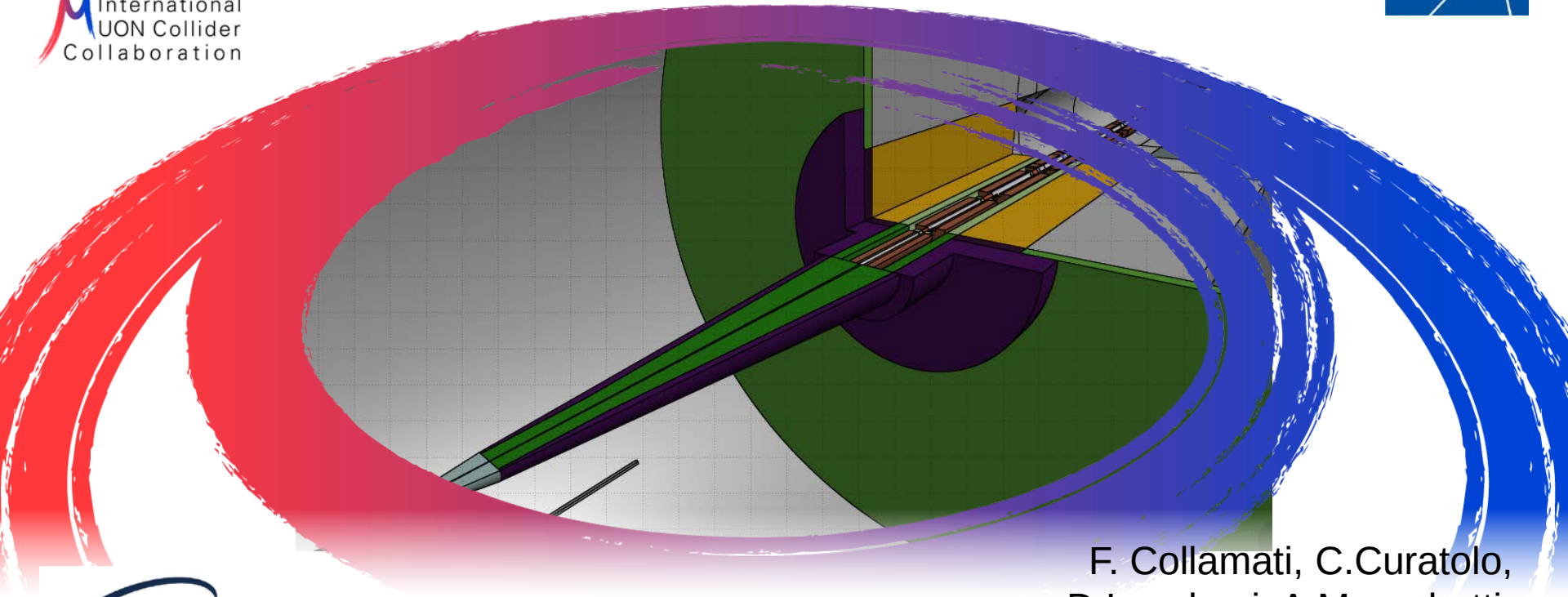
Beam Induced Background



F. Collamati, C.Curatolo,
D.Lucchesi, A.Mereghetti,
N.Mokhov, M.Palmer, P.Sala

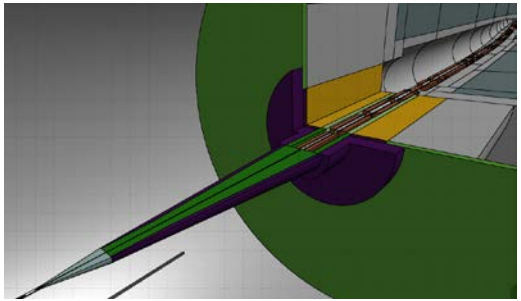
BIB simulations

- Full simulation of muon trajectory, decay, and transport of decay products
  - Including hadron production by leptons and photons, and muon pair production by photons
- Machine layout directly from optics files through the LineBuilder interface ➔ flexibility to adapt to new optics
- First guess for shielding elements (nozzles) from MAP design at 1.5 TeV
- Optimization foreseen at higher energies
- Provide list of particles and their properties at the interface betw machine and detector hall, to be transported in the detector
- Provide radiation maps in the detector

