FCC-hh Detector Cross-Talk

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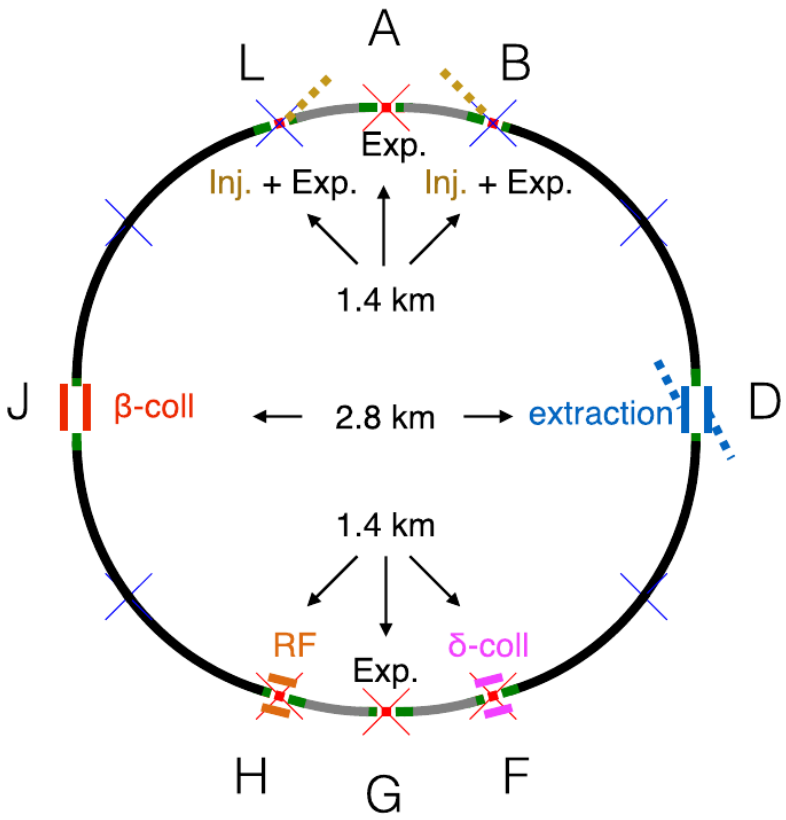
Many thanks to D. Schulte, A. Langner, M. I. Besana, F. Cerutti

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

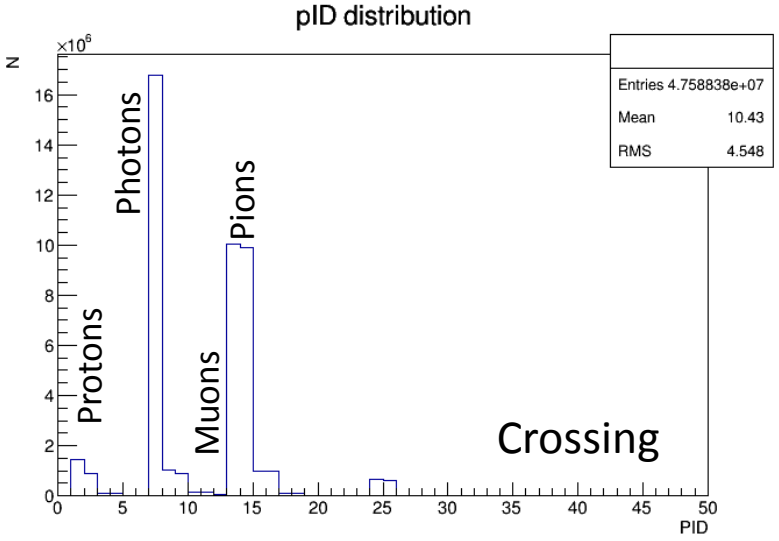
Questions:

- 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.

