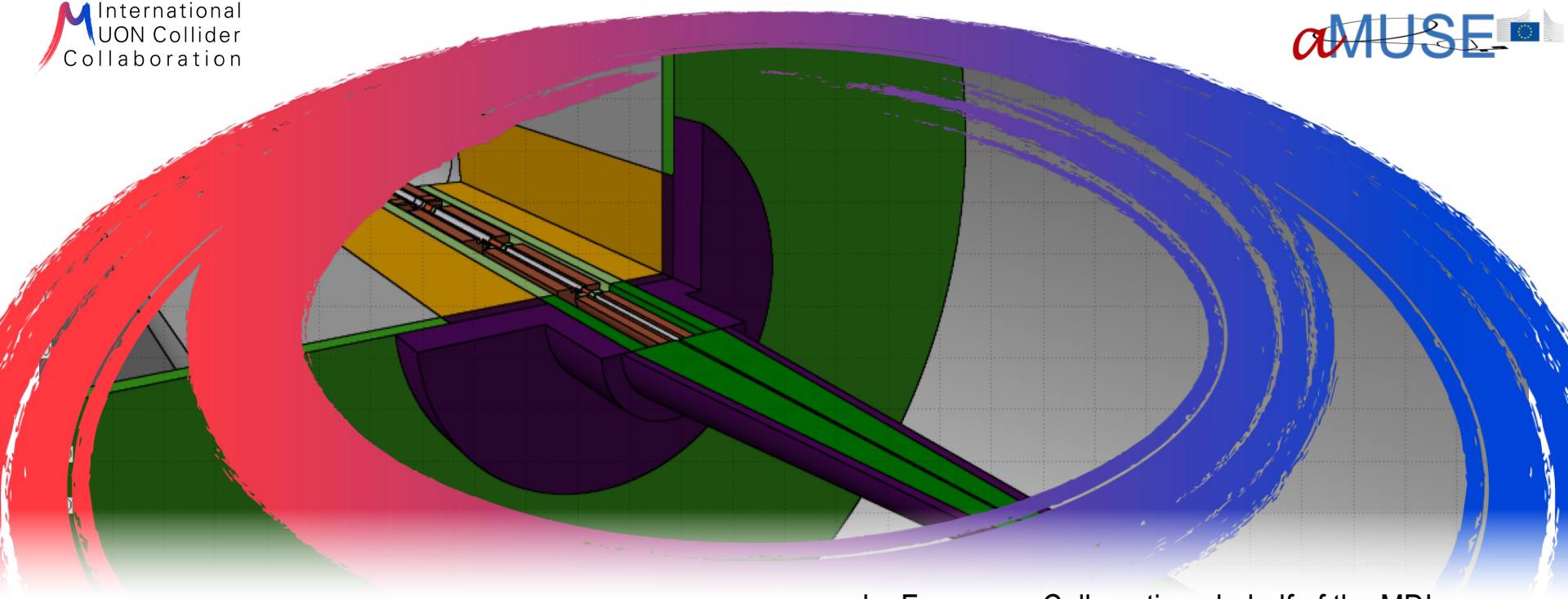
# Machine-induced background studies for 1.5 TeV and 3 TeV



*Credits: C. Curatolo, P. Sala*

by Francesco Collamati, on behalf of the MDI group
INFN Rome
12 10 2022

# Outline

- The software: FLUKA + LineBuilder
- Code benchmark with MARS: the 1.5TeV case
- First results in the 3TeV case

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- The software: FLUKA + LineBuilder
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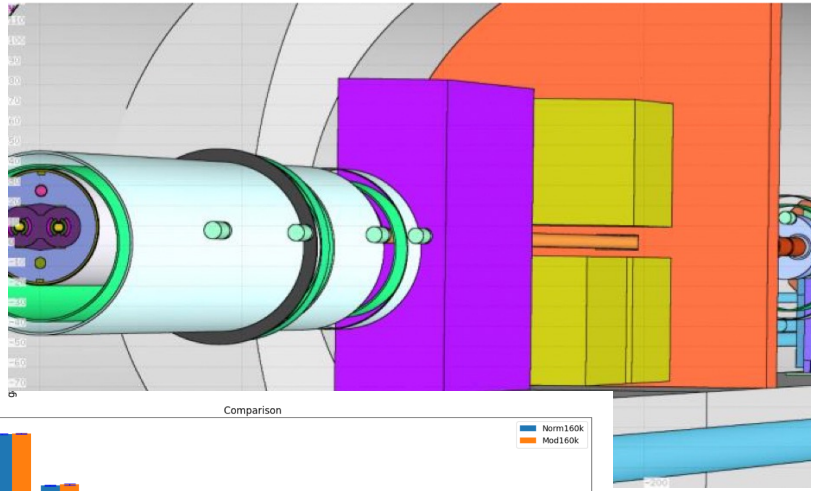
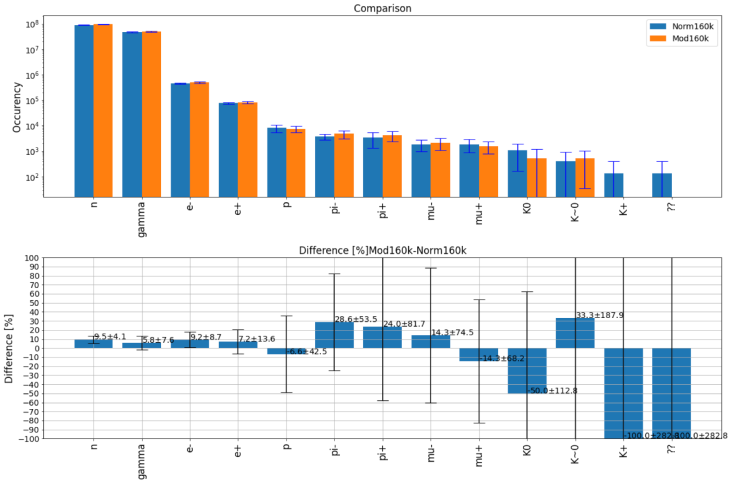
# The Software



