FCC-hh Detector Cross-Talk Update

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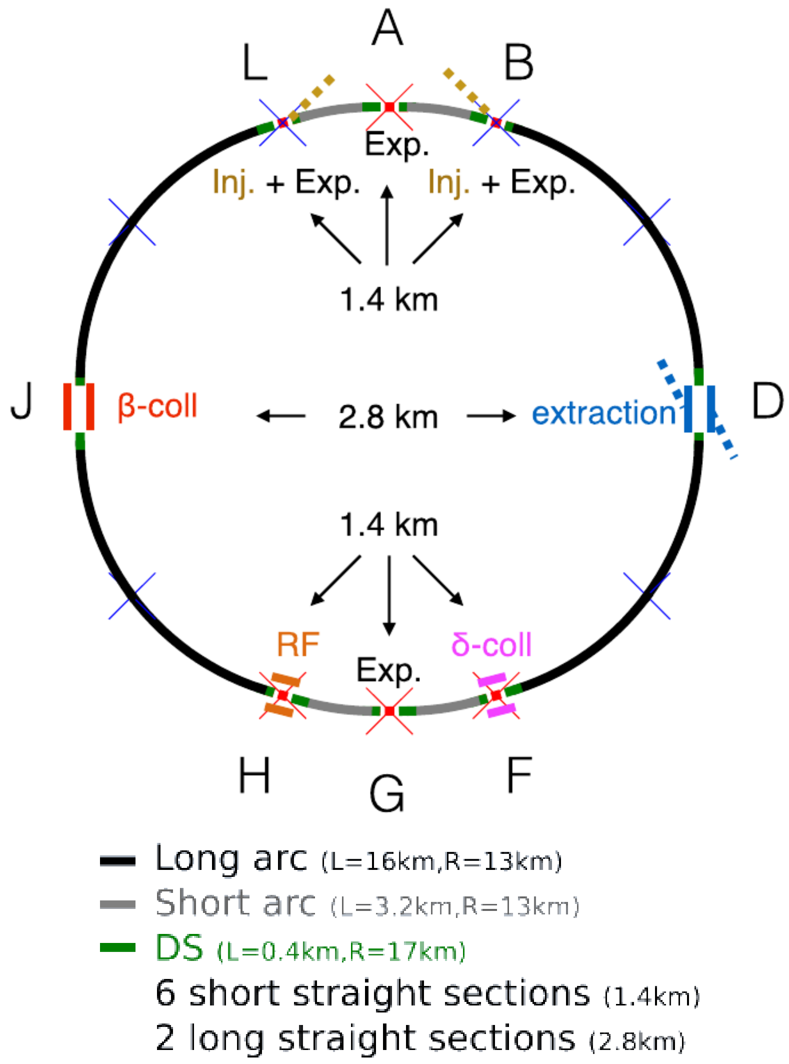
Many thanks to D. Schulte, A. Langner, M. I. Besana, F. Cerutti, J. A. Fernandez, A. M. Krainer

Cross-talk

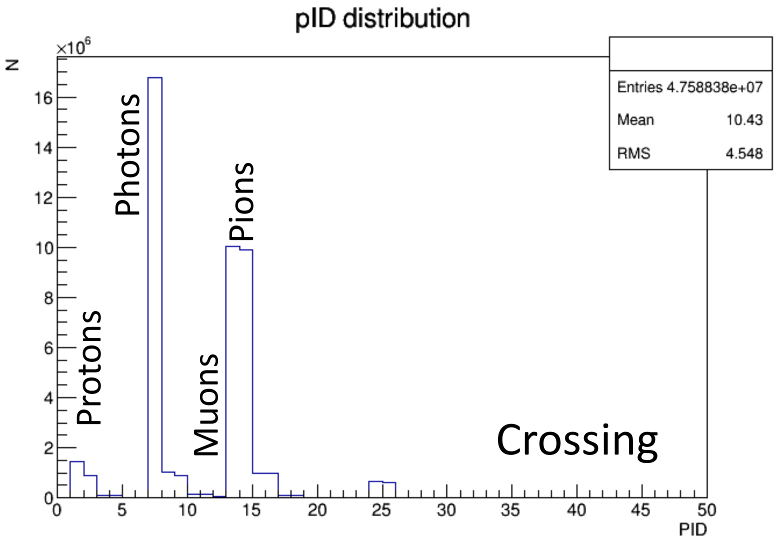
- The FCC-hh Experimental Interaction Region (EIR) is critical in defining FCC-hh performance
- Experimental cross talk is a possible issue due to high luminosity and energy proton beams
- We use IPA to IPB as a representative case



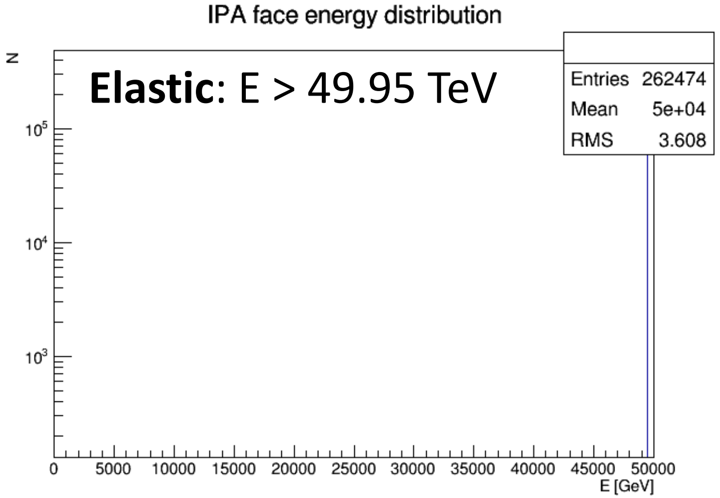
Questions:

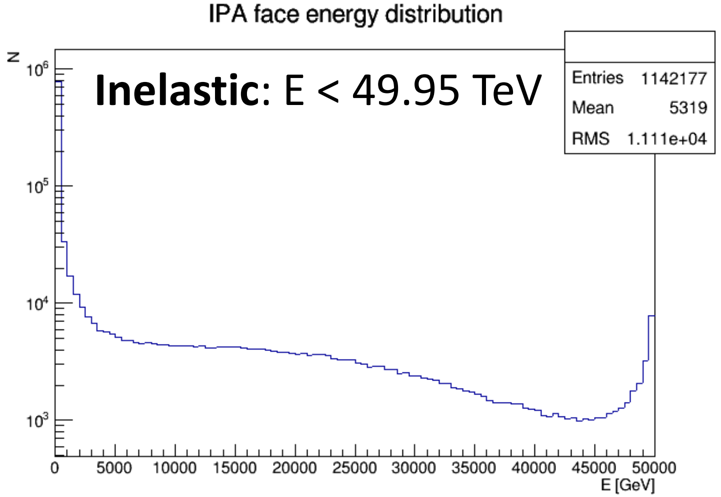
- Do protons from collisions reach the next detector?
- What effect will this have on operation (background, emittance, losses, etc)?
- Do other collision products reach the next detector?
- Are there any areas of concern? – if so how do we address them.