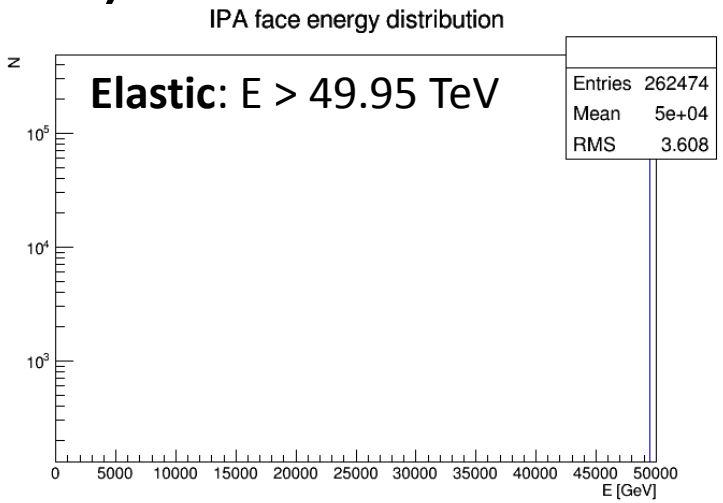


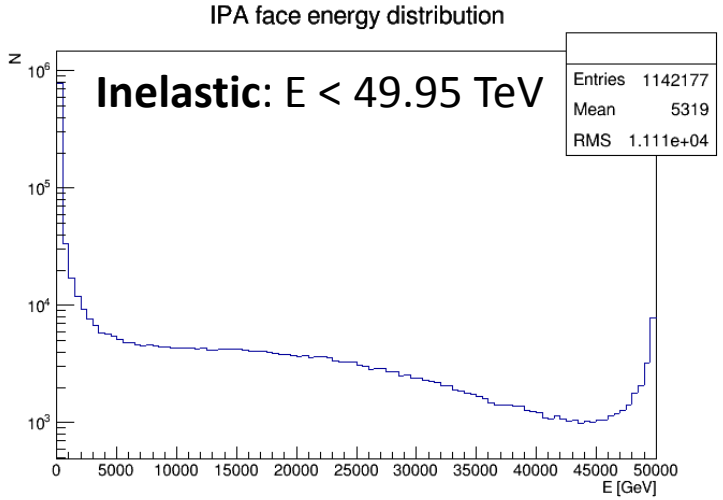
Long arc (L=16km,R=13km)
Short arc (L=3.2km,R=13km)
DS (L=0.4km,R=17km)
6 short straight sections (1.4km)
2 long straight sections (2.8km)

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

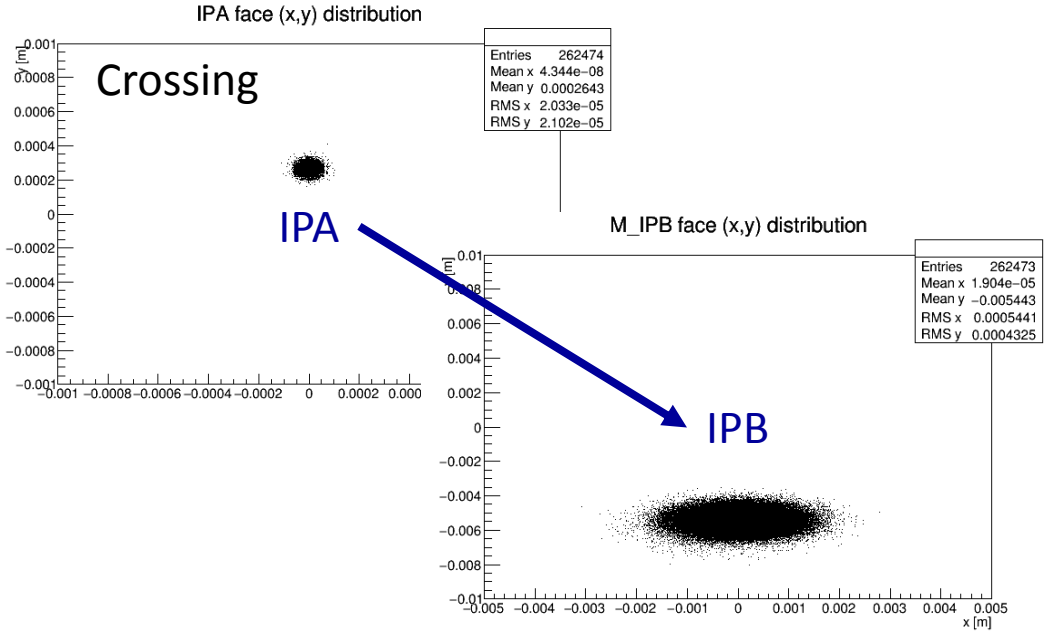
Split protons into 2 cases: Elastic and inelastic