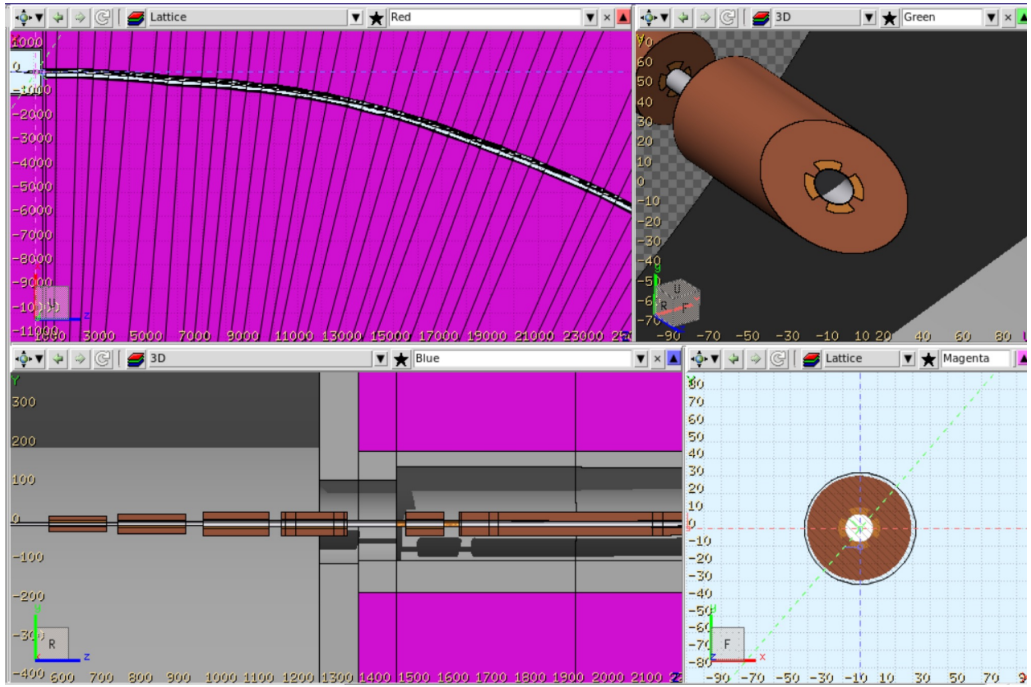



- FLUKA + LineBuilder used to reconstruct the machine geometry in the simulation
  - Direct connection between optics files and Monte Carlo
    - Easy to test the effect of possible variations in the machine configuration, beam energy, MDI optimization..
- (semi) Automized analysis program to quickly evaluate the effect of any modification

# Outline

- The software: FLUKA + LineBuilder
- Code benchmark with MARS: the 1.5TeV case
- First results in the 3TeV case

# The 1.5TeV case benchmark

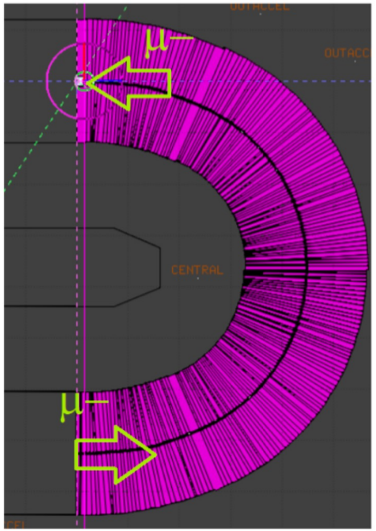



- Optics files and MARS results provided by *MAP*
- MDI *passive elements* retrieved by MAP publications
- Energy cuts:
  - 200keV for γ and e+/-
  - 100keV for neutrons
  - 1MeV for proton & μ
- Only μ decays within 25m from IP considered for the comparison
- Realistic beam of $2 \times 10^{12}$ $\mu^-$

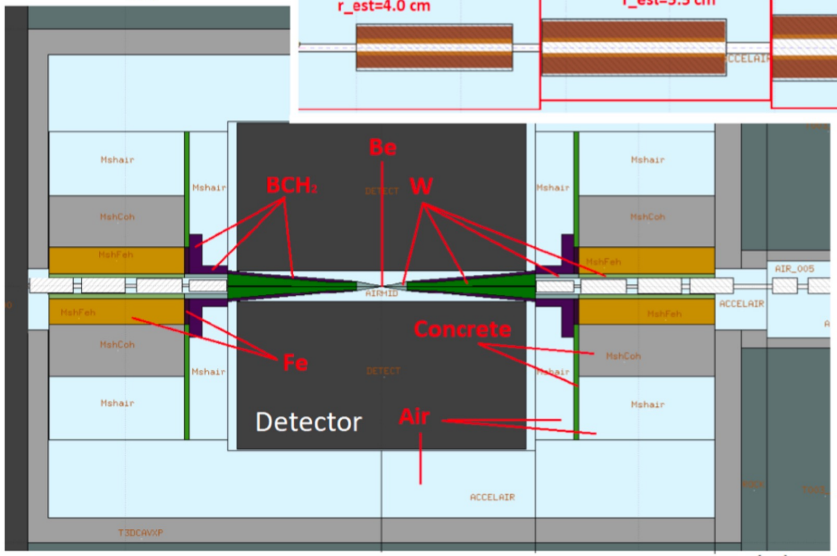
# The 1.5TeV case benchmark

## MDI Layout Description

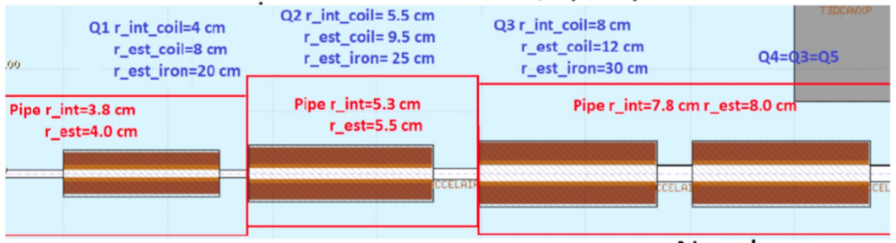
750 GeV muon beam travels half ring to IP



