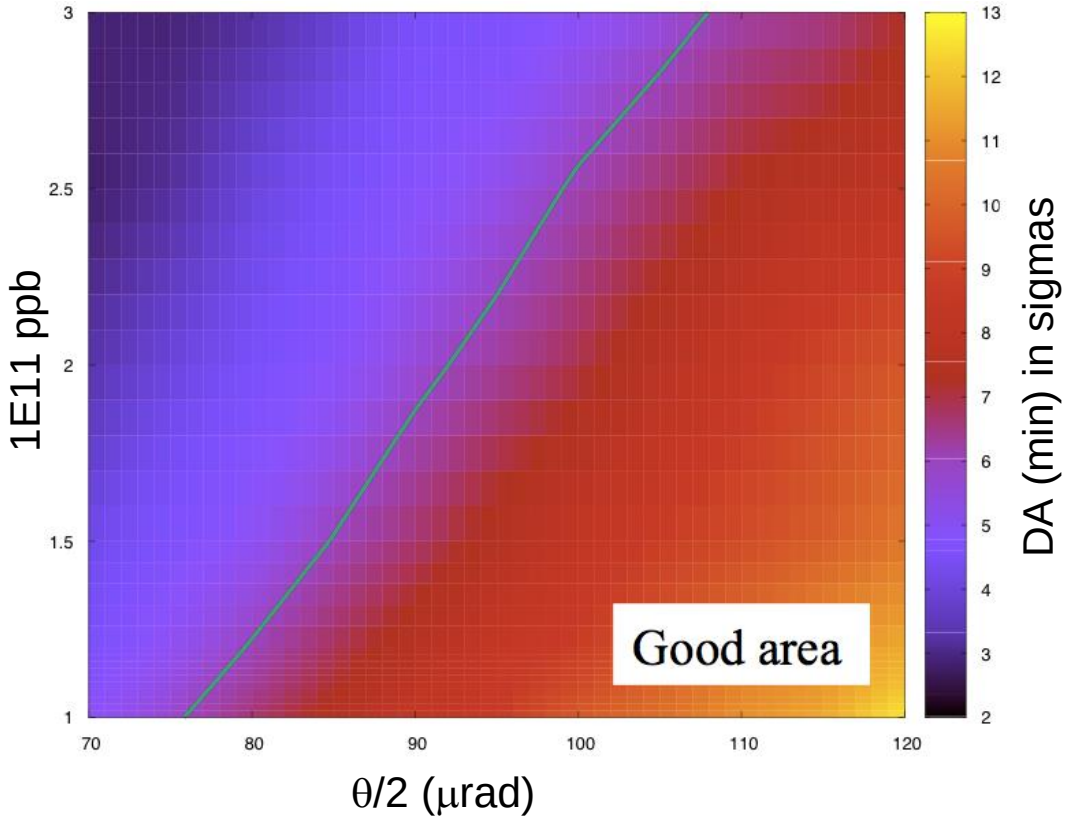
L*=45m layout w/o & with spectrometer

More details in the talk of Francesco Cerutti

Beam-beam and luminosity

- **Studying beam-beam constraints**
  - **Simulate the dynamic aperture and instabilities in the presence of beam-beam collisions for different design options. In particular study round and flat beam options and identify the acceptable limit to the beam-beam interaction**

- **Preliminary:**
  - **DA for 45m L* is OK**
  - **Emittance growth, effect of noise to be studied**
  - **As well as alternatives and flat beams**



More details in the talk by T. Pieloni, J. Barranco Garcia, X. Buffat

Conclusions

- **Experimental Interaction Region progress**
  - **Converged on L* of 45m**
  - **Optics of IR with new L***
  - **Aiming at beta* of 0.3 m**
  - **Study of inner triplet shielding and beam-beams are encouraging**
  - **Cross-talks between IRs show the issues likely tolerable**
  - **IR orbit correction works**
  - **Further optimization of triplet for alternative beta* and L* ongoing**
  - **More detailed studies and explorations of parameters are ongoing**
  - **Thanks to the entire team!**