Collision Products (3 [m] post IPA)



Mean protons per primary 1.43
Mean energy of protons 13418 GeV
Mean mu- per primary 0.142
Mean energy of mu- 10.7 GeV
Mean charged hadron per primary 23.4
Mean energy of CH 396 GeV
Mean gammas per primary 19.3
Mean energy of gammas 238.9 GeV





Charged hadrons other than protons ignored (for cross-talk) due to rigidity.

Generated using DPMJET-III inside FLUKA

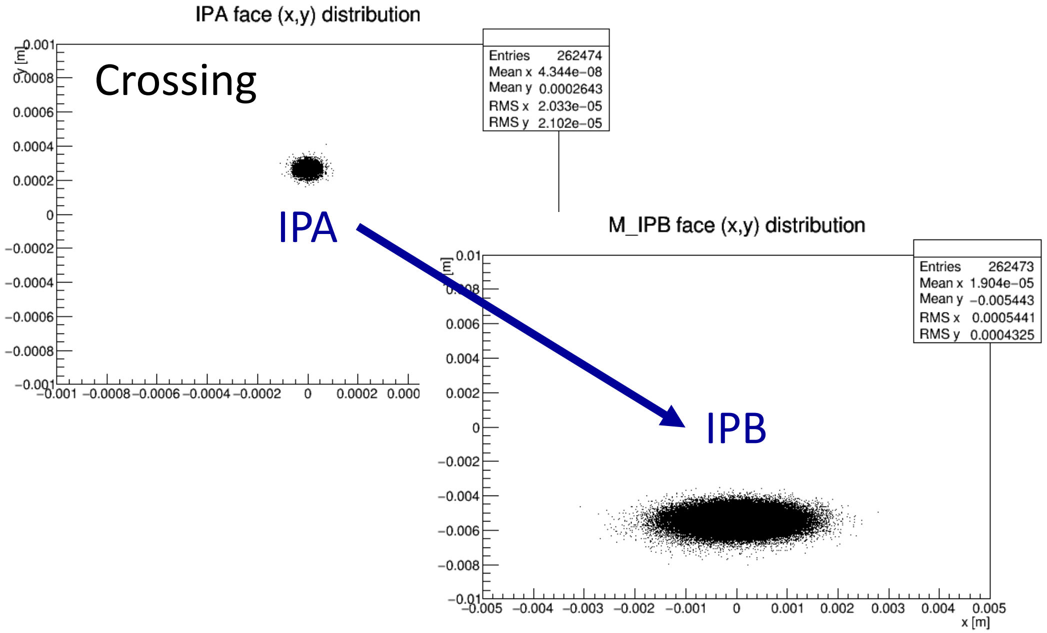
Split protons into 2 cases: Elastic and inelastic

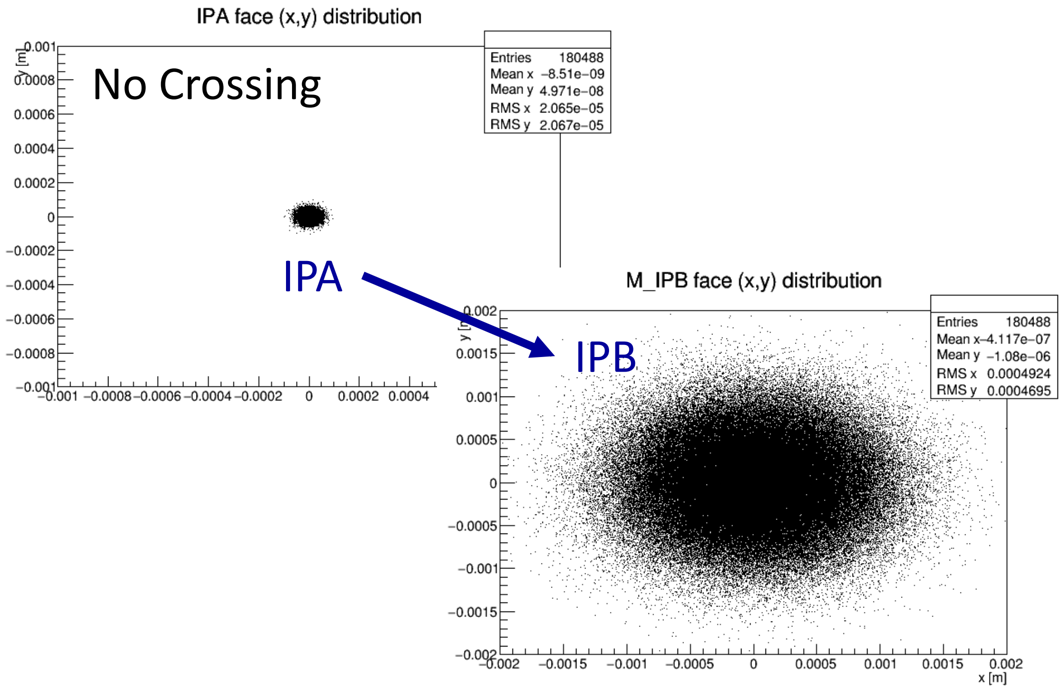
Elastic Protons

Tracking performed with PTC and MERLIN

Elastic protons all reach IPB with no losses. This will lead to emittance growth.