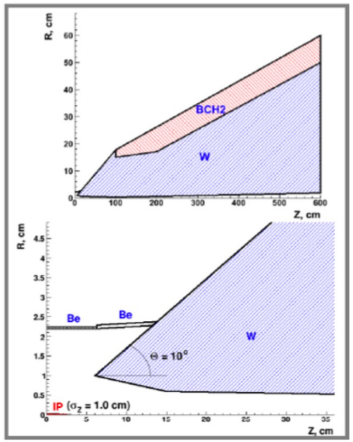

IR




IR Quadrupoles



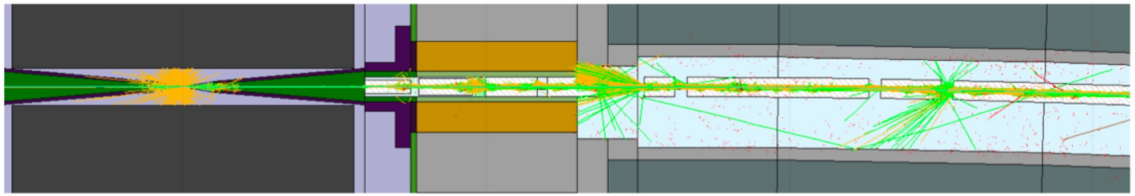

Nozzle



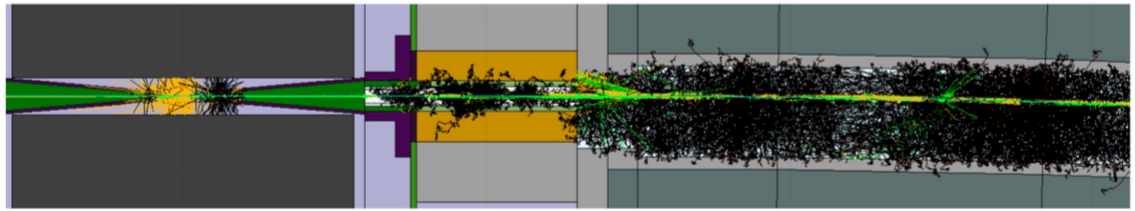
# The 1.5TeV case benchmark

## Sample Event

FLUKA tracking without neutrons

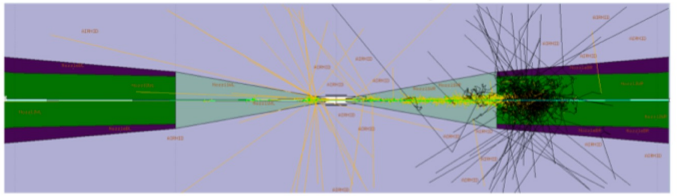


FLUKA tracking with neutrons

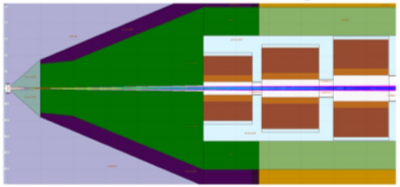


Photon
Neutron
Electron/Positron
Proton
Pion
Muon

zoom on a selected decay

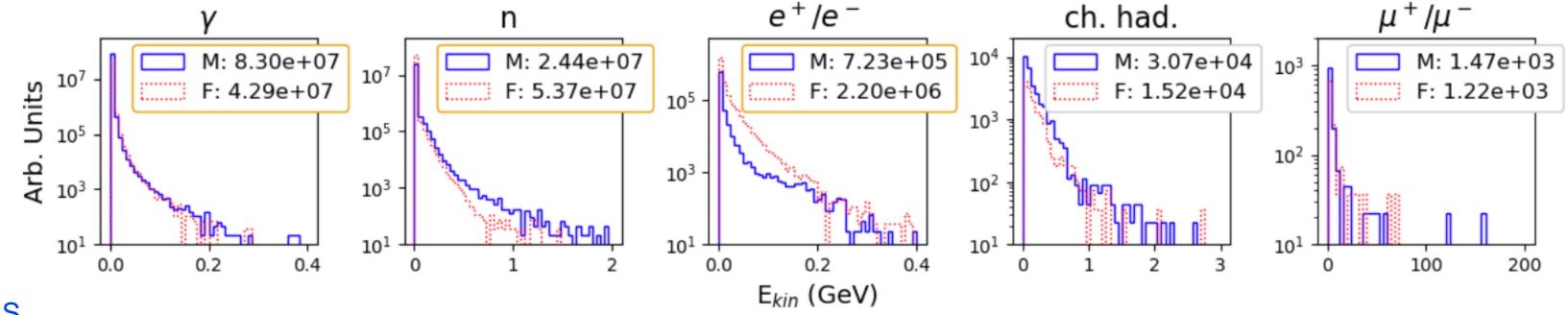


muon beam focusing at IP

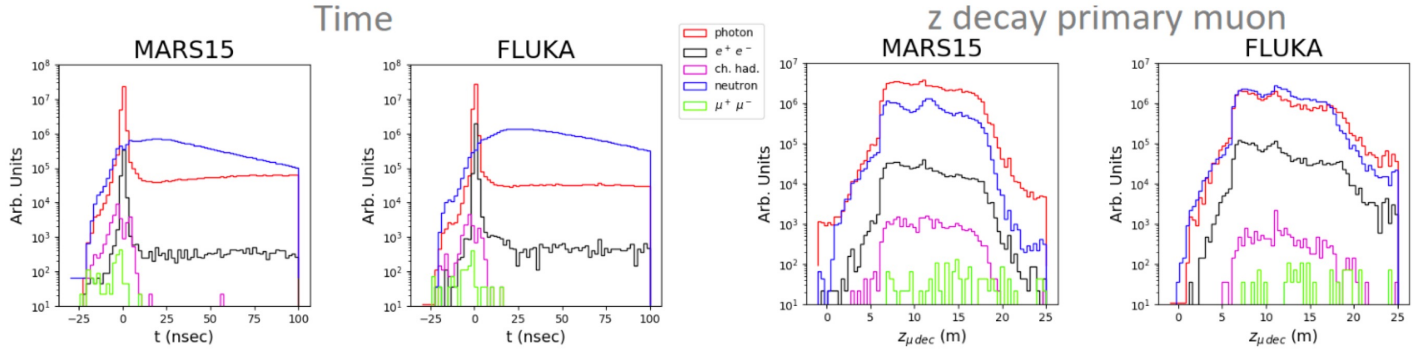


# The 1.5TeV case benchmark

## MARS-FLUKA Results Comparison




MARS
FLUKA



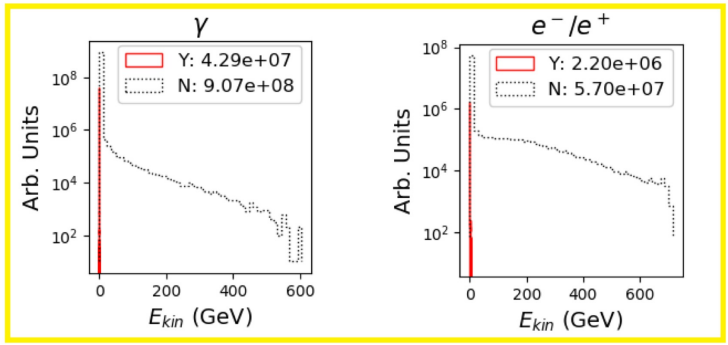

Residual discrepancies in **particles time and energy distribution**:

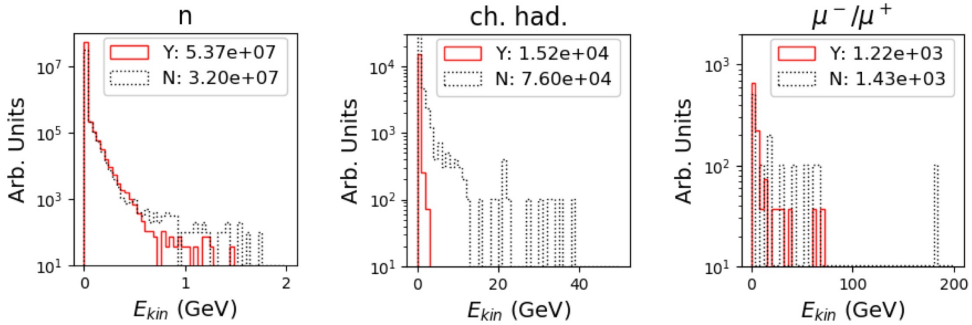
- Minor layout differences (passive elements, absorbers)
- Intrinsic differences between codes

# The 1.5TeV case benchmark

## MARS-FLUKA Results Comparison

The role of the Nozzle:



# Outline

- The software: FLUKA + LineBuilder
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# The 3 TeV case

- Simulation baseline: “ideal” muon beam ($\sigma_{x,y}=\sigma'_{x,y}=0$), solenoidal (detector) magnetic field 3.57 T in IR, no liners/masks, minimum beam pipe @1 m
- Machine design and optics files provided by MAP
- Same IR layout and nozzles design for 1.5 TeV

| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
|---|---|---|---|---|---|---|
| aperture (mm) | 90 | 110 | 130 | 150 | 150 | 150 |
| G (T/m) | 267 | 218 | -154 | -133 | 129 | -128 |
| B (T) | 0 | 0 | 2 | 2 | 2 | 2 |
| length (m) | 1.6 | 1.85 | 1.8 | 1.96 | 2.3 | 2.85 |

