



BEAM DELIVERY SYSTEM MUON BACKGROUND SIMULATION

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CLIC BEAM DELIVERY SYSTEM

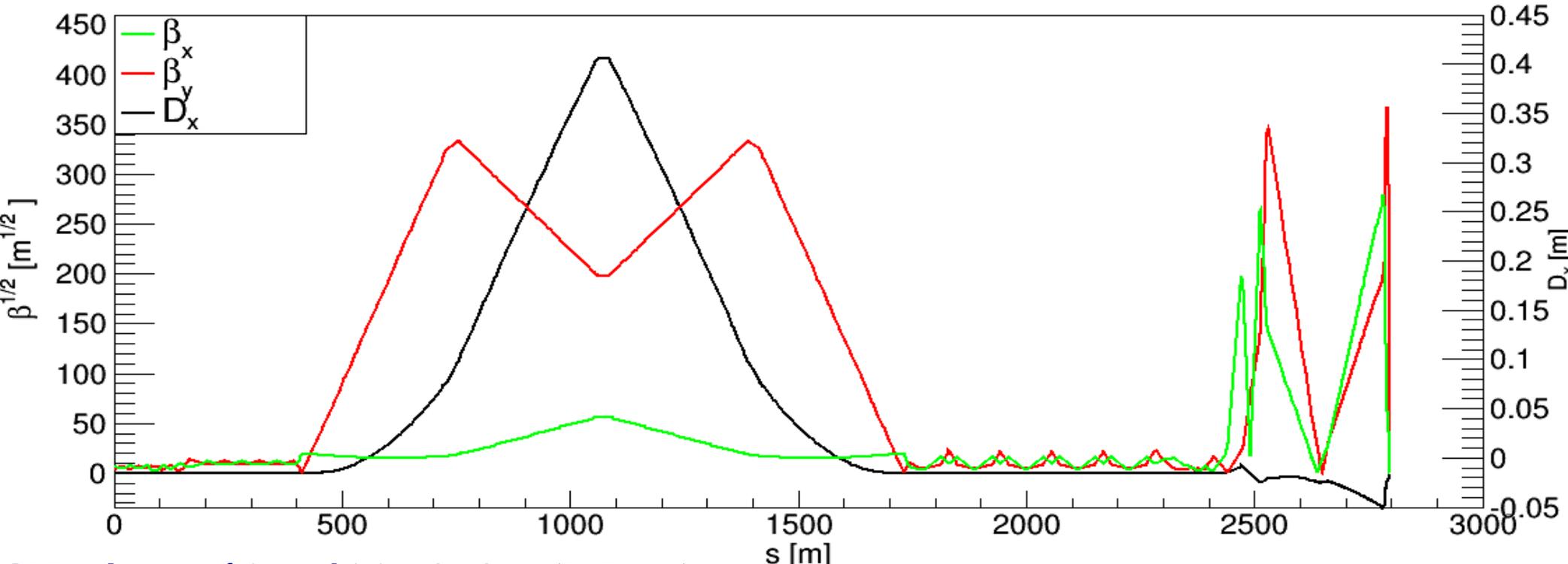
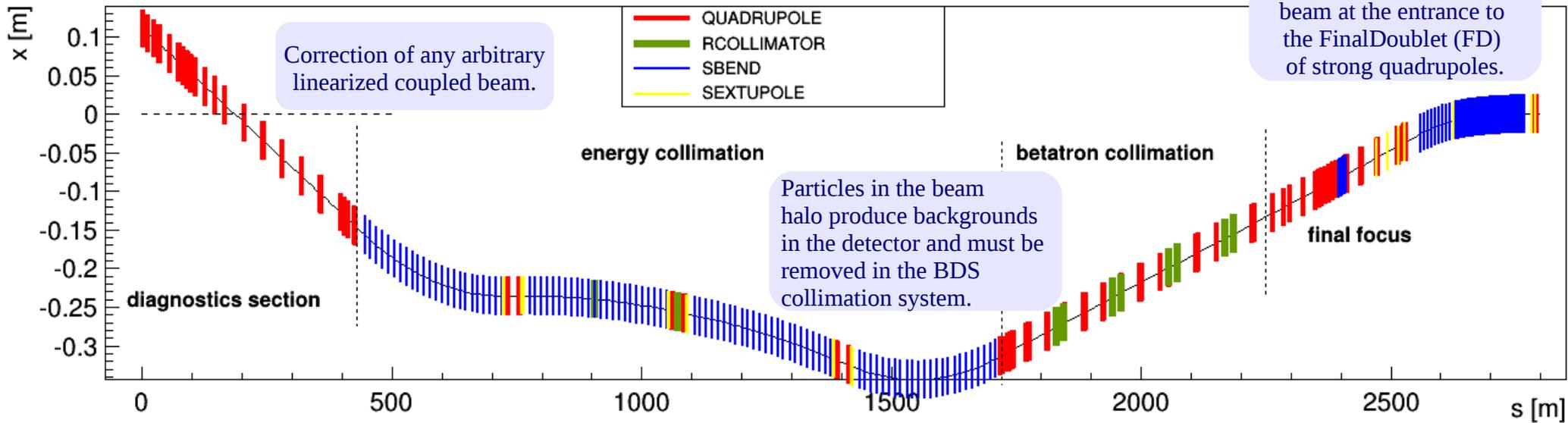
BEAM TRACKING