Not a major concern, so we concentrate on inelastic protons



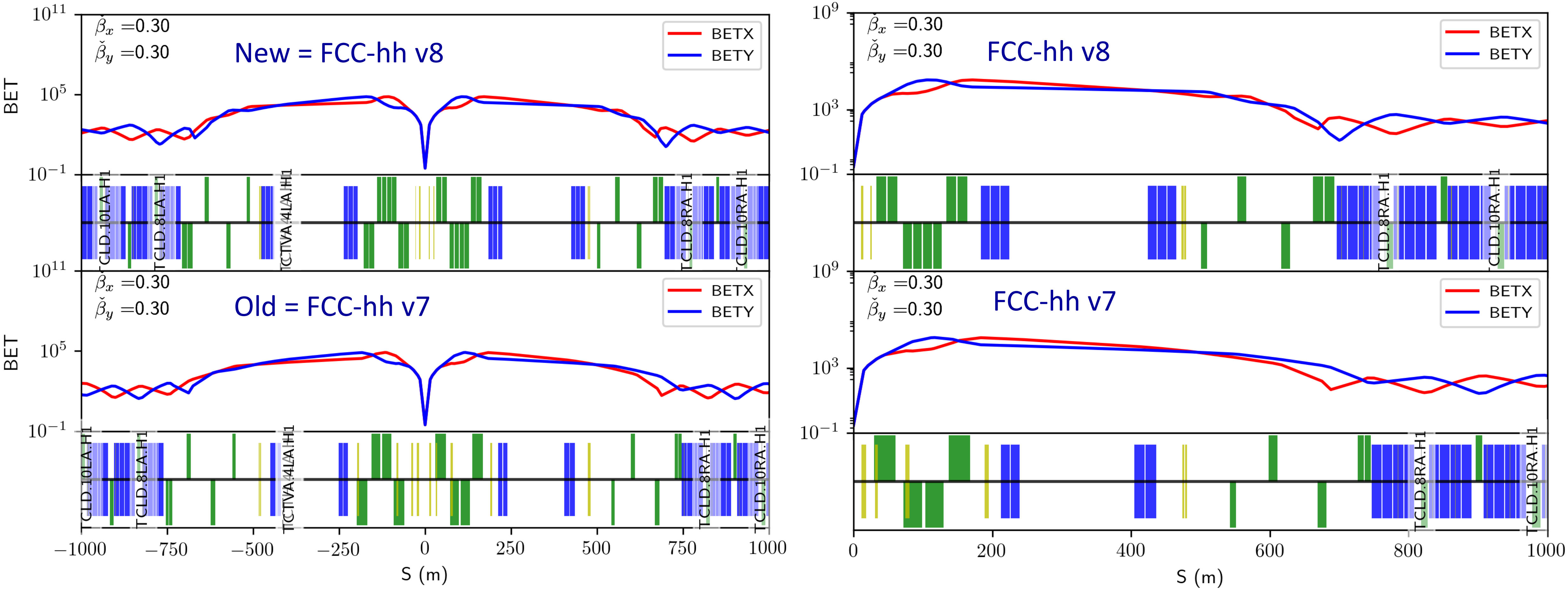


Previous Results

- Elastic protons all reach IPB – emittance growth
- Muon range analytically calculated – too short
- Muons tracked in FLUKA – don’t reach IPB (confirmed analytical)