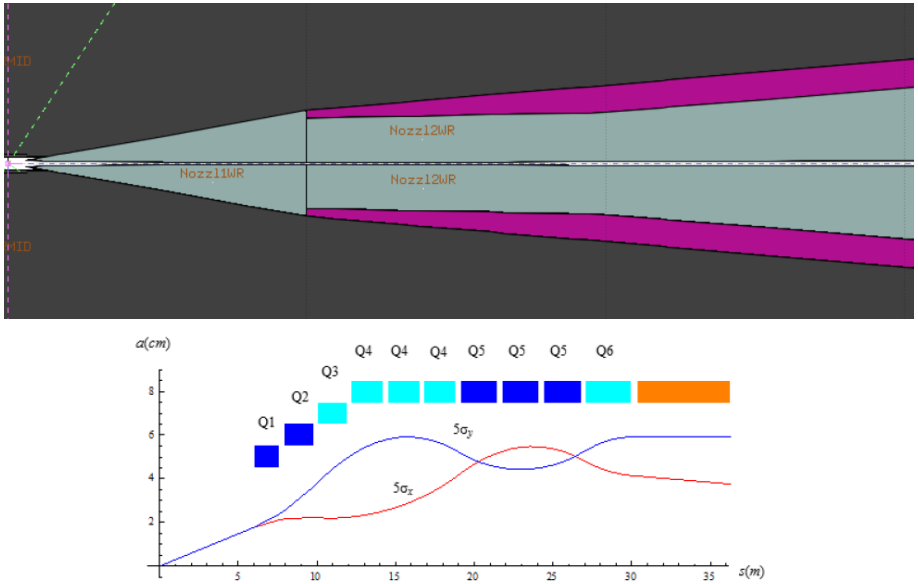


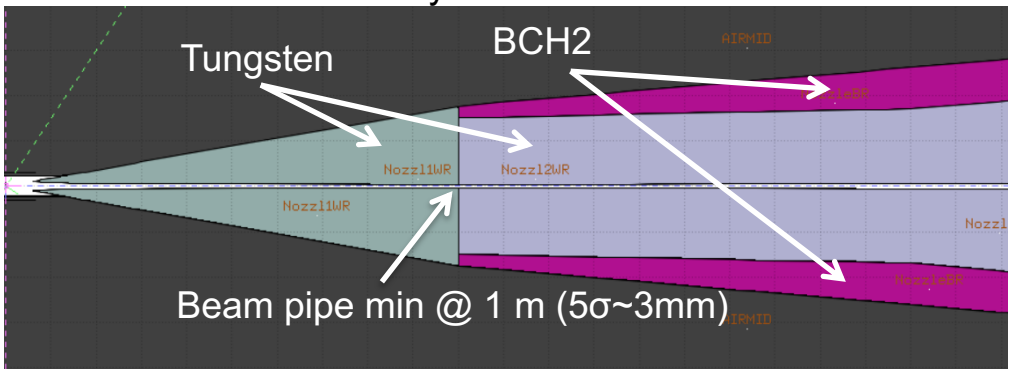

Figure 3: Quadruplet FF quadrupole apertures and 5$\sigma$ beam envelopes for $E_{\text{c.o.m.}}$= 3 TeV and $\beta^*$ = 5mm. Defocusing magnets with 2 T dipole component are shown in cyan. Beam parameters are given in the summary table of Section 5.

# 1.5 vs 3 TeV

Injected at 200m from IP
Beam $\sigma_{x,y}=\sigma'_{x,y}$ from optics

Injected at opposite IP
"Ideal beam" $\sigma_{x,y}=\sigma'_{x,y}=0$

Only one muon beam (mu- counterclockwise), $2\times10^{12}$ particles
Solenoidal (detector) magnetic field in the IR 3.57 T
BCH2 nozzles cladding, no liners/masks
Muons decay within 100m from IP

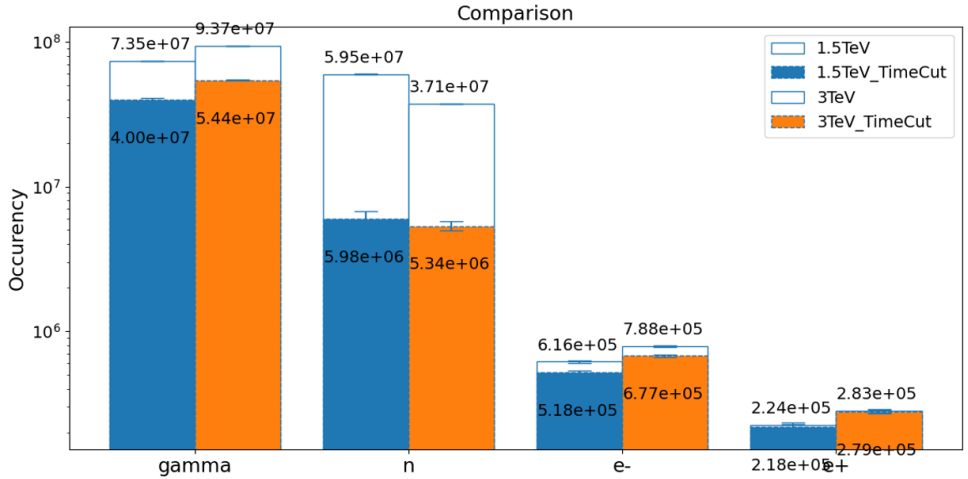


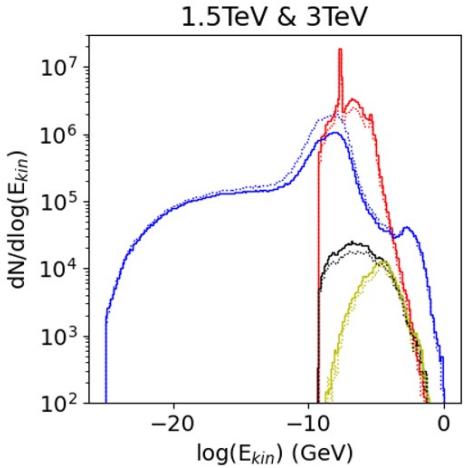

NB: when applied, time cut = [-1, 15] ns

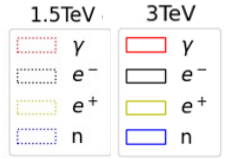
International MUON Collider Collaboration

# Particles' Number

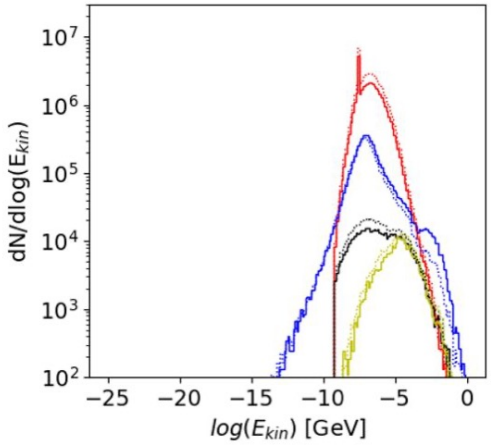
Cuts:
- 100keV for gamma, e+, e-
- $10^{-14}$GeV for N