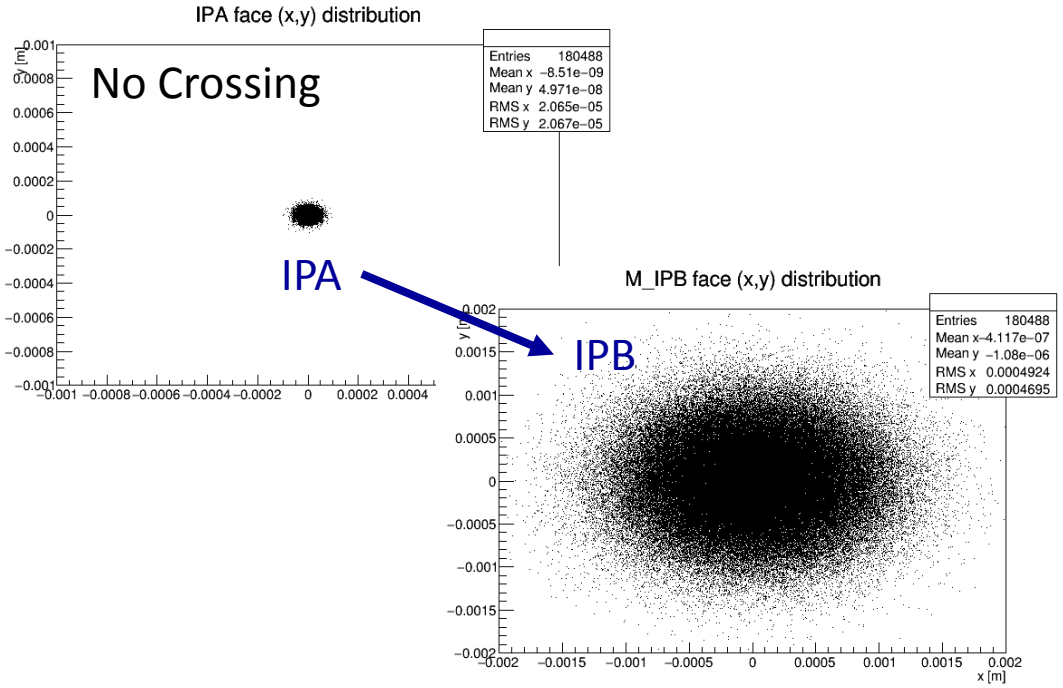
Elastic Protons

Tracking performed with PTC and MERLIN

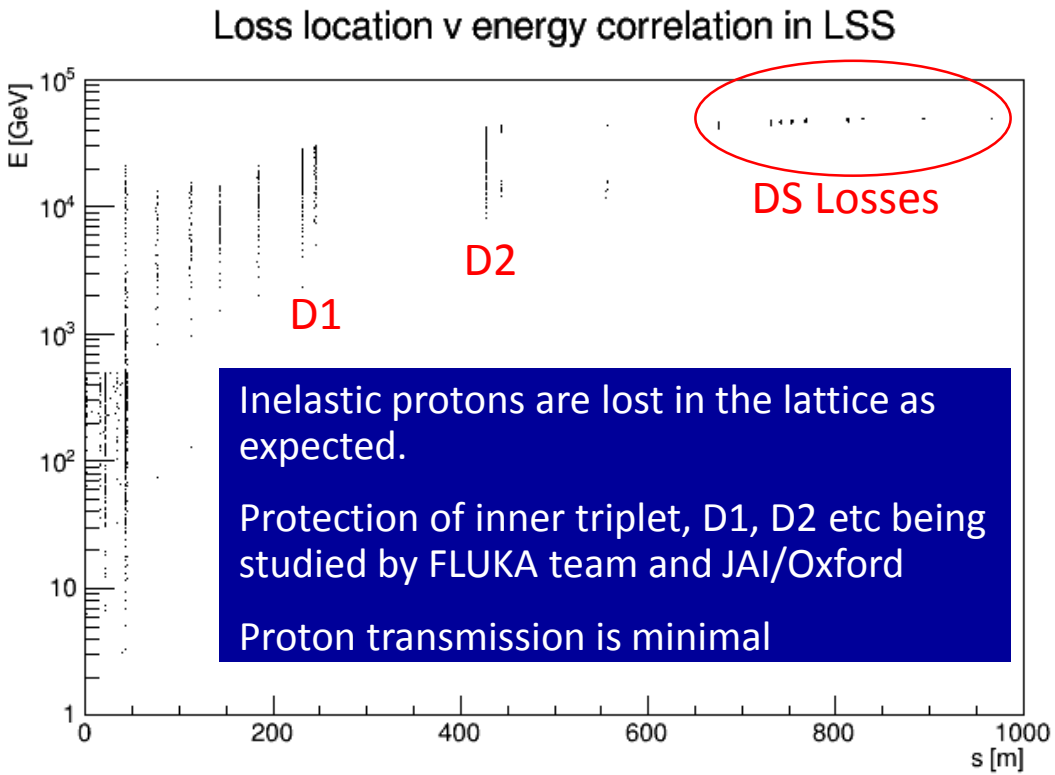
Elastic protons all reach IPB with no losses. This will lead to emittance growth.

