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.
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.

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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

Haroon Rafique - FCC Week 2017 Berlin
Energy Deposition, MQ Coils, after IPA, with crossing

5-10 mW / cm **3 limit (E. Todesco)

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

31/05/2017
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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

\[ \frac{dE}{dx} = a(E) + b(E)E \]

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

\[ b = b_{\text{brem}} + b_{\text{pair}} + b_{\text{nucl}} \]

Note \( b(E) \) is \( \ll a(E) \) for most materials, when \( E \leq 100 \text{ GeV} \).

The range in the continuous slowing down approximation is given by

\[ R(E) = \int_{E_0}^{E} \left( a(E') + b(E')E' \right) \frac{1}{E'} dE' \]

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

\[ R(E) \sim \frac{1}{b} \ln\left(1 + \frac{E}{E_c}\right) \]

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 \( \approx \) 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

TCLD Power < 1 kW