# Energy Spectra

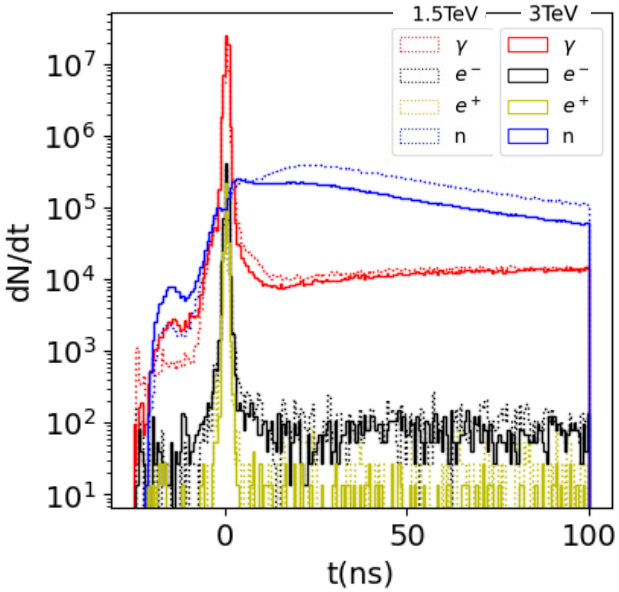



+ Time cut
[-1 ns, 15 ns]

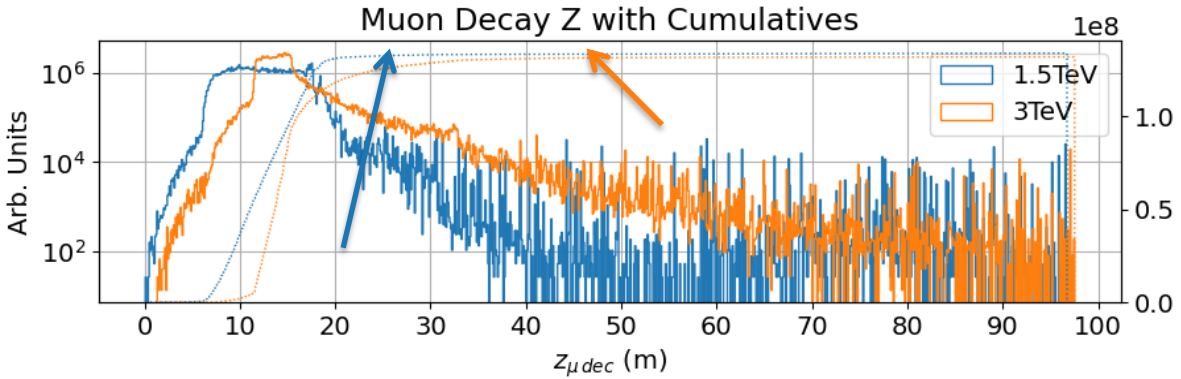
→ << slow n.
→ << photons
→ < e-
→ ~ e+

# Time and z muon decay

## Time Distribution

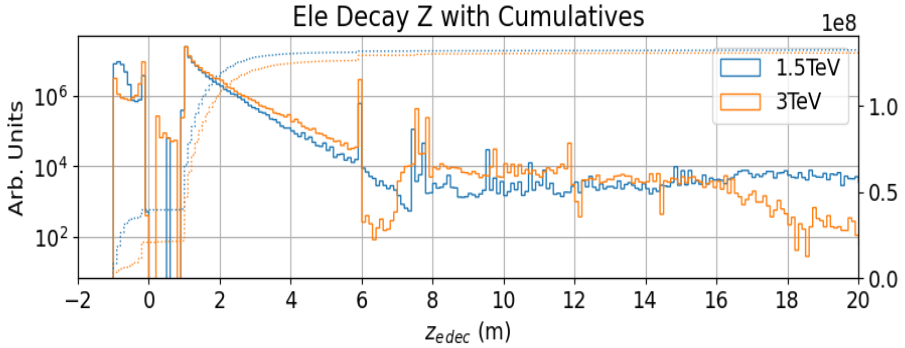



## Muon Decay Z-Position

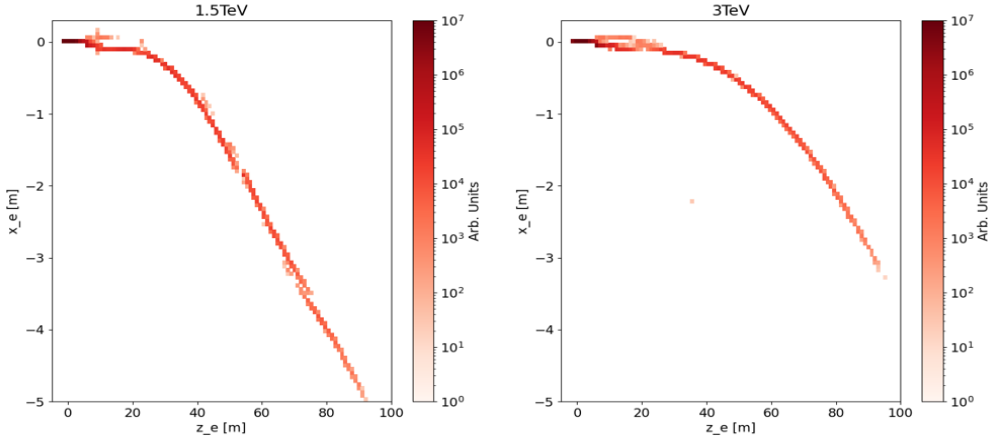



- Primary muons decay to consider for BIB:
  @1.5 TeV $z_\mu$ < 25 m
  @3 TeV $z_\mu$ < 40 m