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TUNNEL FILLER / MASSIVE SHIELDING

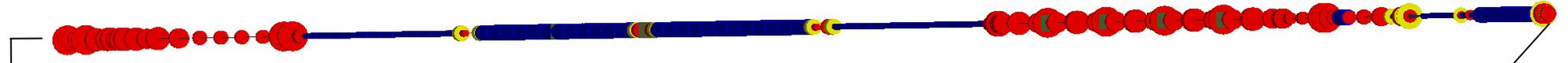
BEAM DELIVERY SYSTEM



BEAM TRACKING with BDSIM

BEAM

IP



BDSIM - Accelerator Beamline simulation tool : Geant4 base particle transport in accelerator beam line.
ROOT interface analysis

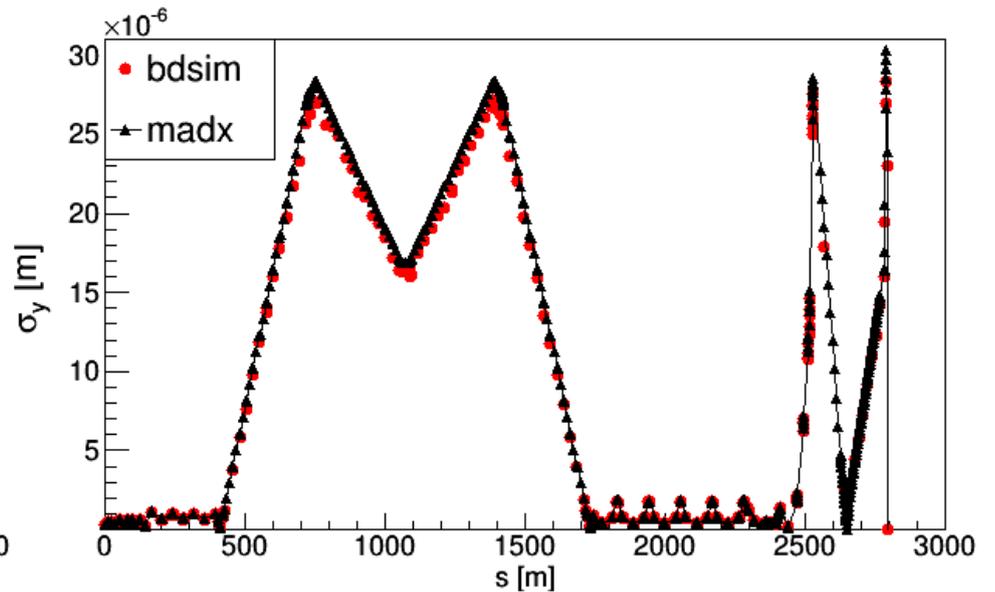
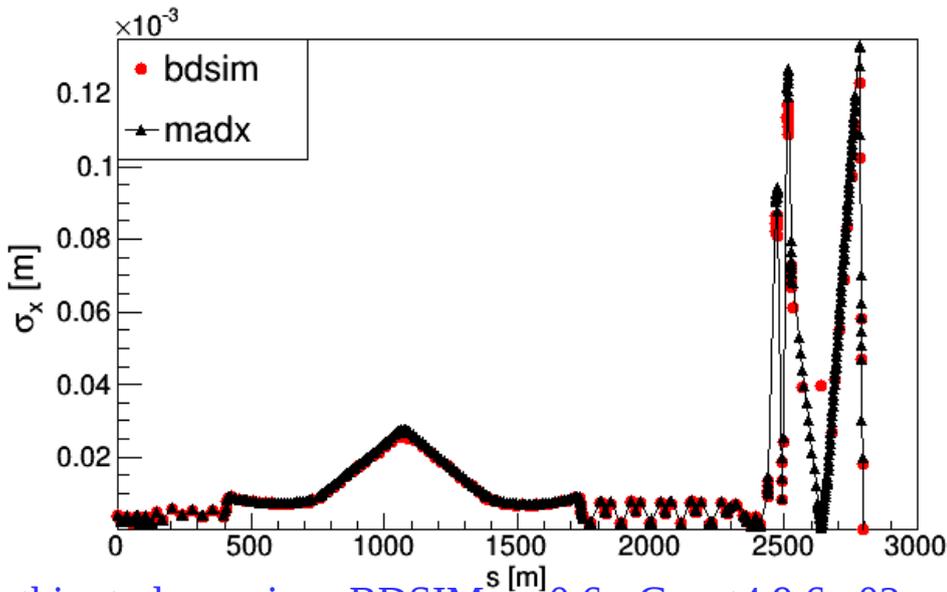
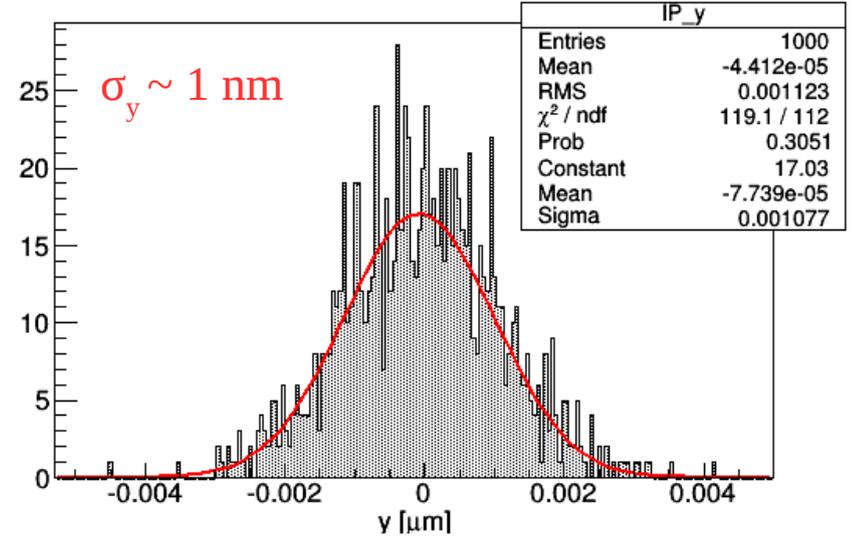
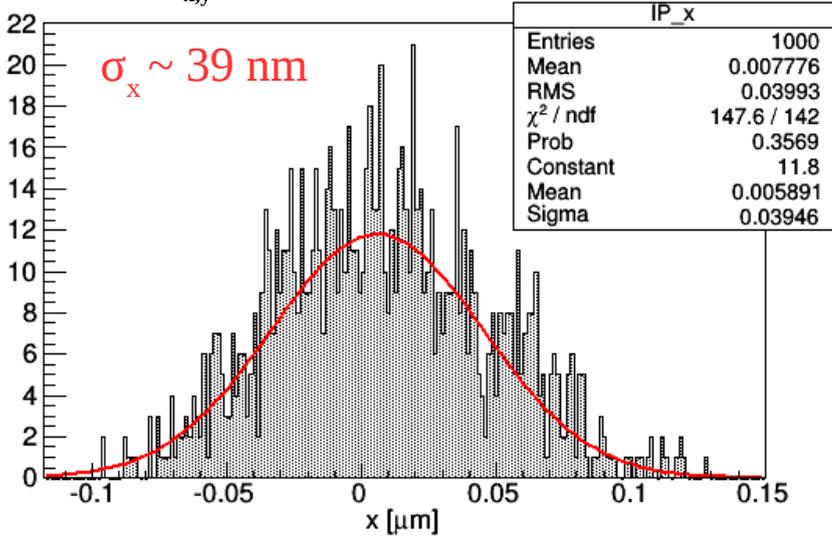
@ the starting point