Not a major concern, so we concentrate on inelastic protons





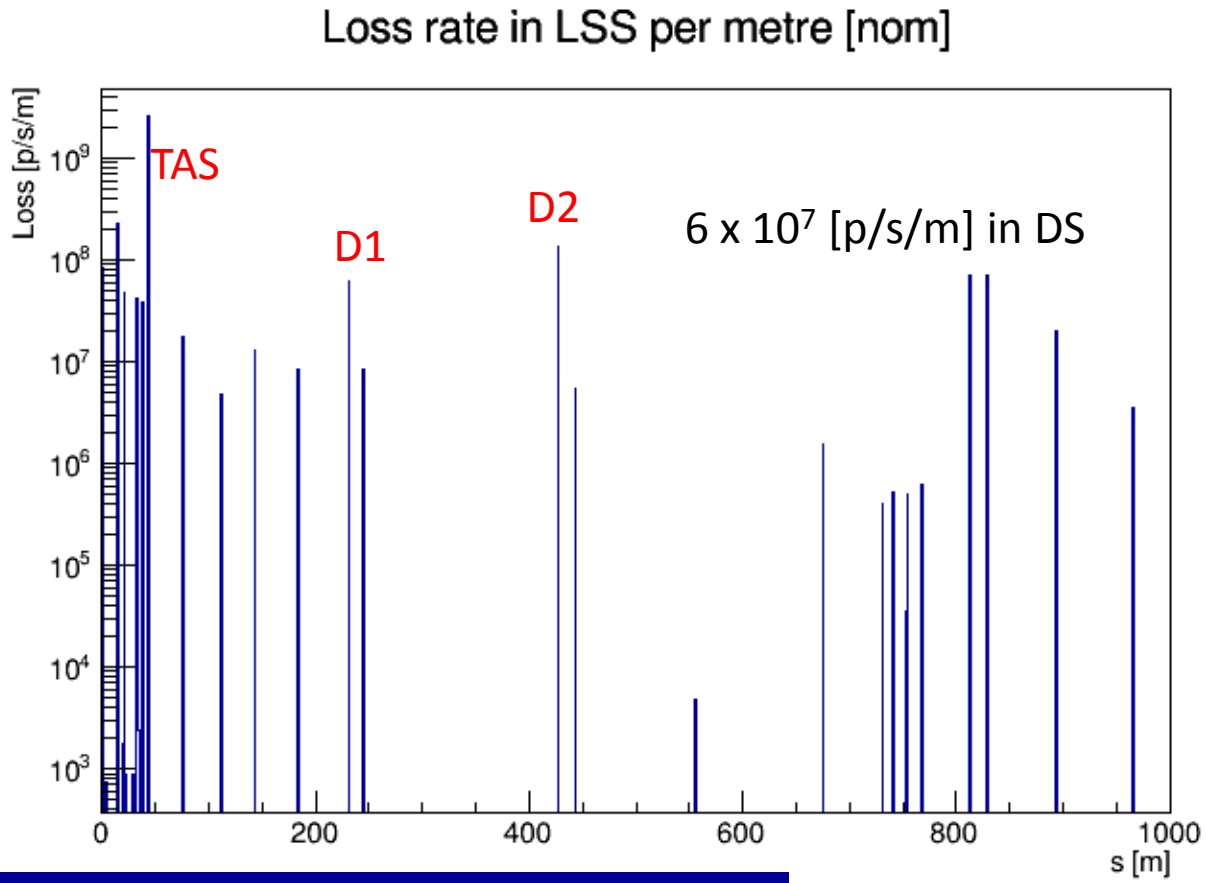
Inelastic losses IPA – IPB, Crossing On [PTC]



Inelastic protons are lost in the lattice as expected.

Protection of inner triplet, D1, D2 etc being studied by FLUKA team and JAI/Oxford