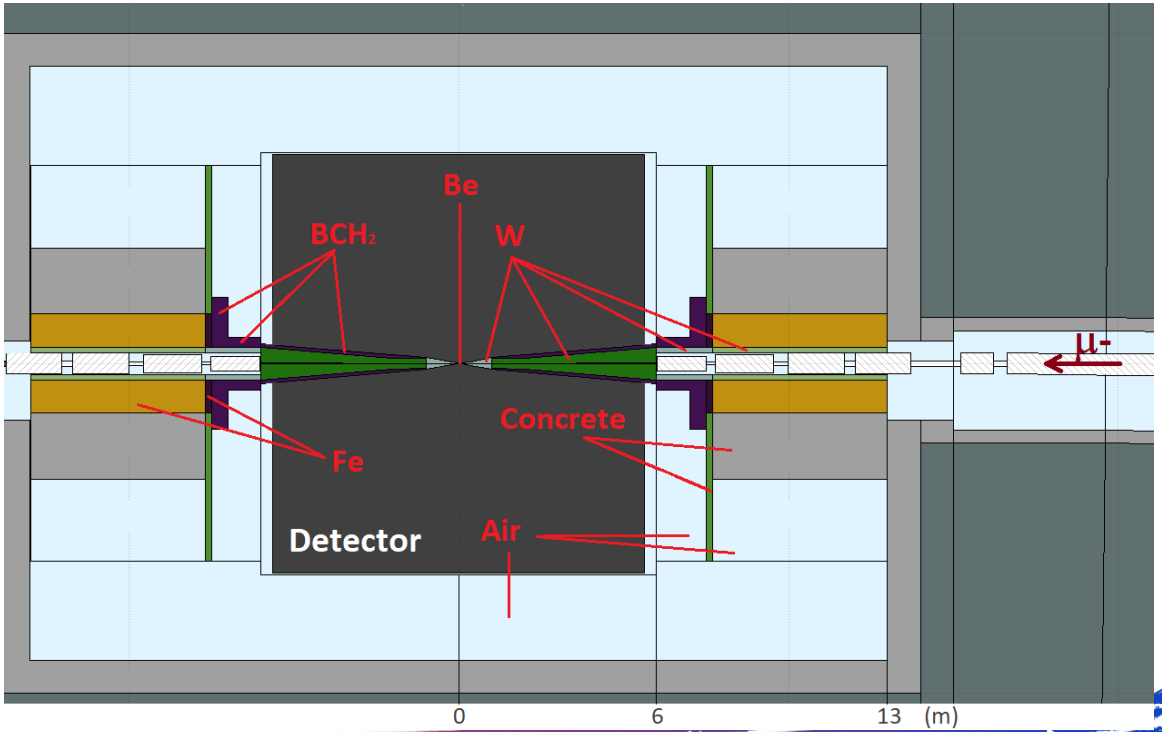
1.5 TeV

N.V. Mokhov and S.I. Striganov, Physics Procedia 37 (2012),2015.

- Starting point and crosscheck vs. MAP reference

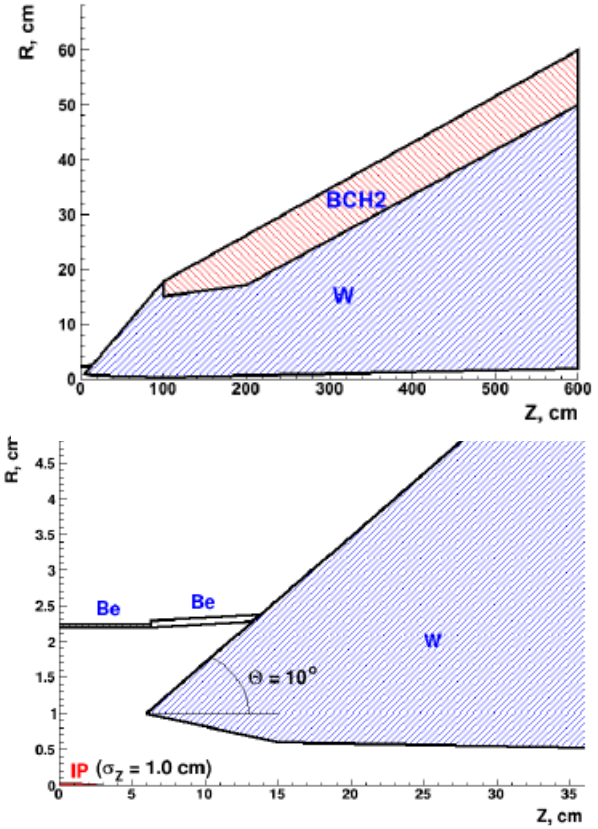


For BIB: detector replaced by perfectly absorbing material (BlackBody)



More details

- Only one muon beam
- Injected at 200m from IP
- Beam σ and divergence from optics
- Decay length biased (i.e. artificially reduced) to increase statistics
- Solenoidal (detector) magnetic field in the beam pipe