$\beta_x = 66.14 \text{ m}, \beta_y = 17.92 \text{ m}, \alpha_{x,y} = 0.0$

$\epsilon_x = 2.25 \times 10^{-13}$

$\epsilon_y = 6.8 \times 10^{-15}$

Sync. Rad. → Off



For this study versions BDSIM - v0.6 - Geant4.9.6.p02

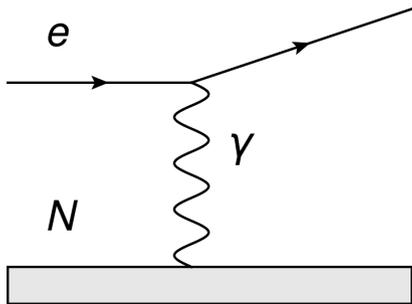
HALO PARTICLES

Core particles can significantly increase in amplitude and become halo particles by following processes ^{1,2} :

- Beam-Gas Elastic Scattering
- Beam-Gas Inelastic Scattering
- Scattering off Thermal Photons
- Intrabeam Scattering
- Synchrotron Radiation

- Known dominate processes
 - Scattering from residual gas nucleus
 - HTGEN generates halo particles.
- (<http://hbu.web.cern.ch/hbu/HTGEN.html>)

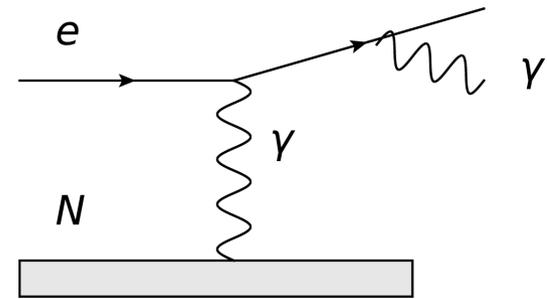
Elastic Scattering (Mott / Coulomb)



$$\sigma_{el} = \frac{4\pi Z^2 r_e^2 \beta_y}{\epsilon_N \gamma}$$

- No energy loss only
- change trajectory of the scattered particles.

Inelastic Scattering (Bremsstrahlung)



$$\sigma_{in} = \frac{A}{N_A} X_0 \left(\frac{-4}{3} \log k_{min} - \frac{5}{6} + \frac{4}{3} k_{min} - \frac{k_{min}^2}{2} \right)$$