Proton transmission is minimal



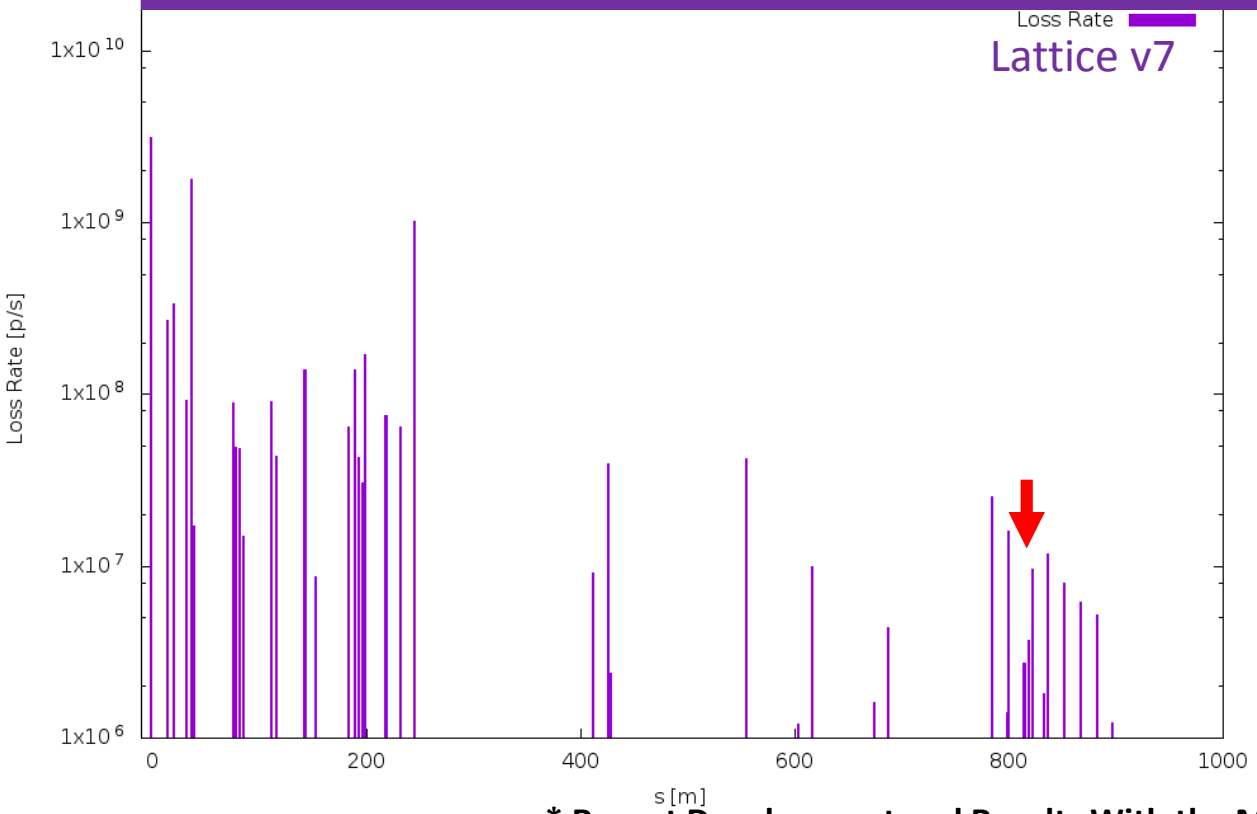
Protons at IPA = 1142177
Protons at IPB = 4263
Particles at IPB PER BX [nom]: 1.457946
Particles at IPB PER BX [ult]: 8.747676
Particles at IPB PER SEC [nom]: 46040400.0
Particles at IPB PER SEC [ult]: 276242400.0
Mean energy of protons at IPB [GeV]: 49889.6530665