# Z-Position of Parent e- first interaction




→ ~80% within 2m

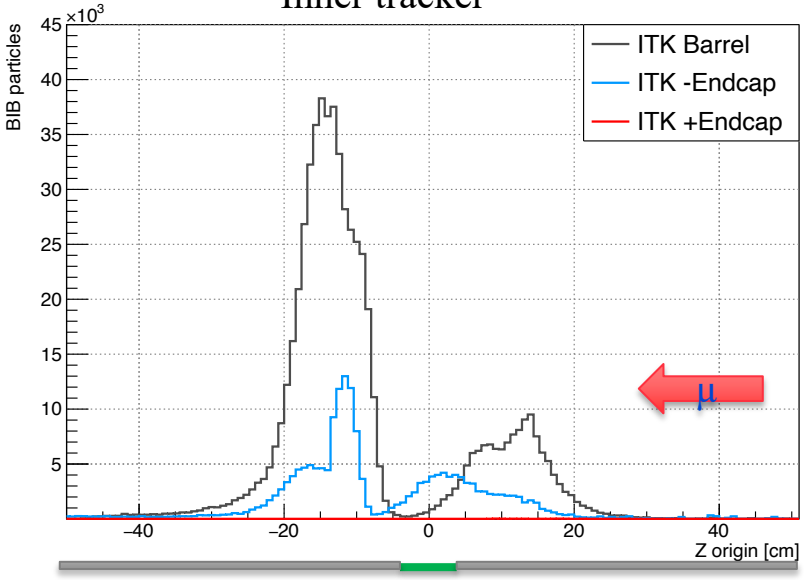


# Origin of Beam-Induced Background in the Tracker

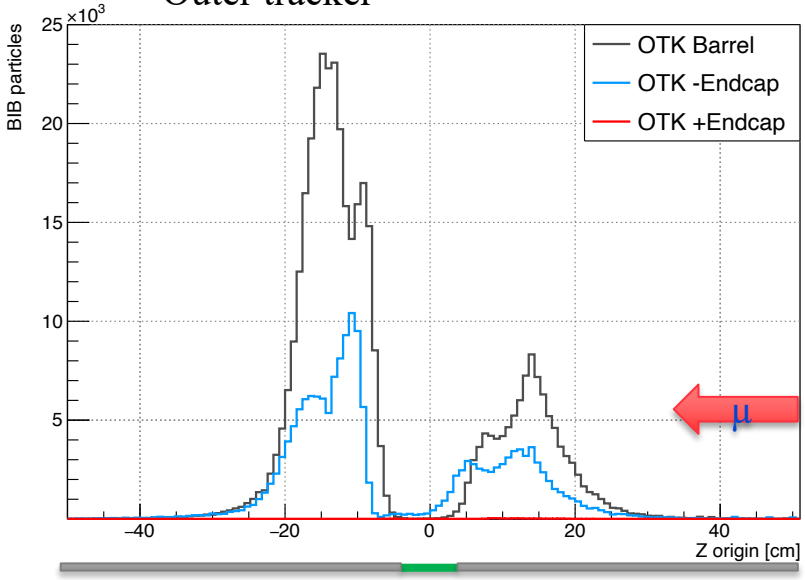
Nazar Bartosik

One beam only, E = 0.750 TeV

Inner tracker




Outer tracker

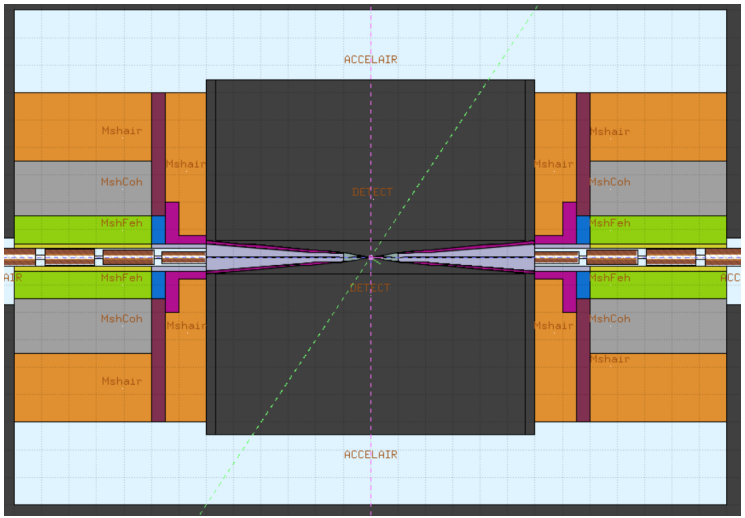


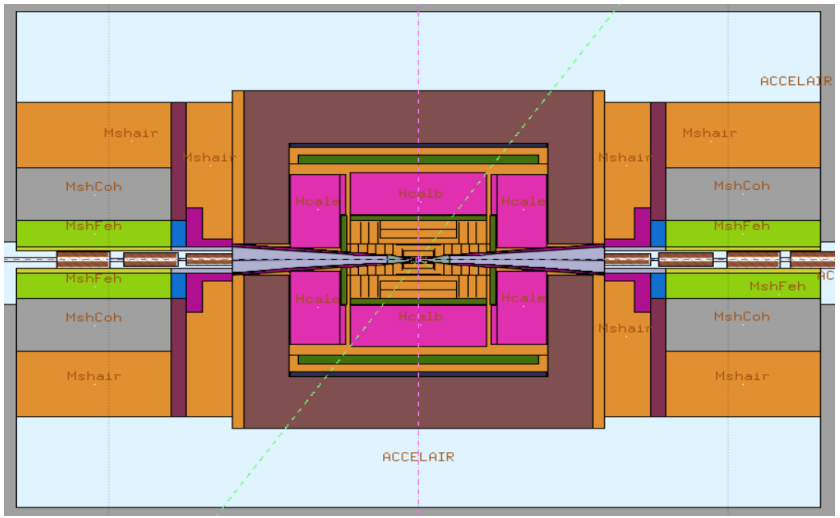

Given a hit in the tracker, central, backward (same side of beam), forward (opposite side of beam), z position of the original particle background that generated it.

Important contribution of back scattering on the nozzle on the other side

# Dose maps

To produce the doses the black body to dump BIB
is substituted by the actual detector in FLUKA

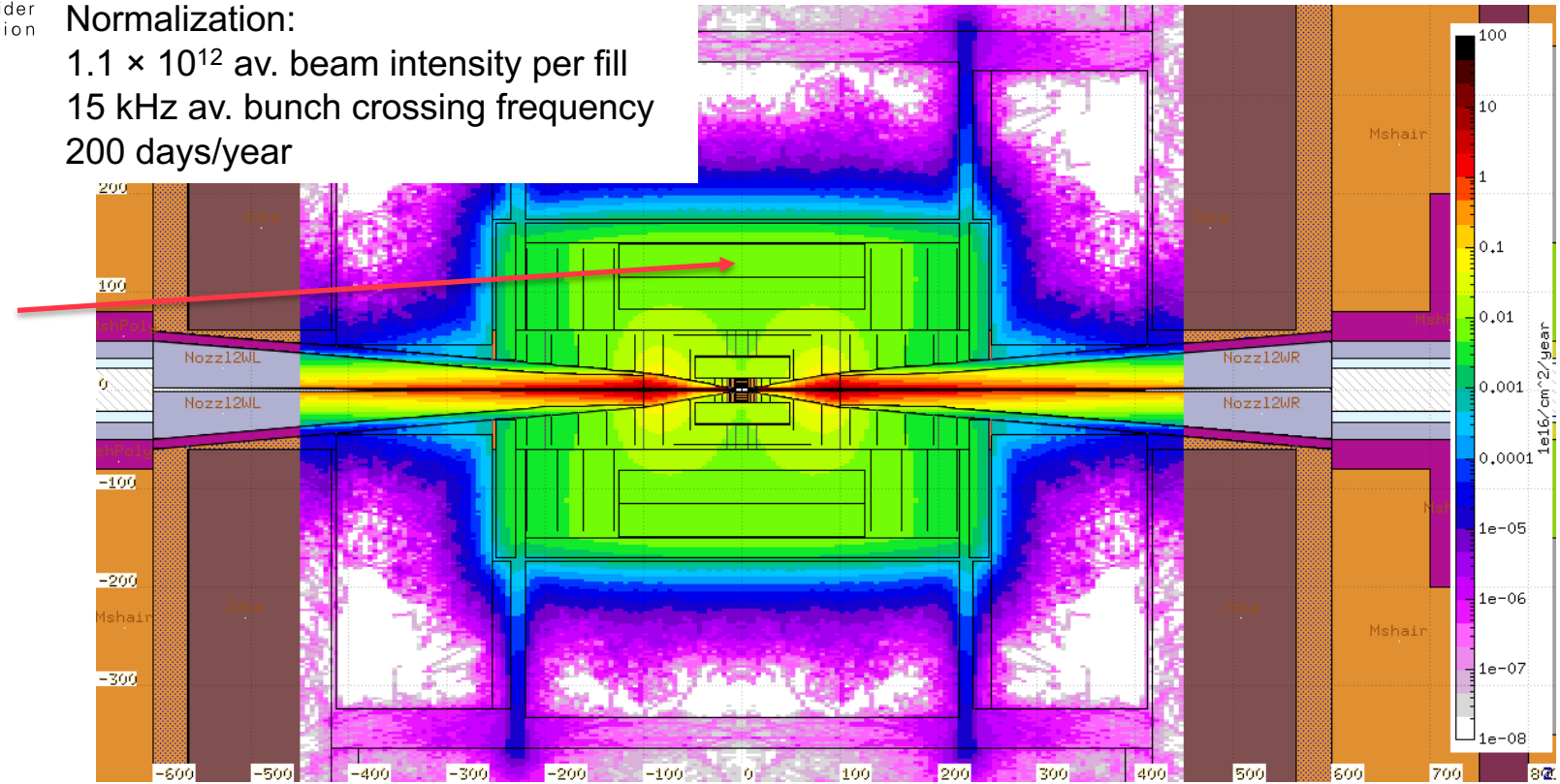


# 1.5 TeV: 1MeV neutron equivalent

Color scale: $10^{16}$ / $cm^2$ / year
Normalization:
1.1 × $10^{12}$ av. beam intensity per fill
15 kHz av. bunch crossing frequency
200 days/year