- Significant amount of energy loss

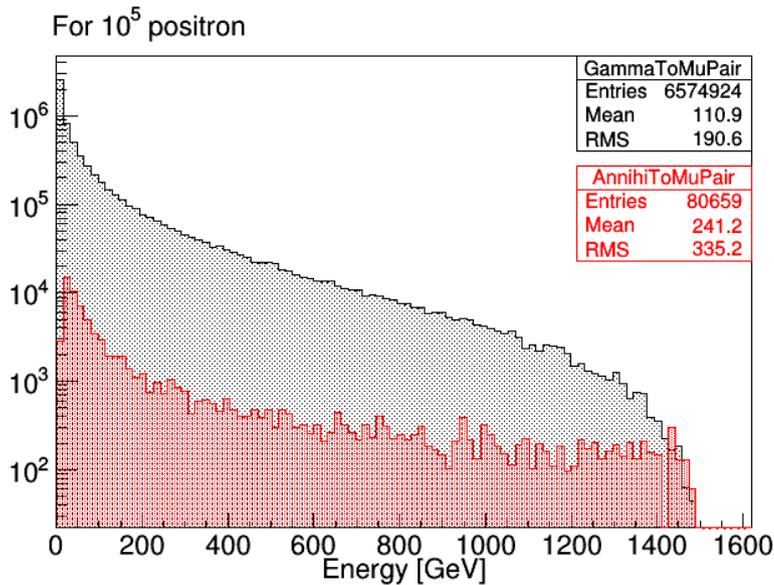
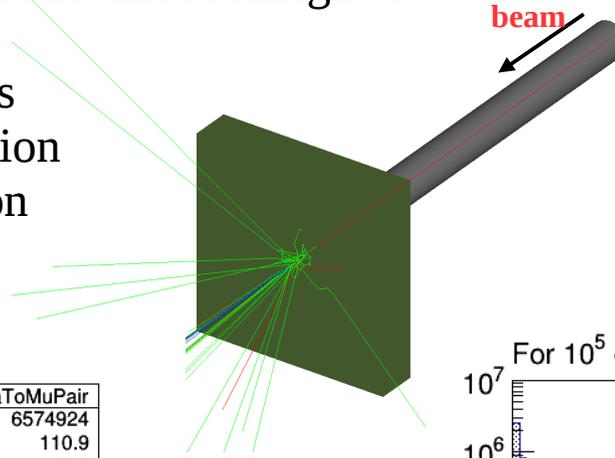
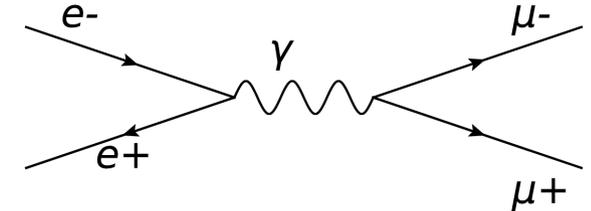
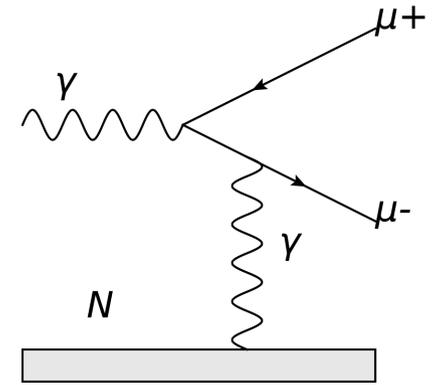
1. H. Burkhardt et. al. "Halo Estimates and Simulations For Linear Colliders", Proceedings of IPAC07, Albuquerque, New Mexico, USA.
 2. H. Burkhardt, I. Ahmed, M. Fitterer, A. Latina, L. Neukermans, D. Schulte, "Halo And Tail Generation Computer Model And Studies For Linear Colliders" EUROTeV-Report-2008-076

MUON PRODUCTION

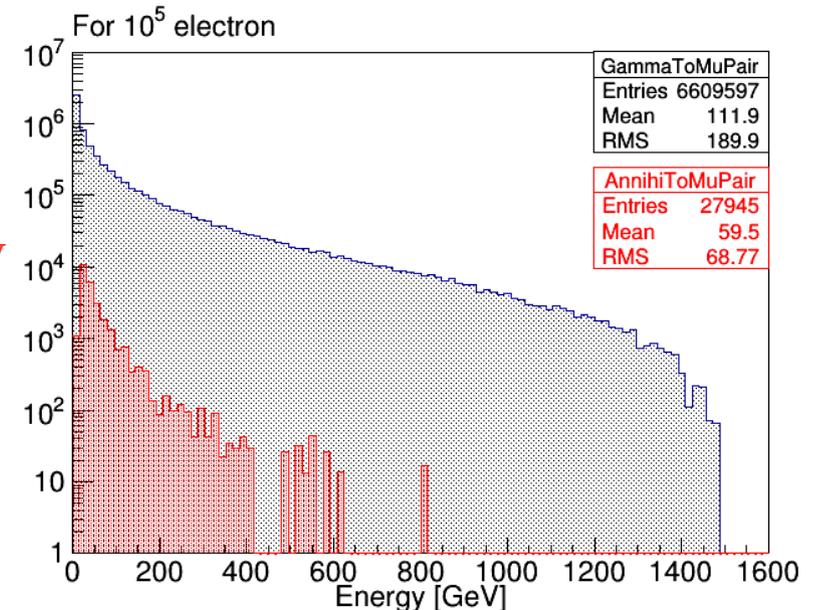
→ Halo particles can be stopped by collimators but this time secondary muons will be potentially dangerous background.