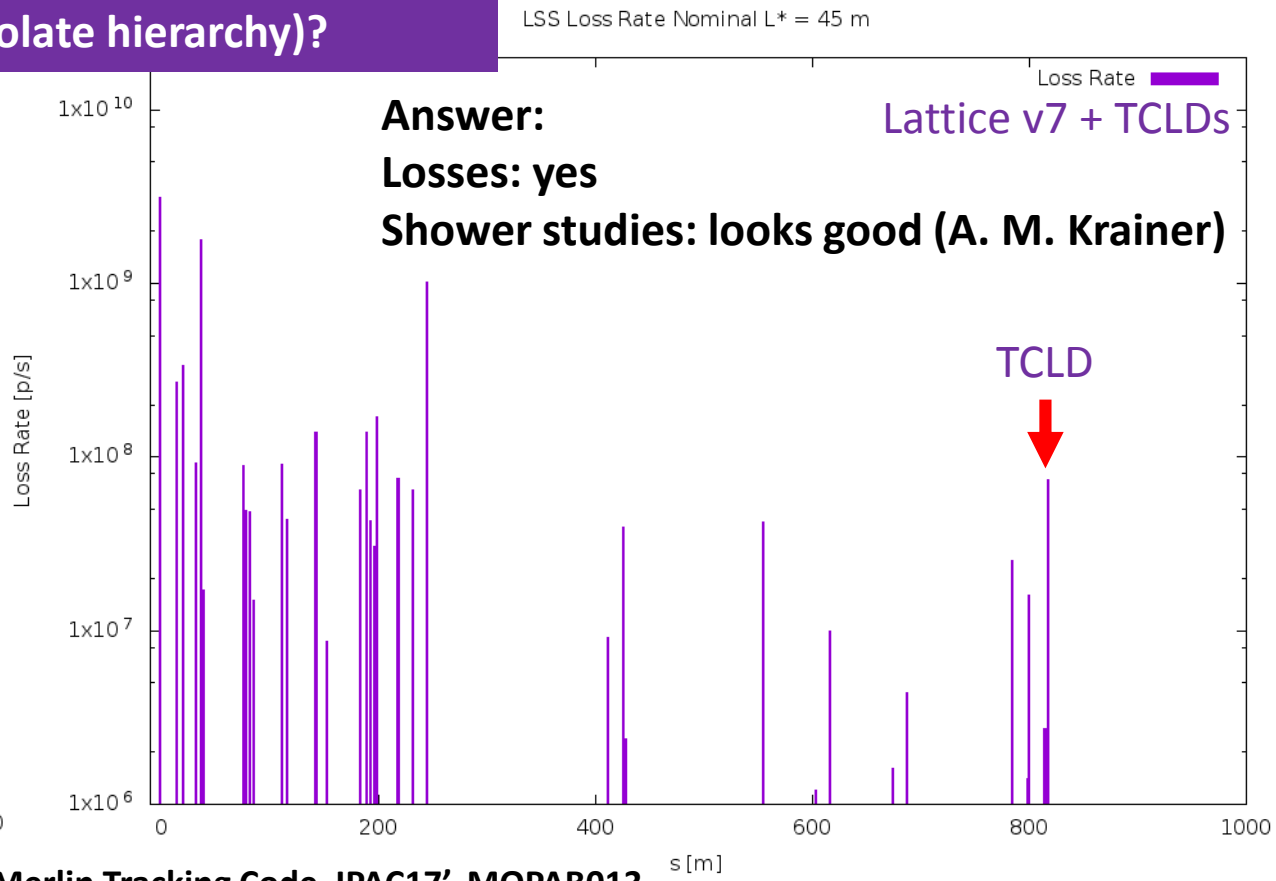
No scattering

Assuming all aperture restrictions = black absorbers

Losses in LSS, Crossing Off [MERLIN*]

Questions:
Can we use the existing TCLD design from post betatron collimation?
Can we operate at the same jaw openings (i.e. don't violate hierarchy)?

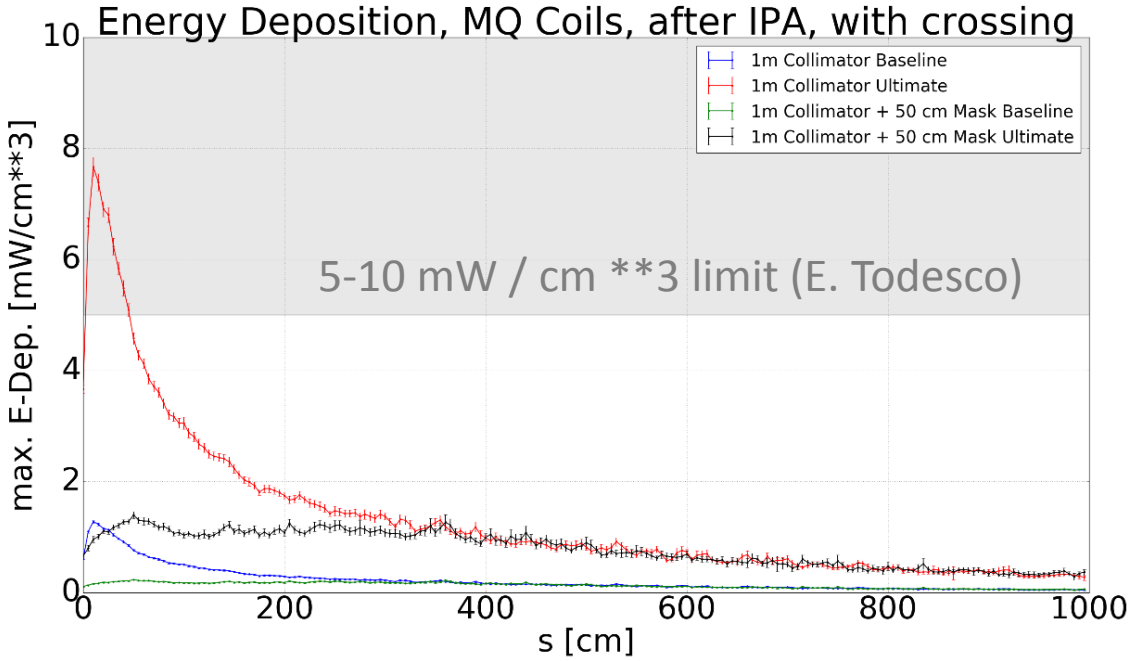




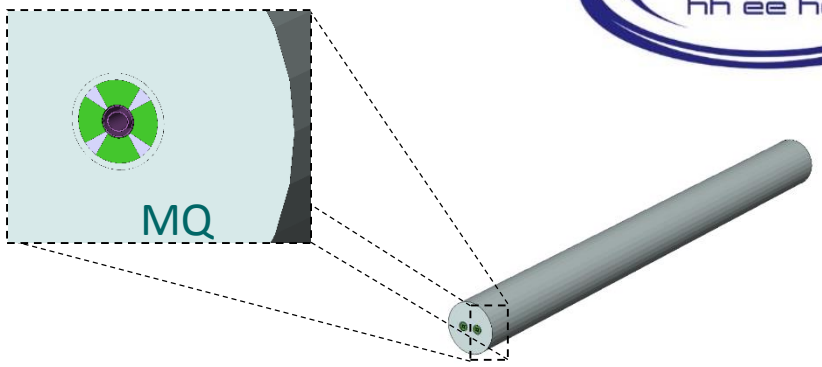
Answer:
Losses: yes
Shower studies: looks good (A. M. Krainer)