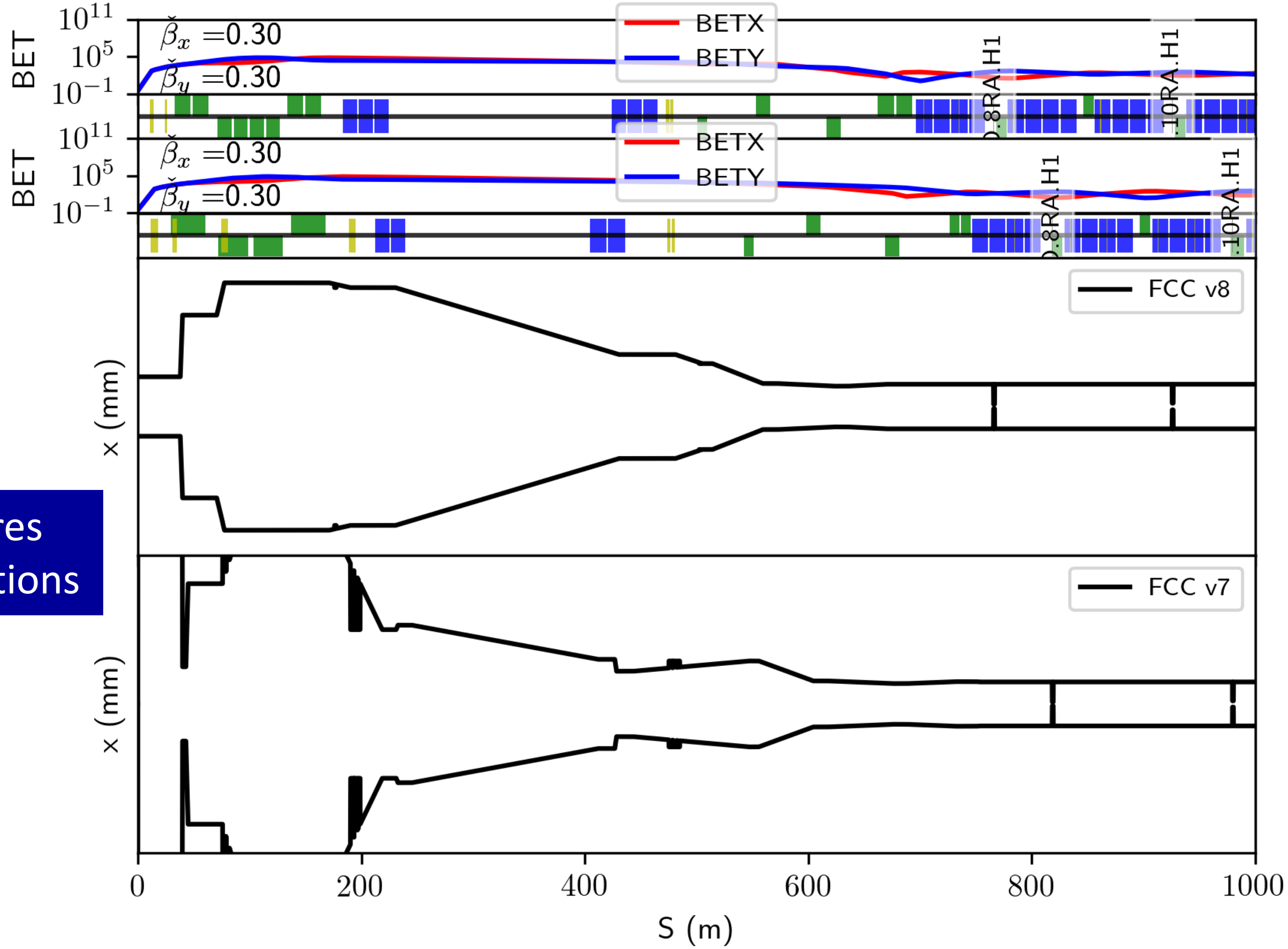
- S = 0 corresponds to IPA

New Layout



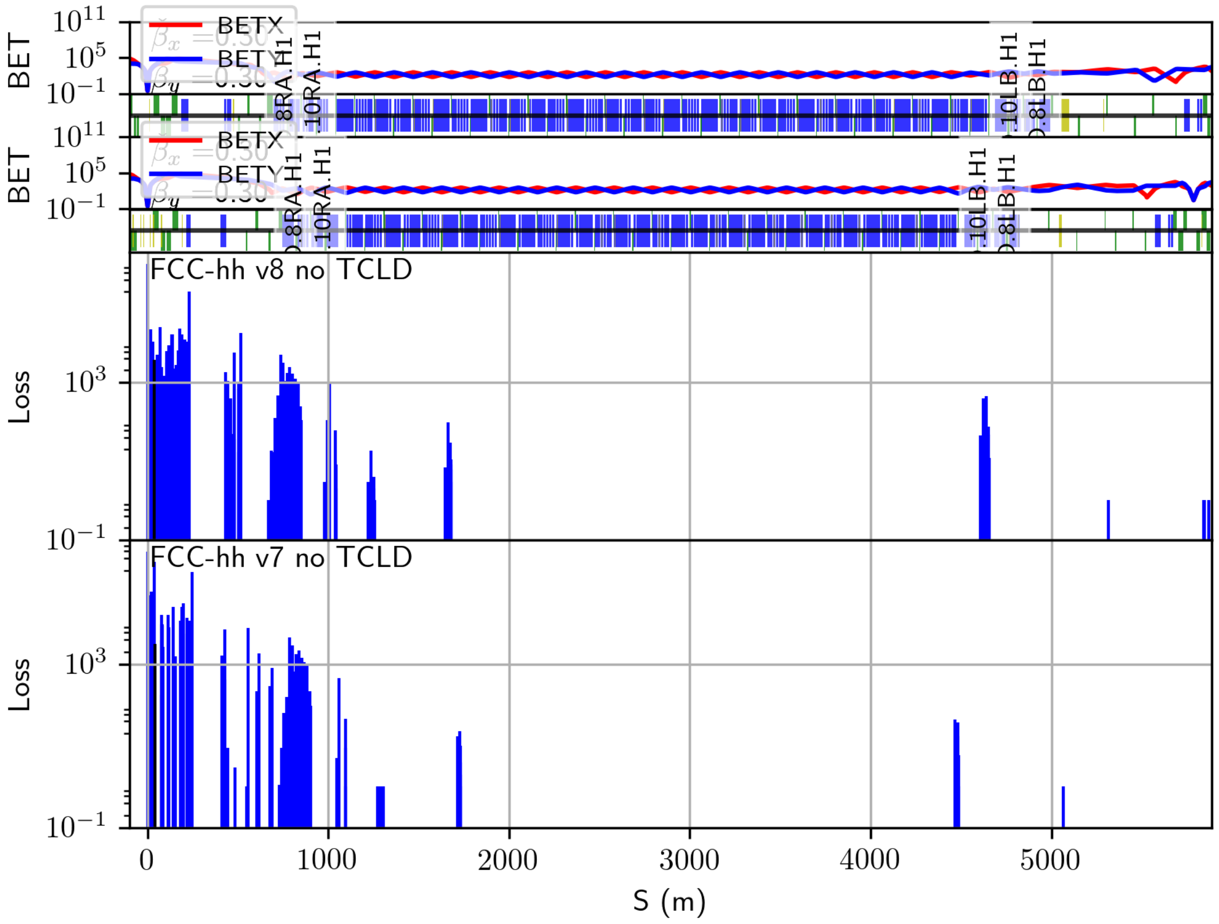
New = FCC-hh v8
Old = FCC-hh v7
FCC-hh v8
FCC-hh v7
BETX
BETY
$\check{\beta}_x$ =0.30
$\check{\beta}_y$ =0.30
BET
S (m)
TCLD.10LA.H1
TCLD.8LA.H1
TCTVA.4LA.H1
TCLD.8RA.H1
TCLD.10RA.H1