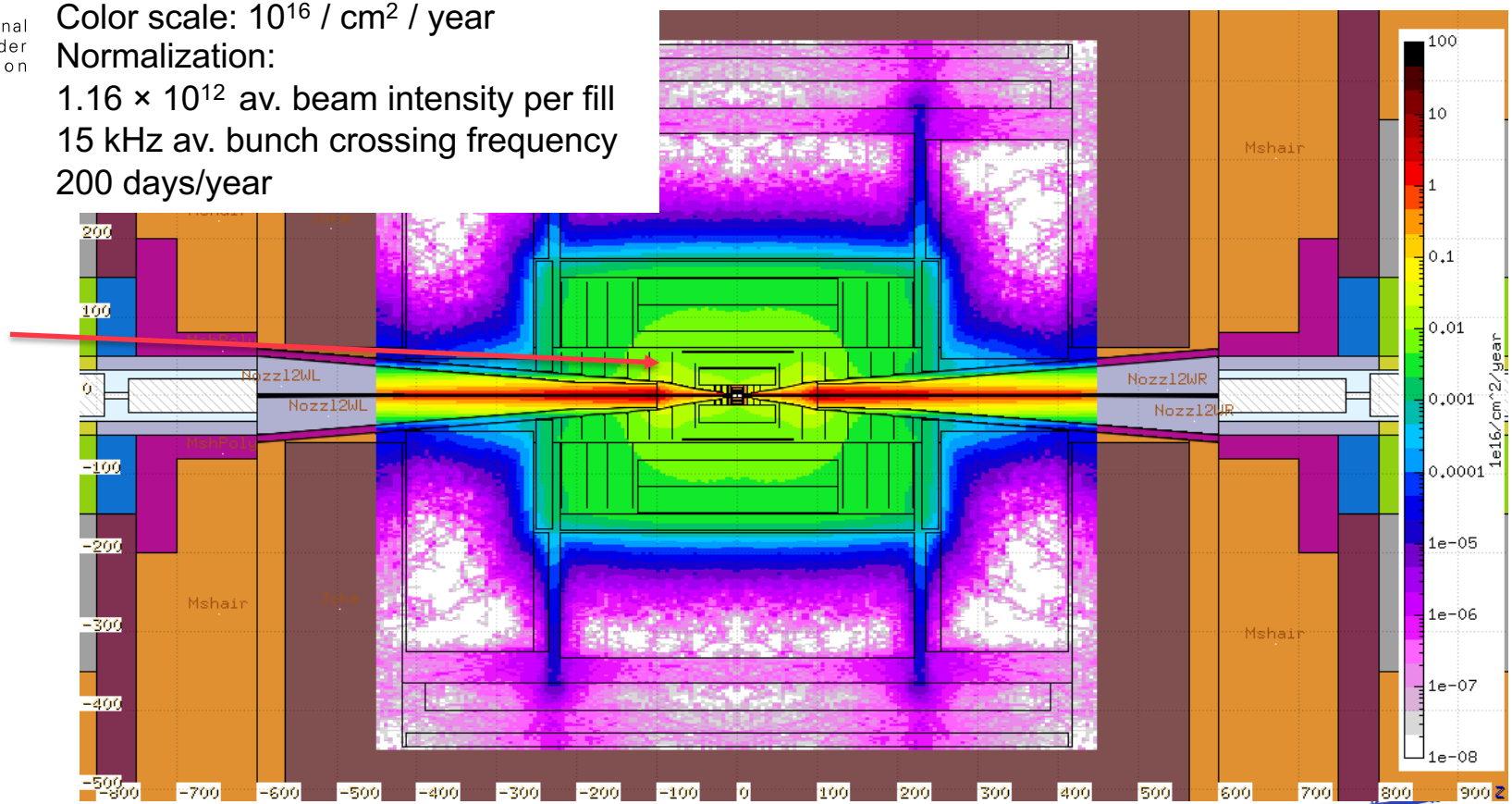
~$10^{14}$ $cm^{-2}$/y



# 3 TeV: 1MeV neutron equivalent

Color scale: $10^{16}$ / cm$^2$ / year
Normalization:
1.16 × $10^{12}$ av. beam intensity per fill
15 kHz av. bunch crossing frequency
200 days/year