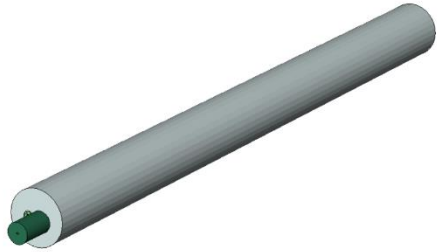
*** Recent Development and Results With the Merlin Tracking Code, IPAC17', MOPAB013**
S. Tygier, R. B. Appleby, H. Rafique, R. J. Barlow, S. Rowan, J. Molson

TCLD Design (A. Krainer, CERN)

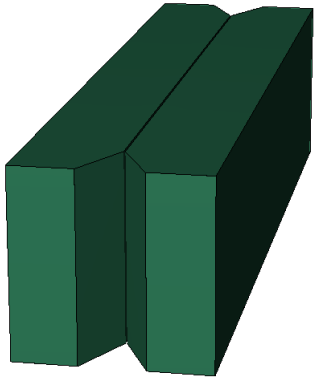


Showers to first quadrupole after TCLD in cell 8, using FLUKA





50 cm Inermet180 Mask



Inermet180 TCLD

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

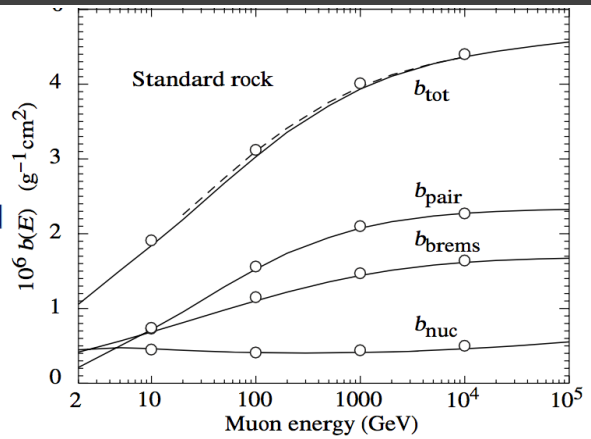
$$R(E) = \int_{E_0}^{E} (a(E') + b(E')E')^{-1} dE'$$

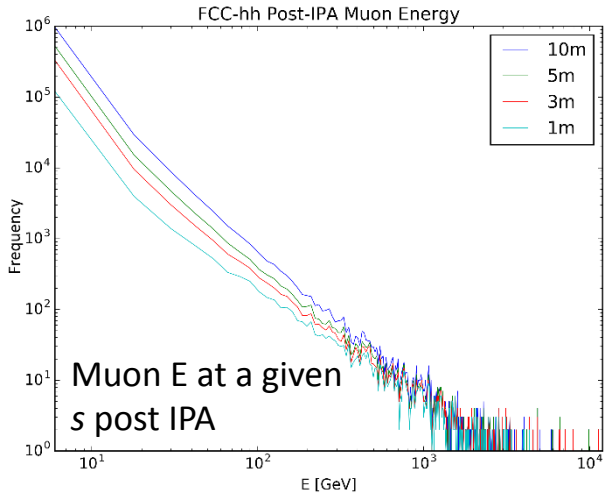
Which is what we use for FCC. However we can do the integral at high energy, when a(E) and b(E) are constant to get

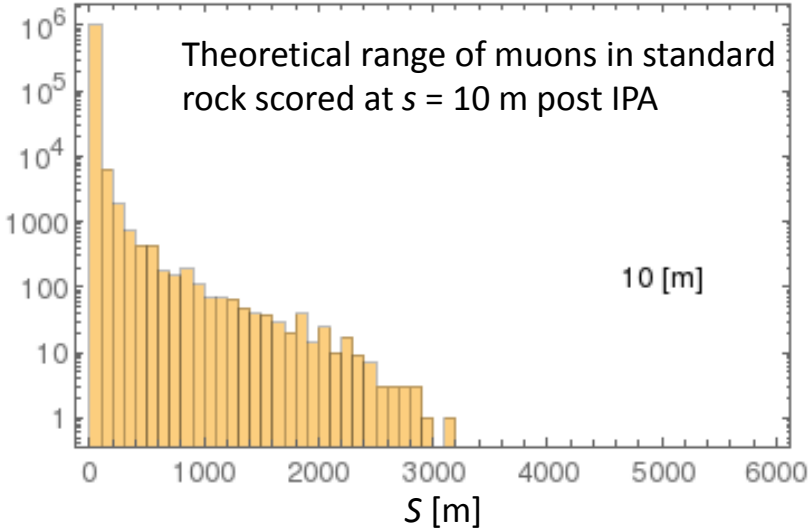
$$R(E) \sim \frac{1}{b} \ln(1 + \frac{E}{E_c})$$