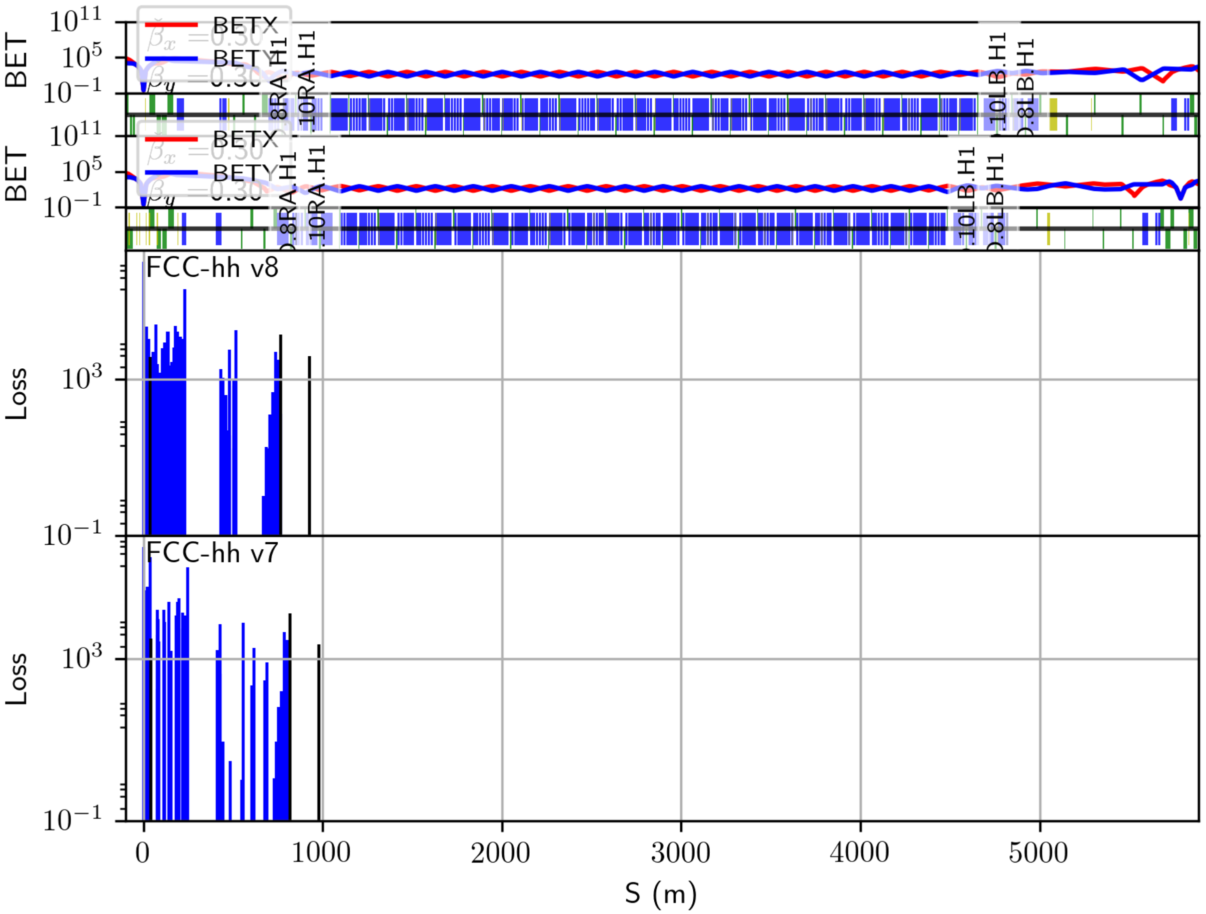
New Layout



Difference in IP apertures
Shift in Collimator positions

Losses with and without TCLDs

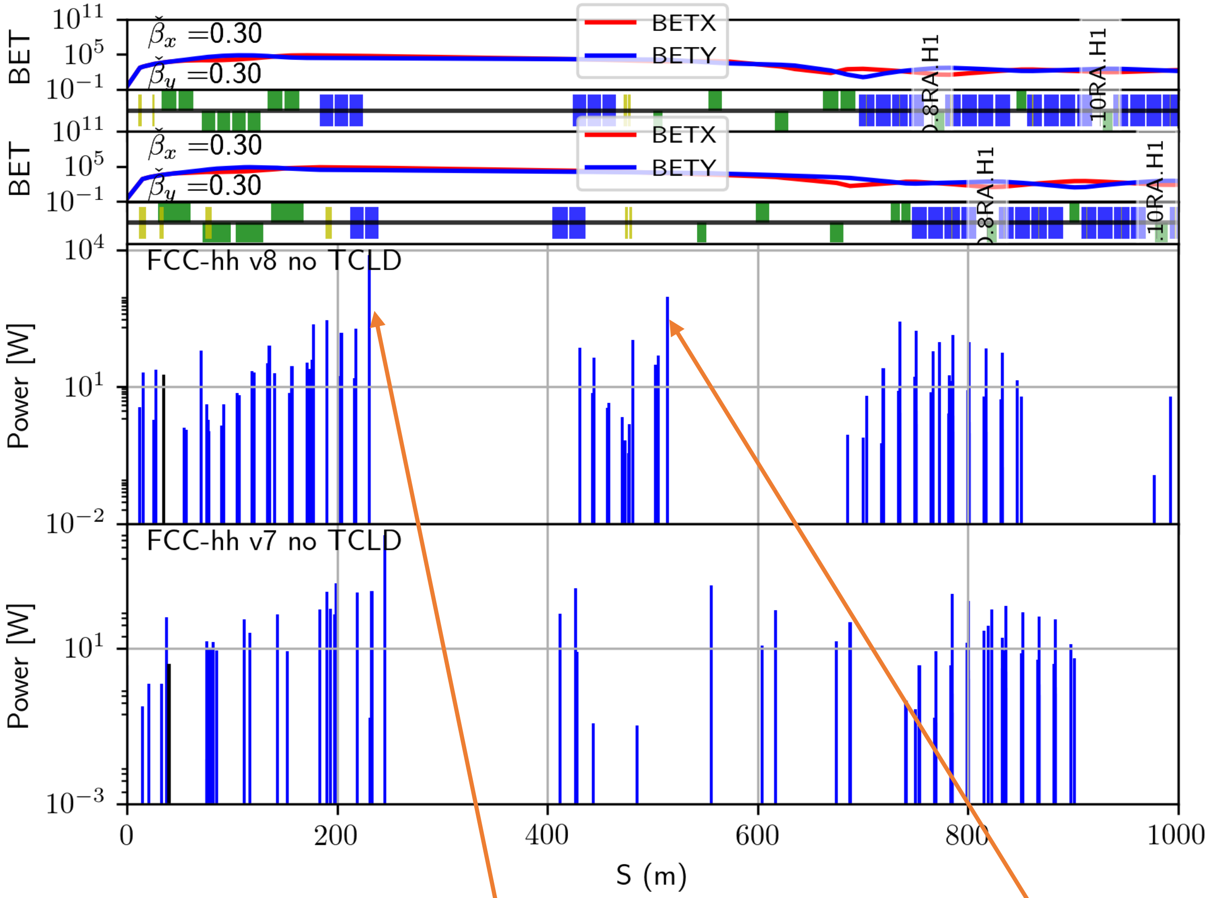


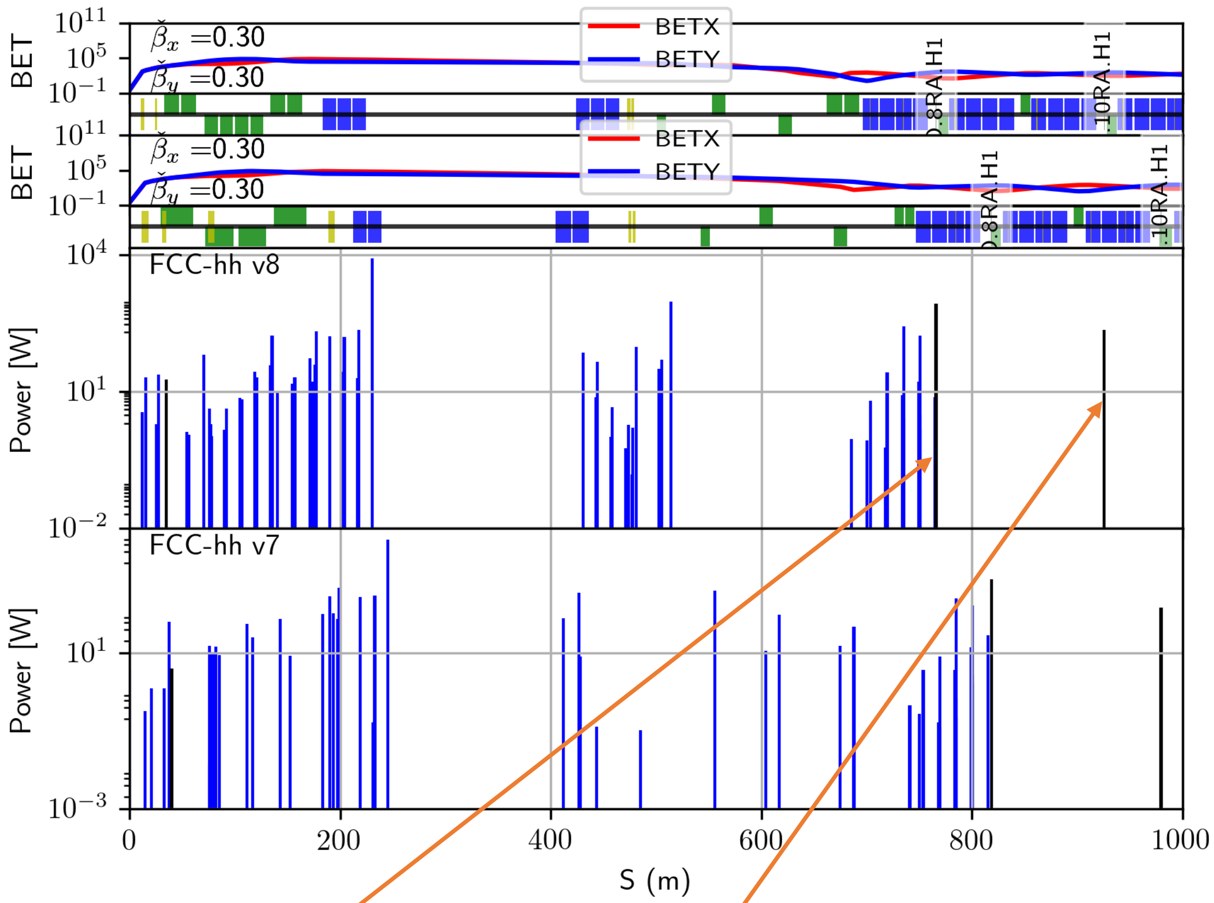


More losses in DS magnets in new lattice

Mitigated with same TCLD settings (35.14 σ)

Power deposited with and without TCLDs





~8 kW in 200 m drift

~1 kW in 45 m drift

790 W in TCLD8

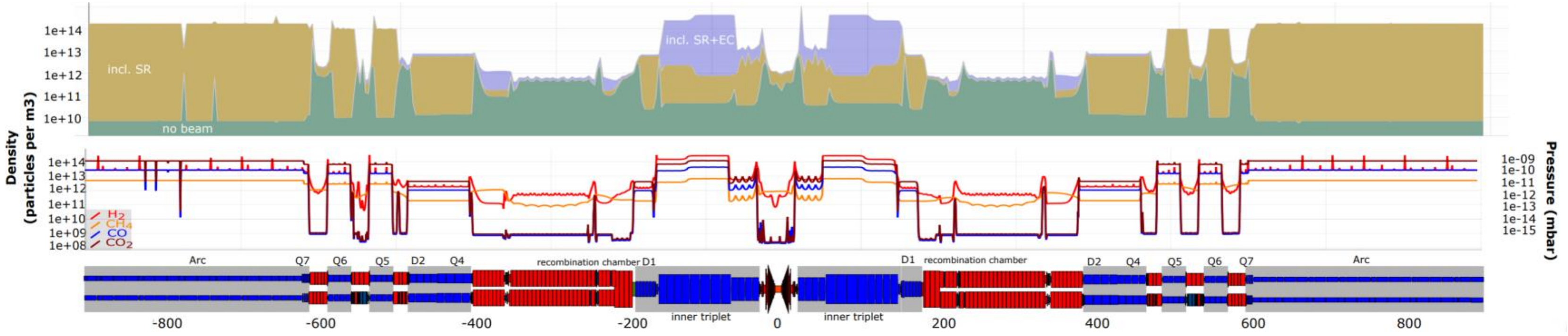
224 W in TCLD10

Cross-talk summary (including previous work)

- 50 TeV proton collisions modelled using DPMJET-III in FLUKA
- Proton tracking performed with PTC and MERLIN
- **Elastic protons all reach the next IP with spot size ≈ beam**
- **Inelastic proton cross-talk not of great concern**
  - 1 – 10 protons per IPA bunch crossing at IPB FCC-hh v7