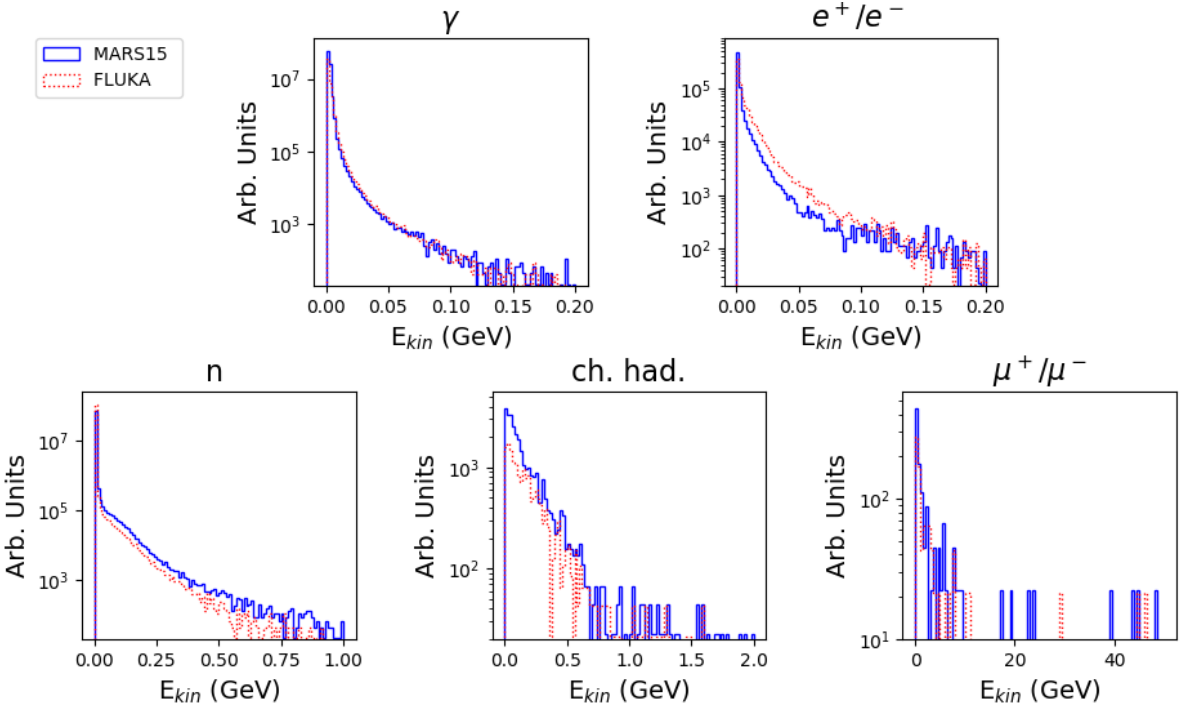


1.5 TeV : particle spectra

arXiv:2105.09116, under revision by JINST

Normalized to 1 bunch,
2×10^{12} muons/bunch

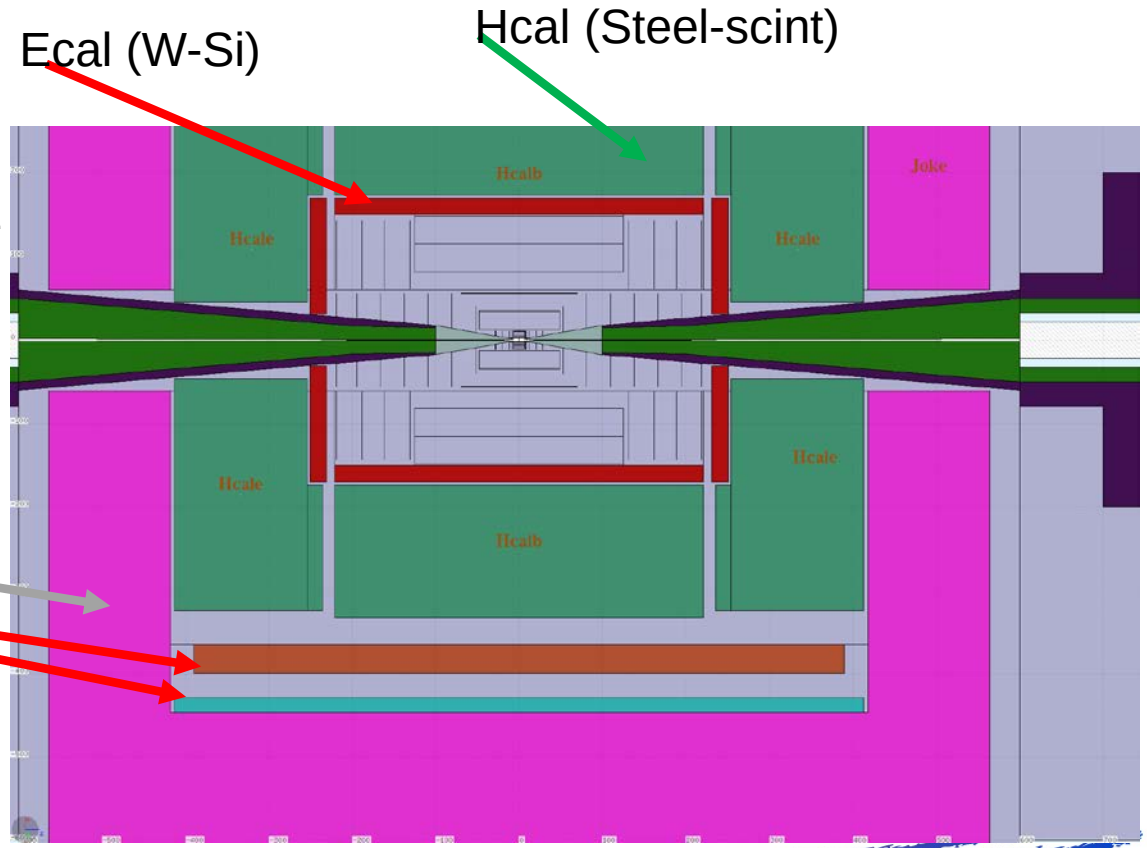
Particle (E_{th})	MARS15	FLUKA
Photon (100 keV)	$8.6\,10^7$	$5\,10^7$
Neutron (1 meV)	$7.6\,10^7$	$1.1\,10^8$
Electron/pos (100 keV)	$7.5\,10^5$	$8.5\,10^5$
Ch. Hadron (100 keV)	$3.1\,10^4$	$1.7\,10^4$
Muon (100 keV)	$1.5\,10^3$	$1\,10^3$



Crosscheck successful
(Same agreement for time distributions)

Radiation levels: geometry

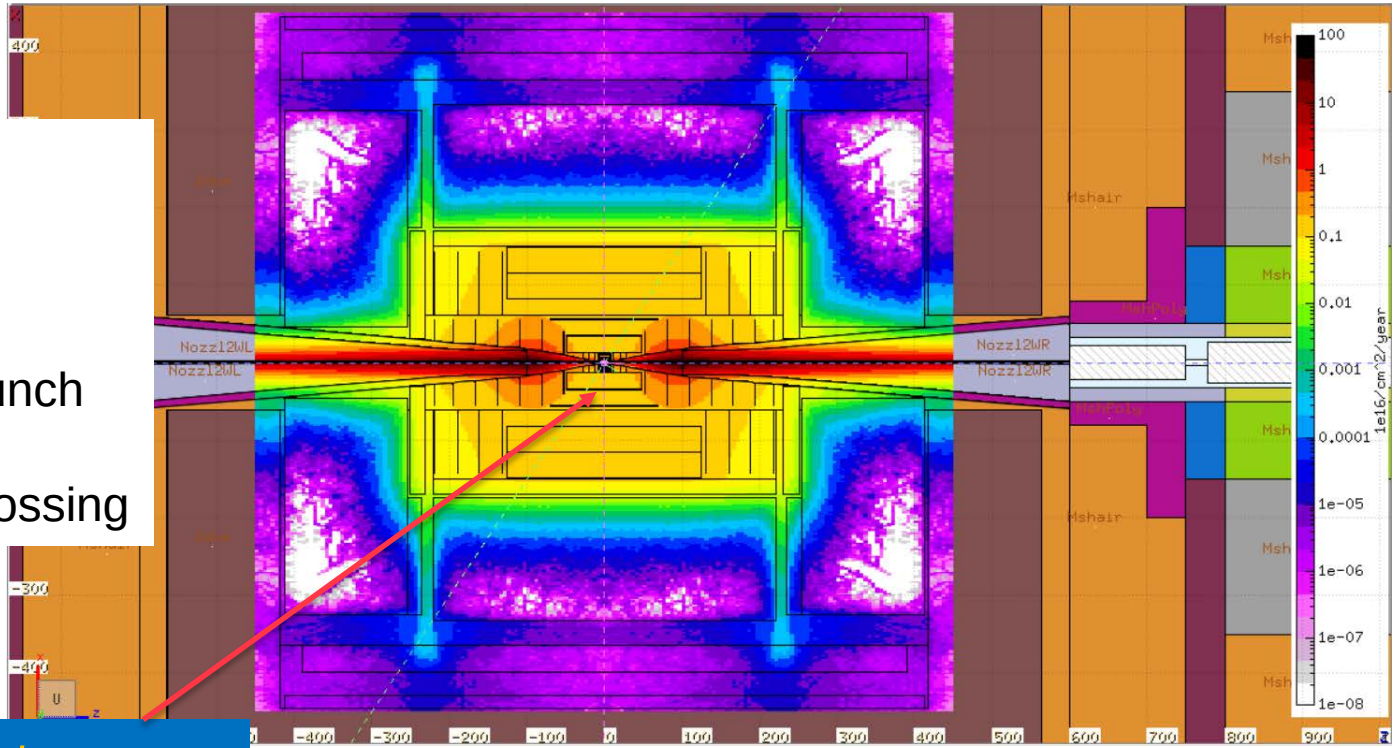
- Calorimeters:
  - no detailed layering, average composition and density
  - Shape simplified from polyhedron to cylinder
- Magnet + Yoke:
  - Average composition and density
  - Uniform B field (3.57 T)