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

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

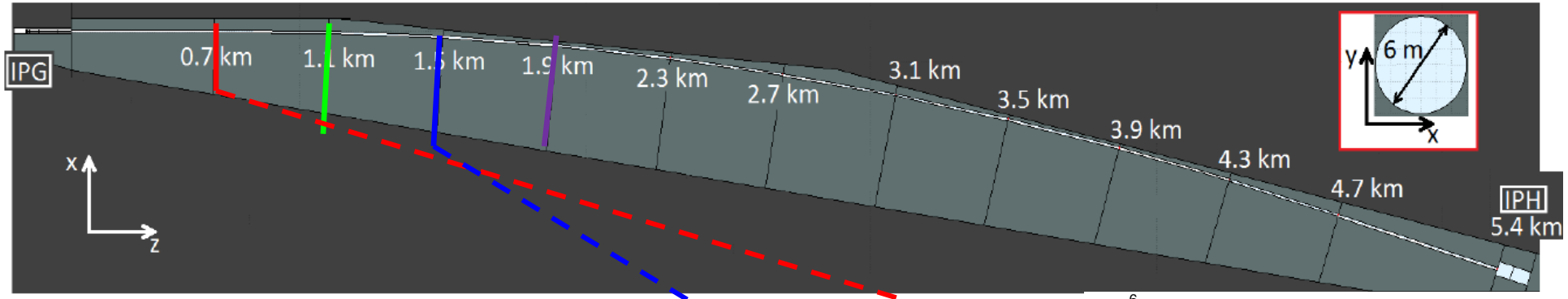


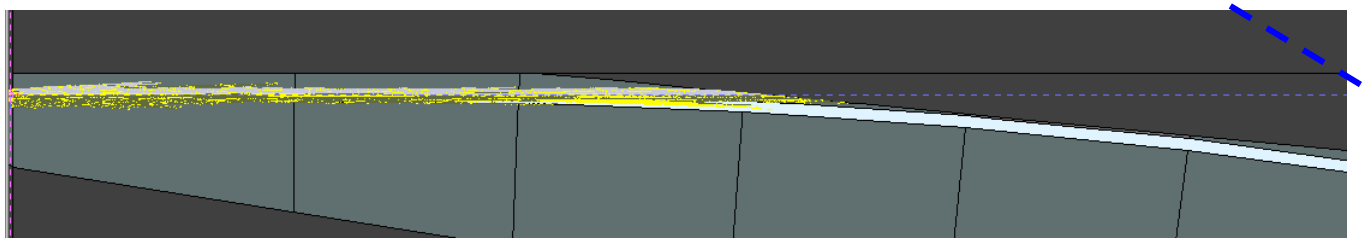


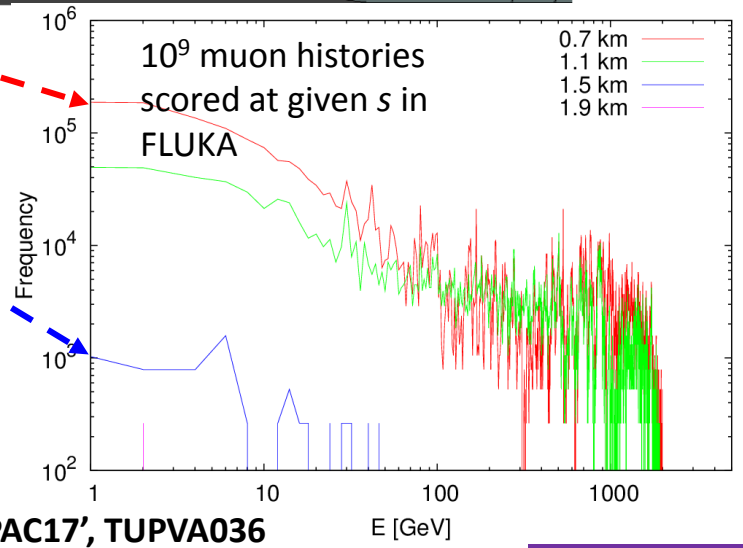


Muon tracking in FLUKA J. L. Abelleira (JAI, Oxford)

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

Summary

- 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
- **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

Thank You

Power Loss on TCLD (Inelastic Protons Tracked from IPA Only)

Require full shower studies with FLUKA/equivalent to include all contributions