  - Slightly reduced for FCC-hh v8
- **DS losses mitigated when using existing TCLD design & settings** – IPAC TUPIK037
- Muon tracking performed with FLUKA
- **Muons do not have the range to get to the next IP** – IPAC TUPVA036
- No major incidents due to new lattice from cross-talk perspective

Machine Induced Background

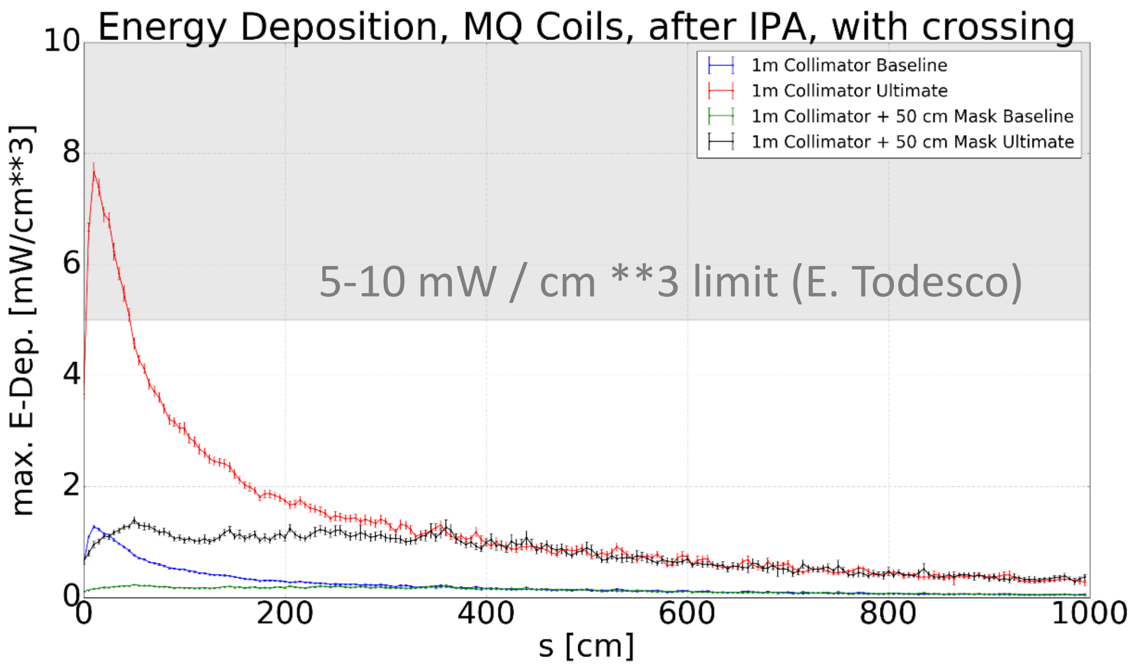
- Major contributors: beam-gas interaction, halo and collision debris losses.
- Propose a study using FLUKA
  - *Sources of machine-induced background in the ATLAS and CMS detectors at the CERN Large Hadron Collider – R. Bruce et al. (NIM 13')*
- Gas density profile required from vacuum team
  - *Pressure Profile in the experimental area of FCC-hh and FCC-ee calculated by an analytical code – I. Aichinger (FCC Week 17')*