1.5 TeV: 1MeV neutron equivalent

Color scale:
10^{16} / cm^2 / year

Normalization:
2 × 10^{12} muons/bunch
200 days/year
100 kHz bunch crossing

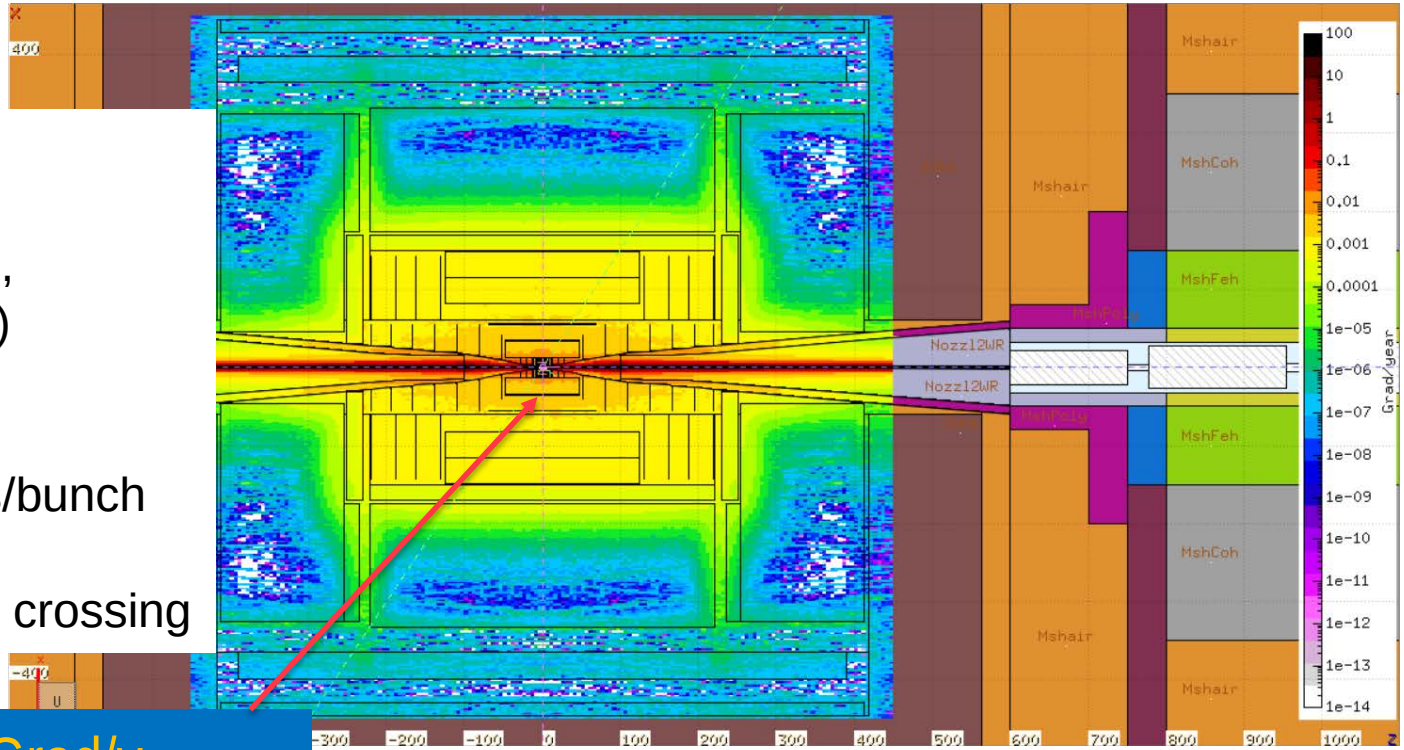


≈ few 10^{15} /cm^2 /y

1.5 TeV: Total Ionizing Dose

Color scale:
Grad /year --
(1 Gy= 100 rad,
1Grad=10MGy)