→ Geant4 includes a set high energy processes of muon production inside the Geant4 Standart Electromagnetic Package⁴.

- Two main muon production process
 - GammaToMuonPair Production
 - AnniToMuonPair Production



**e^-/e^+ @1.5 TeV
impinging on
1 X_0 C target.**

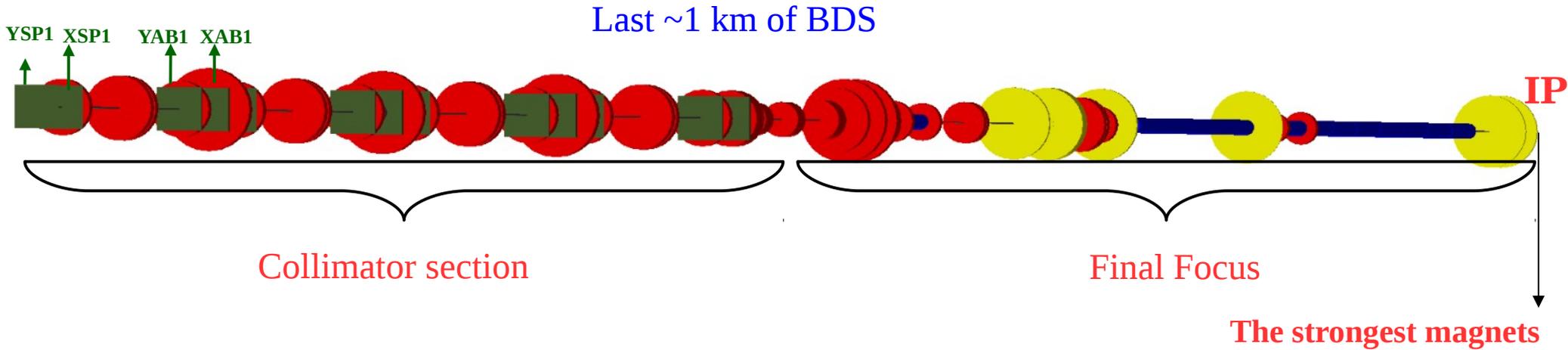


Hadronic process → to be added

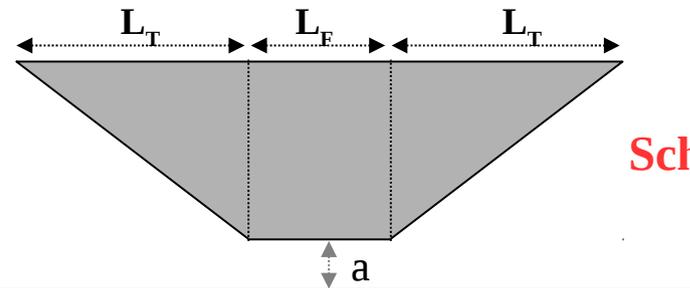
4. A. G. Bogdanov, H. Burkhardt et. al. "Geant4 Simulation of Production and Interaction of Muons", IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL.53, NO.2, APRIL 2006.