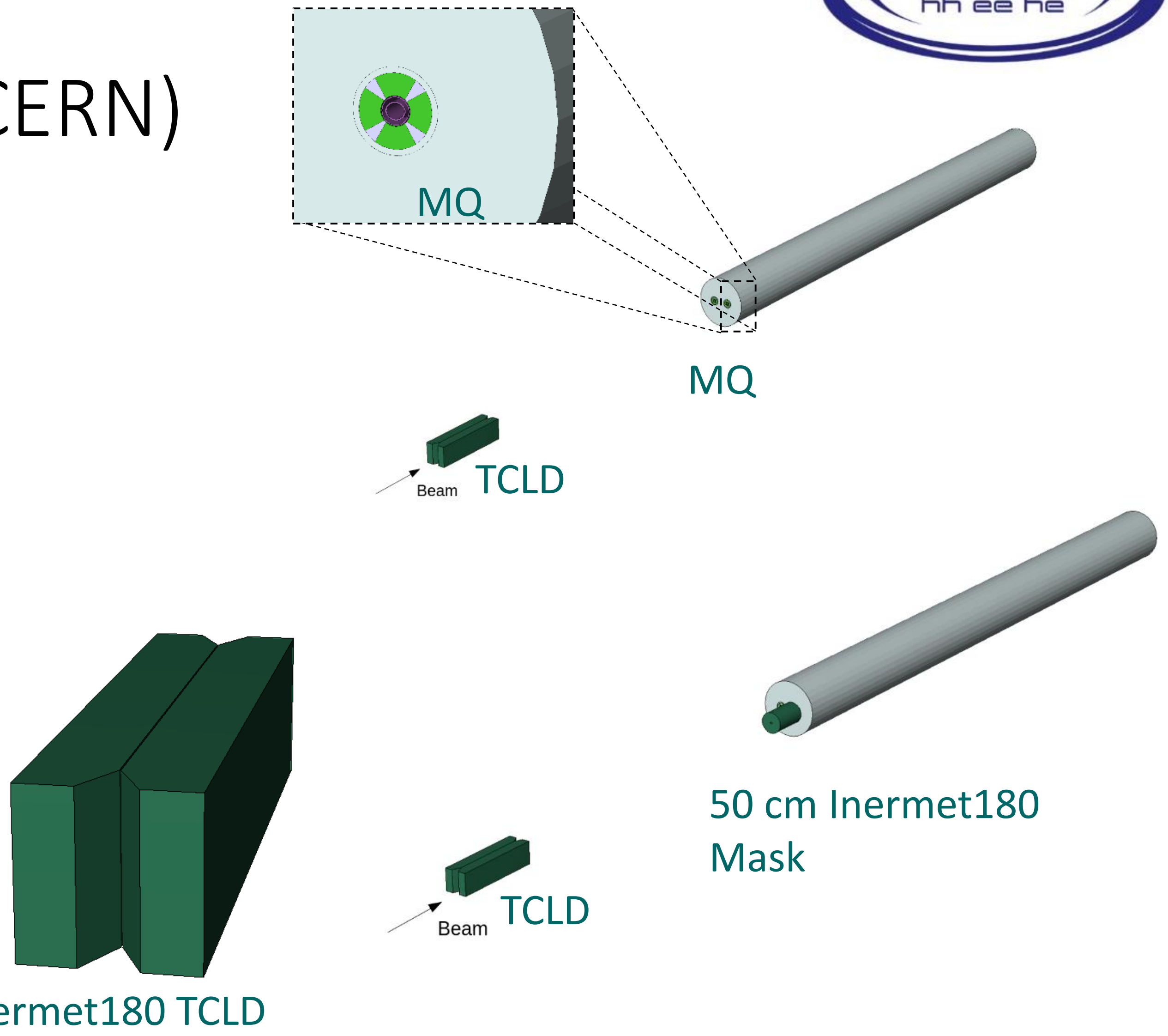
- Interface required from detector team
- Model development with the FLUKA team
- Use of linebuilder?
  - *The FLUKA Linebuilder and Element Database: Tools for Building Complex Models of Accelerator Beam Lines – A. Mereghetti (IPAC 12')*
- Collimator hits from the collimation team

Thank You

TCLD Design (A. Krainer, CERN)



Showers to first quadrupole after TCLD in cell 8, using FLUKA



Proton Cross-Talk and Losses in the Dispersion Suppressor Regions at the FCC-hh, IPAC17', TUPIK037

H. Rafique, R. Appleby, A. M. Krainer, A. S. Langner, J. L. Abelleira

Muons

Muons can travel far in dense materials. Theoretical calculations estimate a range of ~ 3km.

Muon stopping power for high energy muons can be described by

$$\left\langle -\frac{dE}{dx} \right\rangle = a(E) + b(E)E$$

Where E is the energy, a(E) models electronic stopping power (ionization and excitation) and b(E) is due to radiative processes, such that

$$b = b_{brems} + b_{pair} + b_{nucl}$$

Note b(E) is << a(E) for most materials, when E <= 100 GeV.
The range in the continuous slowing down approximation is given by

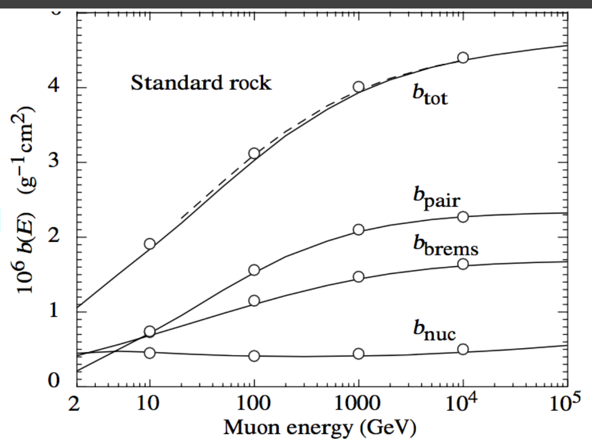
$$R(E) = \int_{E_0}^{E} (a(E') + b(E')E')^{-1} dE'$$