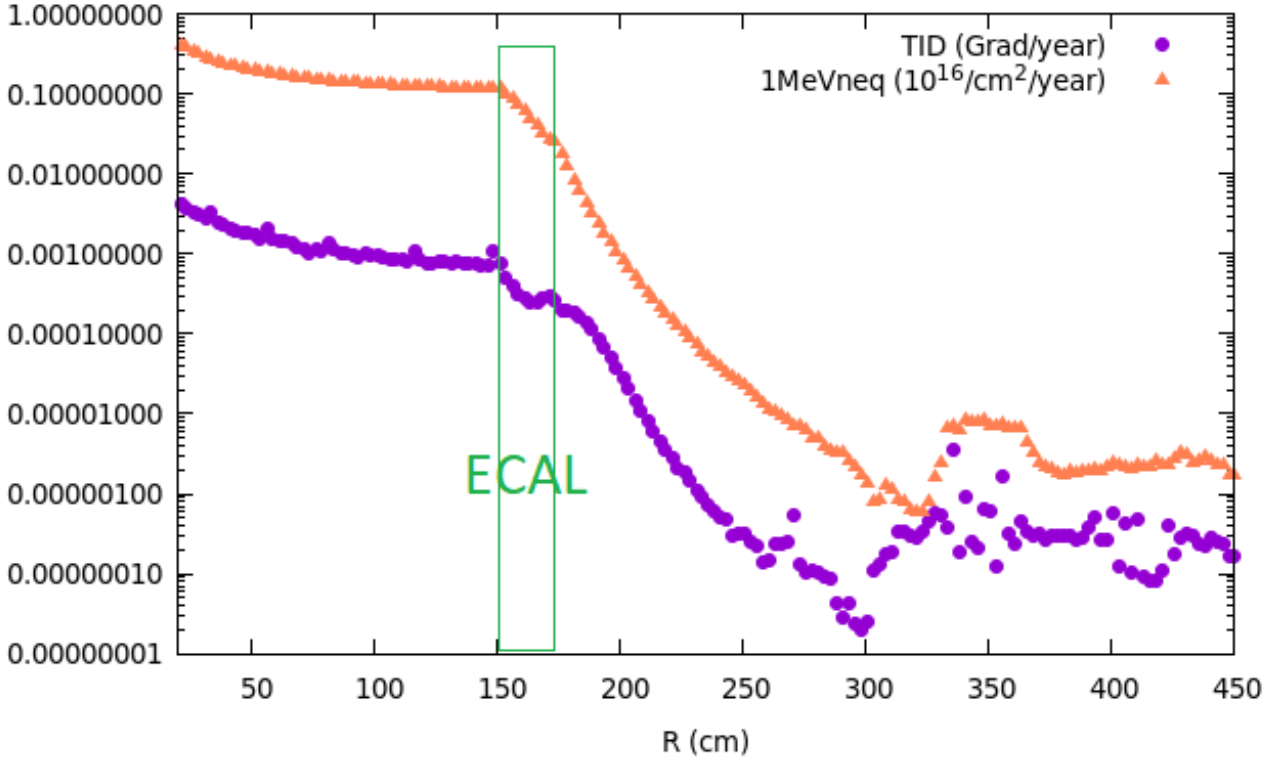
Normalization:
2 × 10^{12} muons/bunch
200 days/year
100 kHz bunch crossing



≈ 10^{-3} -10^{-2} Grad/y

1.5 TeV: TID and 1MeVn Radial distributions

Longitudinal coordinate
Within +- 120cm
From IP



3TeV

- 3 TeV full ring geometry is ready and running
- Lattice and optics from Y. Alexahin et al 2018 JINST 13 P11002 (thanks to the MAP collaboration and to M. Biagini)

	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

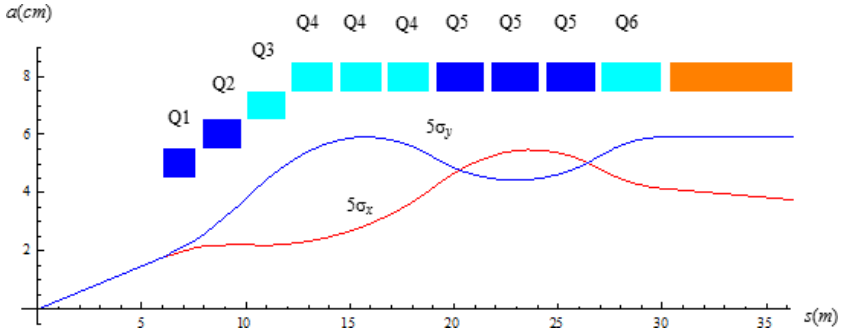


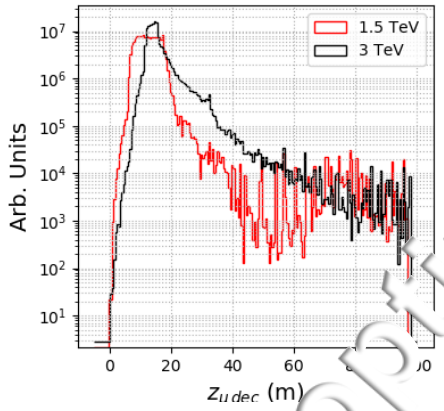
Figure 3. Quadruplet FF quadrupole apertures and 5σ beam envelopes for $E_{\text{c.o.m.}} = 3$ TeV and $\beta^* = 5$ mm. Defocusing magnets with 2 T dipole component are shown in cyan. Beam parameters are given in the summary table of section 5.

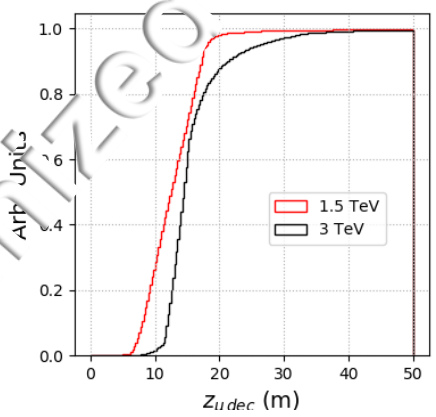
- Initial implementation of nozzles: same as 1.5 TeV case, to be optimized
- Very preliminary results:

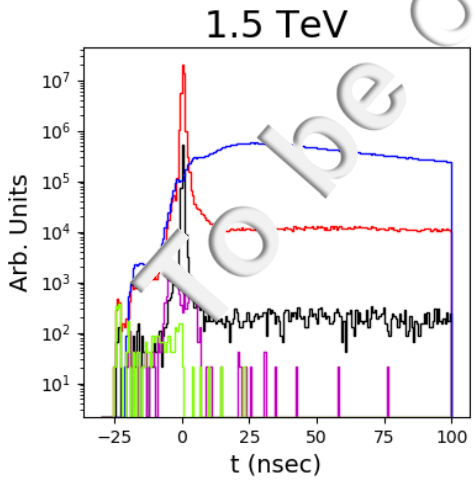
3TeV from where and when (preliminary)

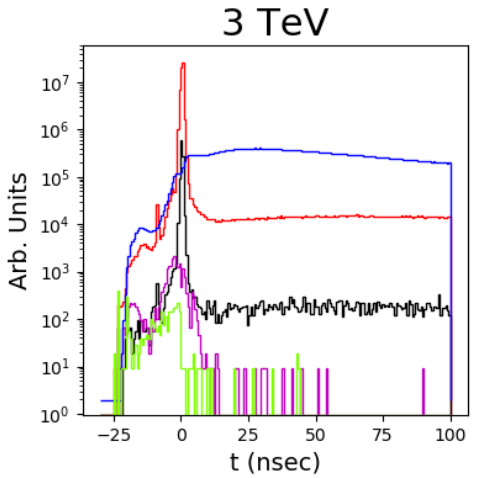
Position of muon decay for all BIB particles excluding secondary muons, and its cumulative distribution:
At 3 TeV, decays as far as ~40m from IP still contribute, vs ~20m at 1.5TeV
Distributions for muons available soon

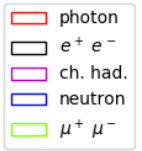
Time distributions of BIB particles: similar to 1.5 TeV





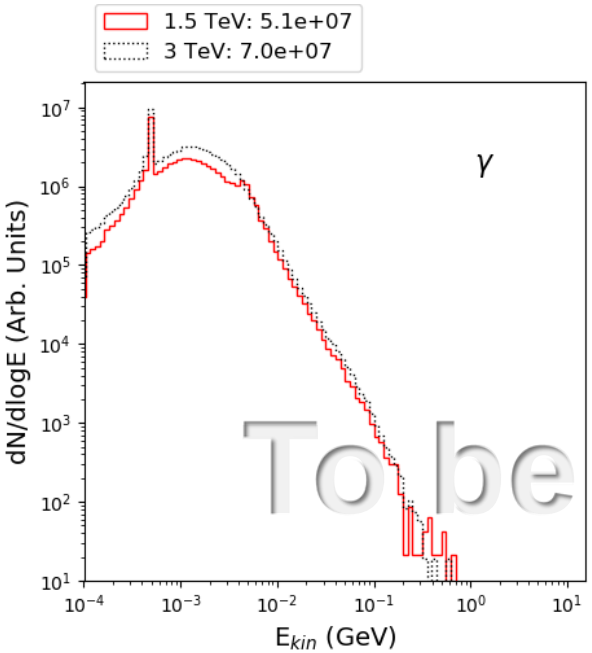


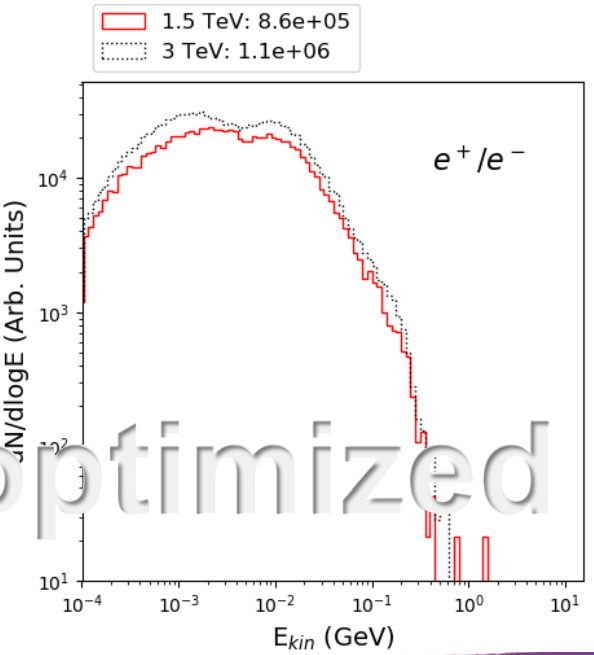


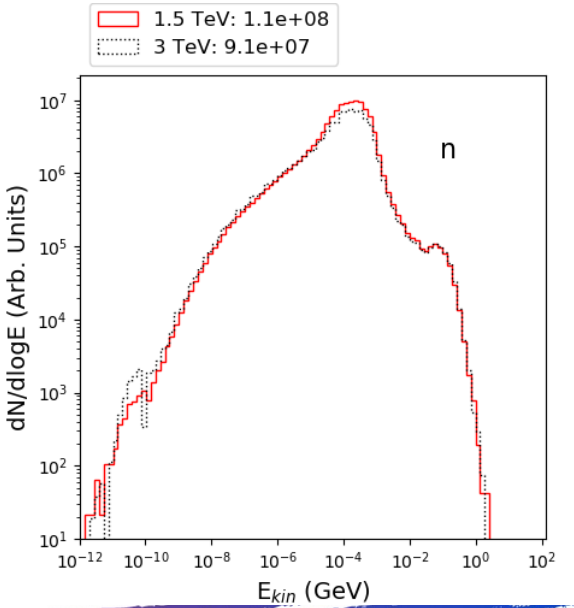


3 TeV particle spectra (preliminary)

BIB per bunch (2 10^{12} μ). Plots in dN/d(logE).
Wrt 1.5 TeV: 20% more electrons, 40% more photons (low E) , less neutrons: not bad as a starting point