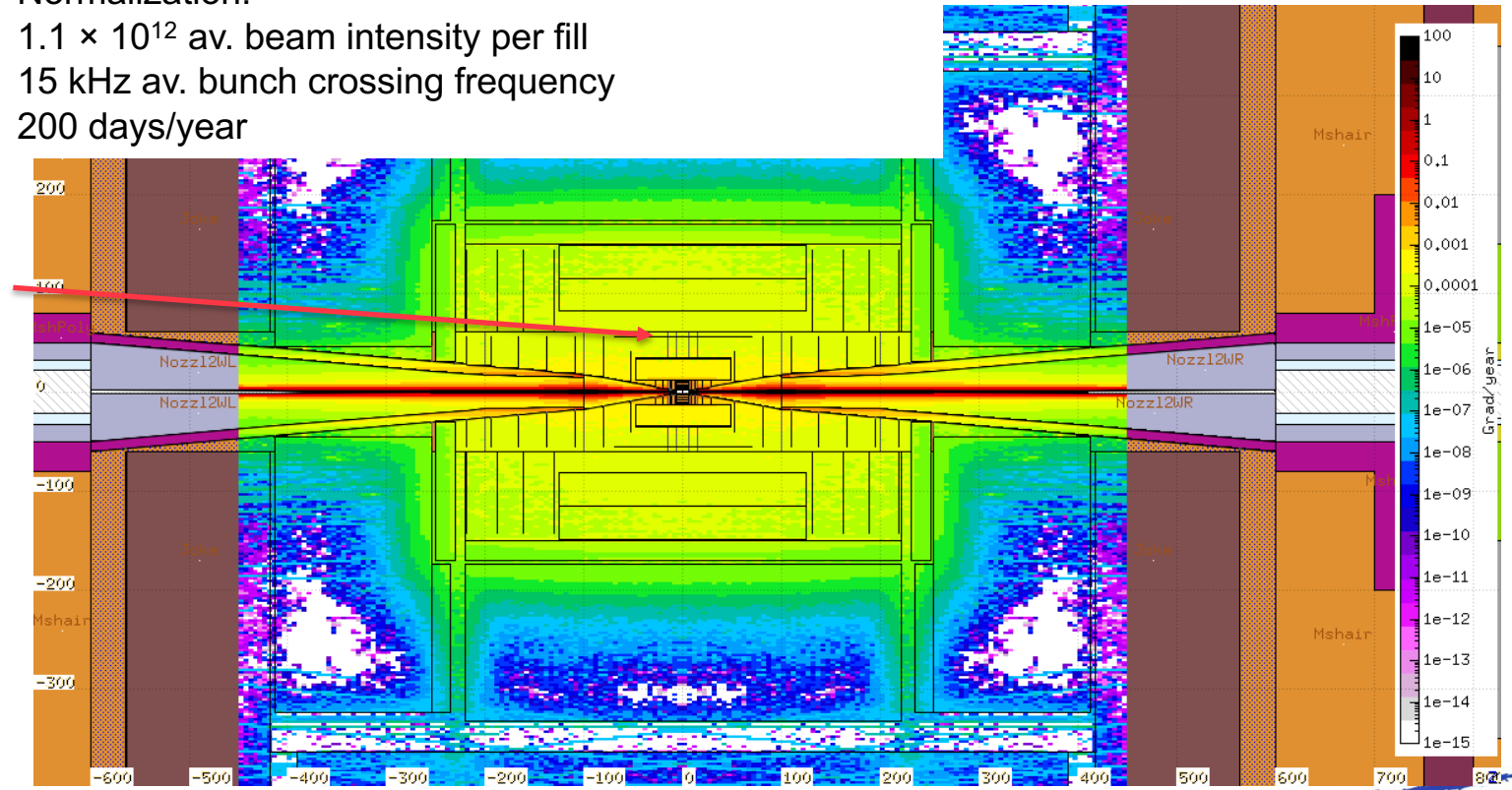
~$10^{14}$ cm$^{-2}$/y



# 1.5 TeV: Total Ionizing Dose

Color scale: Grad/year (GeV/g=1.6e-7Gy, 1Gy=100rad)
Normalization:
1.1 × $10^{12}$ av. beam intensity per fill
15 kHz av. bunch crossing frequency
200 days/year

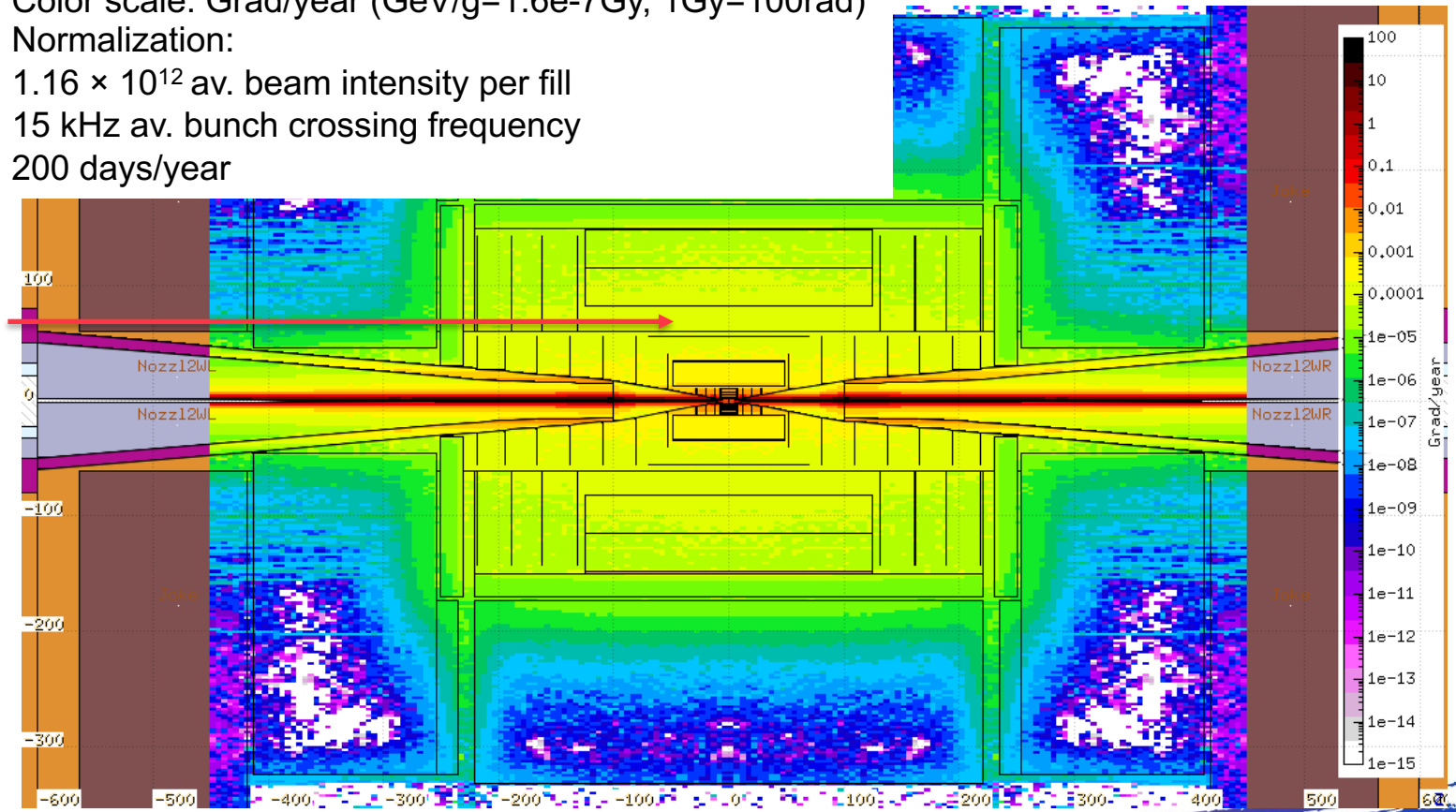
~ $10^{-3}/10^{-4}$ Grad/y



# 3 TeV: Total Ionizing Dose

Color scale: Grad/year (GeV/g=1.6e-7Gy, 1Gy=100rad)
Normalization:
1.16 × $10^{12}$ av. beam intensity per fill
15 kHz av. bunch crossing frequency
200 days/year

~ $10^{-3}/10^{-4}$ Grad/y



# Conclusions & Plans

- Software tool up and running
- Comparison 1.5-3TeV:
  - BIB slightly higher @3TeV (except N), but total numbers very similar
  - Similar effect of time cut
  - Need to consider muon decays from 25m for @1.5TeV and 40m @3TeV
  - Dose maps are similar for the 2 energies:
    - 1MeV neutron-eq ~$10^{14\text{-}15}$ $cm^{-2}$/year on the tracking system and ~$10^{14}$ $cm^{-2}$/year on ECAL
    - TID is ~$10^{-3}$ Grad/year on the tracking system and ~$10^{-4}$ Grad/year on ECAL

**Next Steps:**
- Run 3TeV simulation with realistic beam
- Insertion of liners and masks
- Try different dimensions of nozzles
- Detailed study of dose maps
- Software release

# BIB Studies @1.5-3 TeV with FLUKA

International MUON Collider Collaboration

CERN

*Thank you*
*for attention*

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MUON Collider
Collaboration