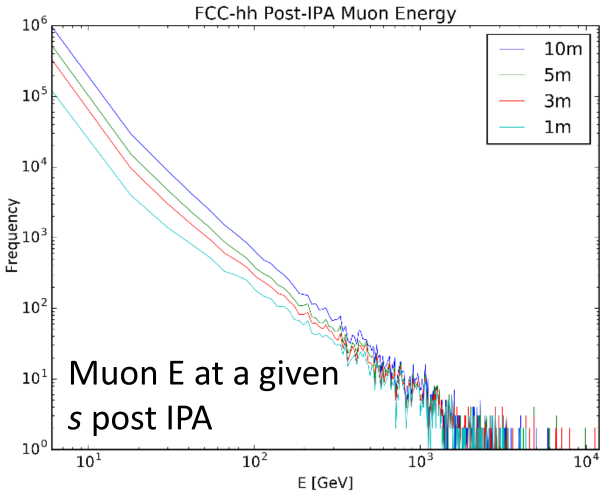
Which is what we use for FCC. However we can do the integral at high energy, when a(E) and b(E) are constant to get

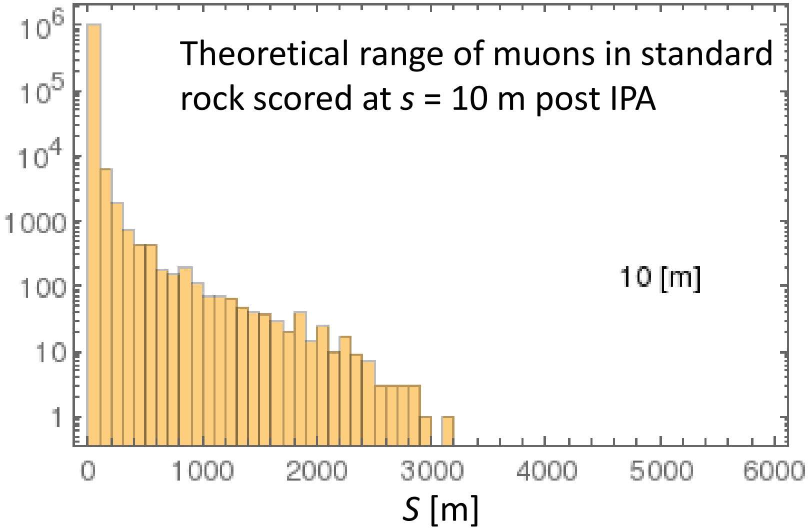
$$R(E) \sim \frac{1}{b} \ln(1 + \frac{E}{E_c})$$

Where the electronic and radiative losses are equal at the 'critical energy'

$$a(E_c) = E_c b(E_c)$$

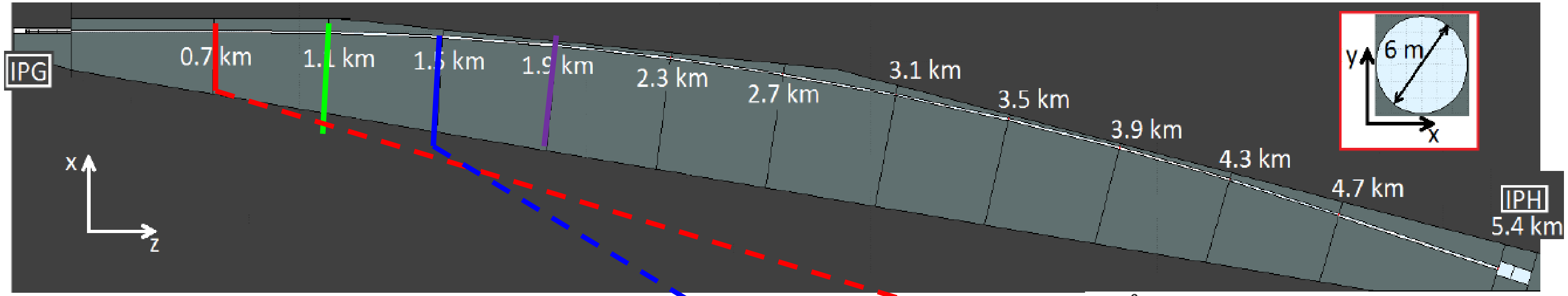


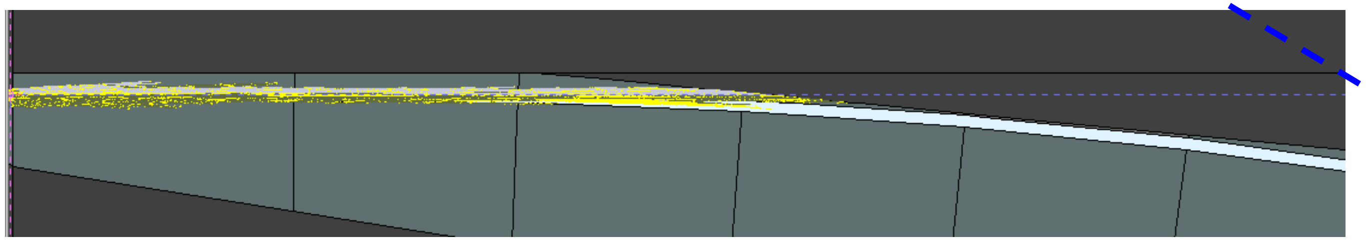




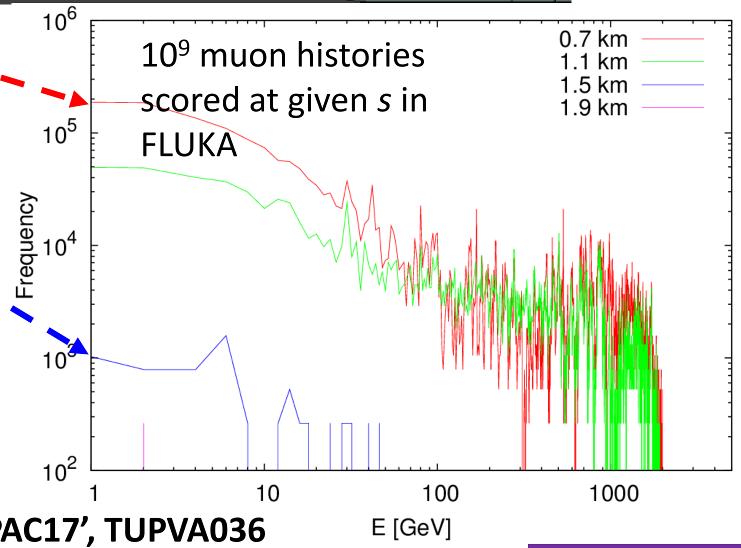
Muon tracking in FLUKA J. L. Abelleira (JAI, Oxford)

Theoretical estimate of range has been confirmed using FLUKA simulations. Muons should not reach the next IP.





Muons generated using DPMJET-III inside FLUKA, with a full detector model, by M. I. Besana



Cross-Talk Studies between FCC-hh Experimental Interaction Regions, IPAC17', TUPVA036

J. L. Abelleira, A. Seryi, M. I. Besana, R. Appleby, H. Rafique