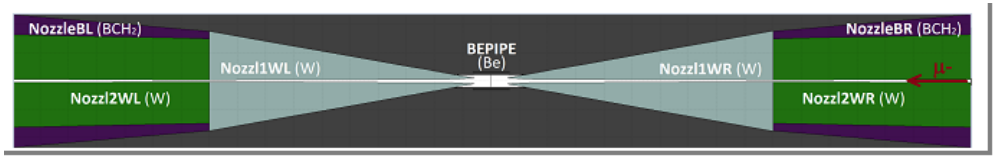




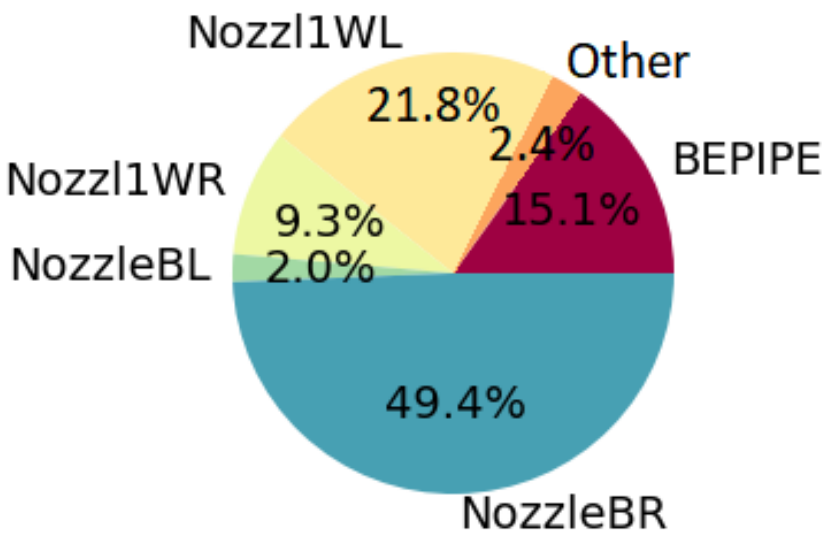


To be optimized

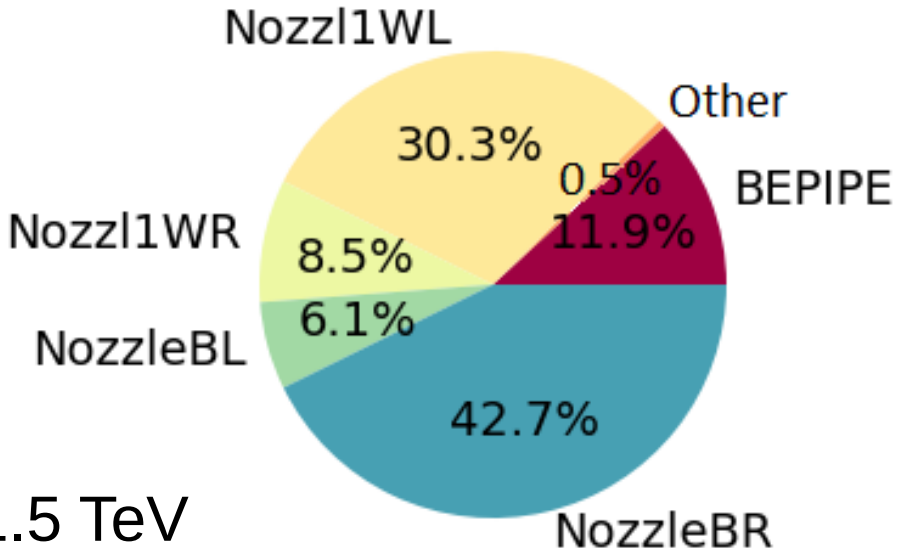
Exit regions



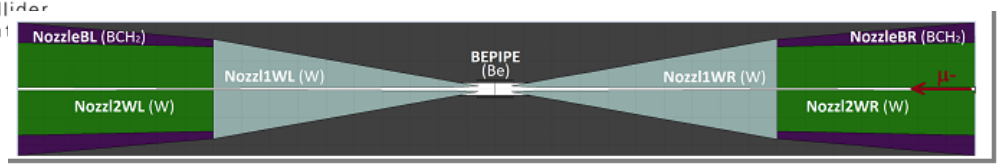
3 TeV



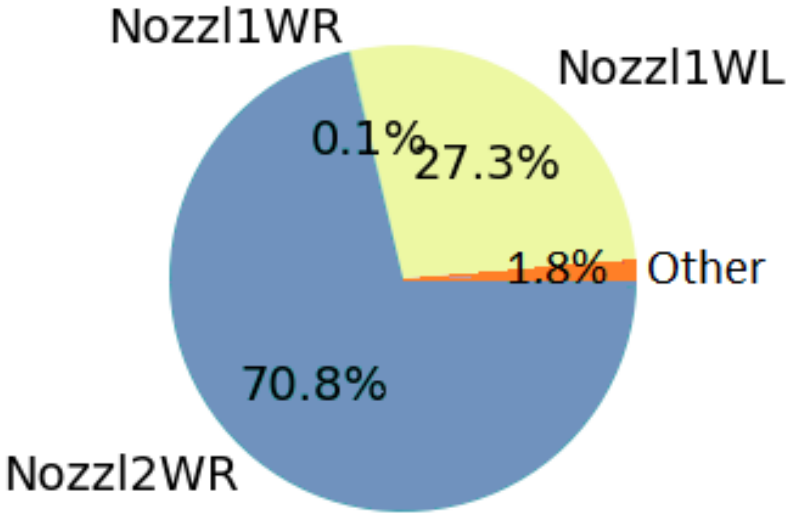
1.5 TeV



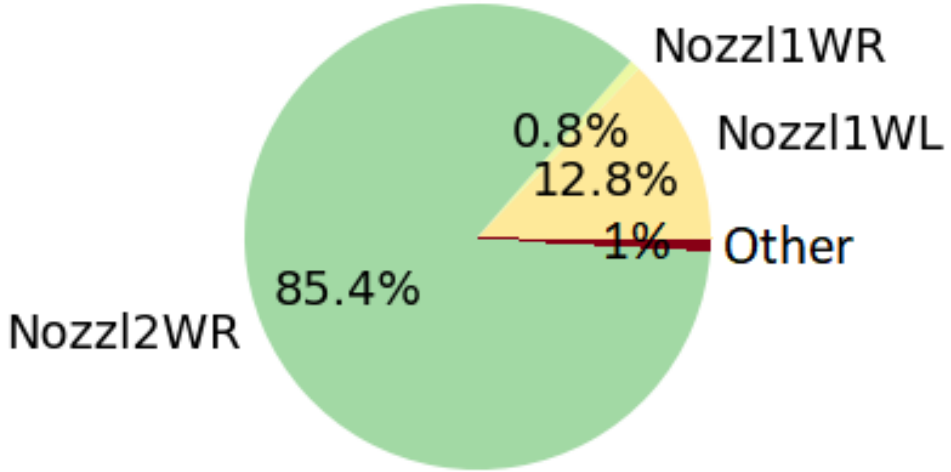
Region of 1st interaction



3 TeV

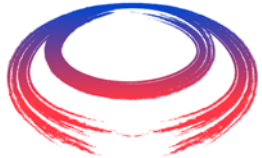


1.5 TeV



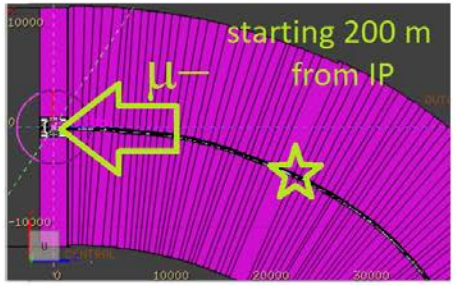
Summary and perspectives

- A flexible full simulation chain has been implemented and validated against previous results at 1.5 TeV
- It can provide not only BIB but also radiation maps
- Preliminary implementation and results for the 3 TeV option
- To be optimized!!! Through iterative process involving detector and machine experts

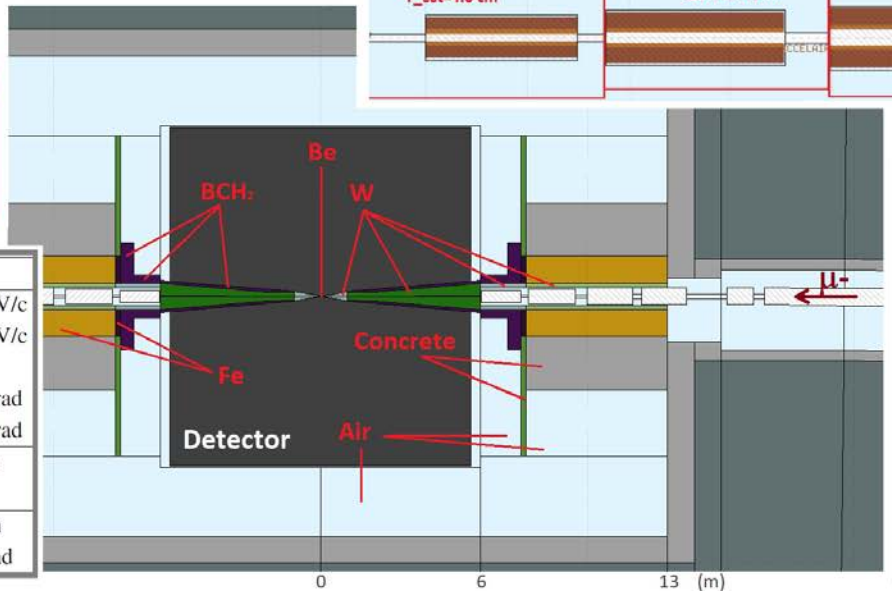


Thank you
for your attention

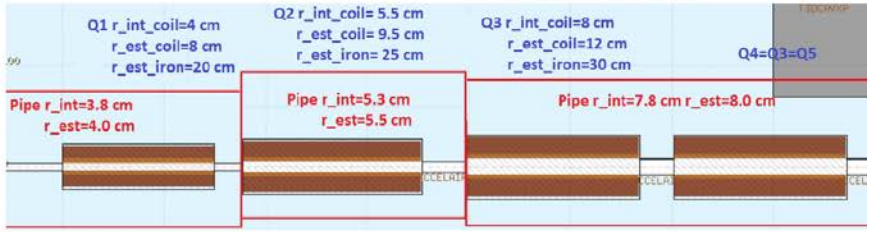
Simulation tool: **LineBuilder + FLUKA**
Data analysis: **Python**



IR

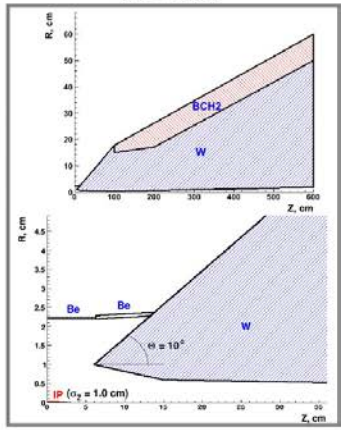


IR Quadrupoles



Parameter	Value	
Beam momentum	750	GeV/c
Beam momentum spread	0	GeV/c
Bunch intensity	2×10^{12}	
$\epsilon^n_{x,y}$ normalised RMS emittance	$25\ \pi\ 10^{-6}$	m rad
$\epsilon^g_{x,y}$ geometric RMS emittance	$3.5\ \pi\ 10^{-9}$	m rad
$\beta_{x,y}$	1	cm
$\alpha_{x,y}$	0	
$\sigma_{x,y}$ RMS beam size	5.96	μm
$\sigma_{x',y'}$ RMS beam divergence	596	μrad

Nozzle



bd "Muon collider interaction region design" Y. I. Alexahin (2011)
bd "A study of muon collider background rejection criteria in silicon vertex and tracker detectors" V. Di Benedetto (2018)

With/without nozzle