COLLIMATOR SECTION GEOMETRY with BDSIM

sbend
 quadrupole
 sextupole
 collimator

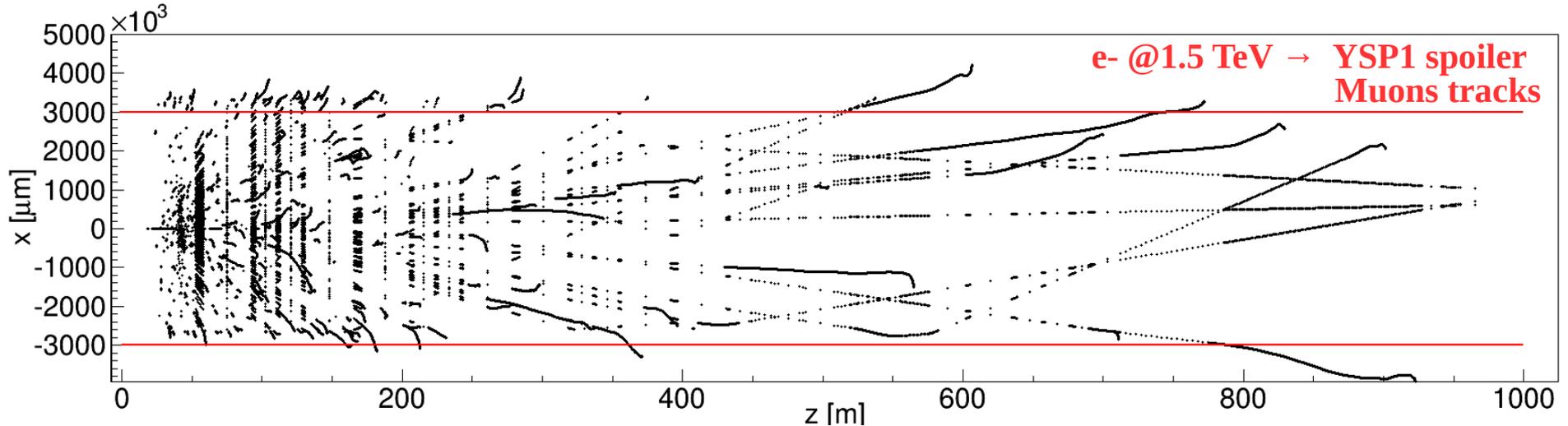


CDR	a_x [mm]	a_y [mm]	L_T [mm]	L_F [mm]	Distance from IP [m]	Mat
YSP1,2,3,4 (rcol)	8	0.1	90	7.2	965.06, 852.22, 739.38, 626.5	Ti-Cu
XSP1,2,3,4 (rcol)	0.12	8	90	7.2	949.24, 836.40, 723.55, 610.7	Ti-Cu
XAB1,2,3,4 (ecol)	1	1	27	648	872.04, 759.20, 646.35, 533.5	Ti
YAB1,2,3,4 (ecol)	1	1	27	648	854.22, 741.38, 628.53, 515.7	Ti

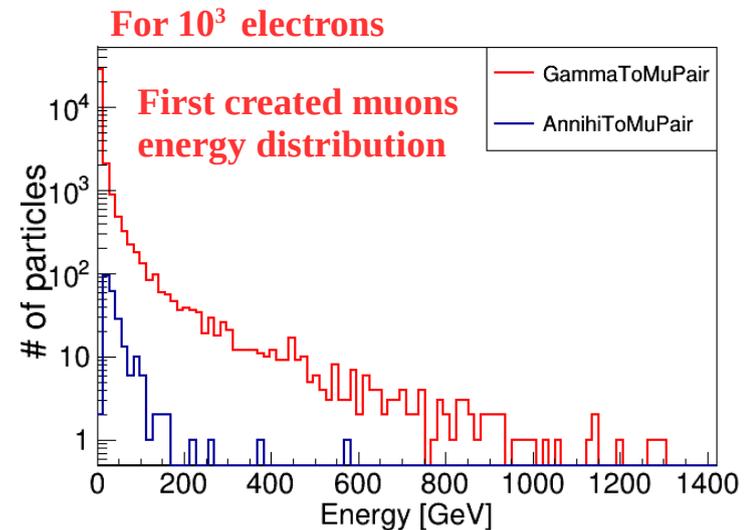
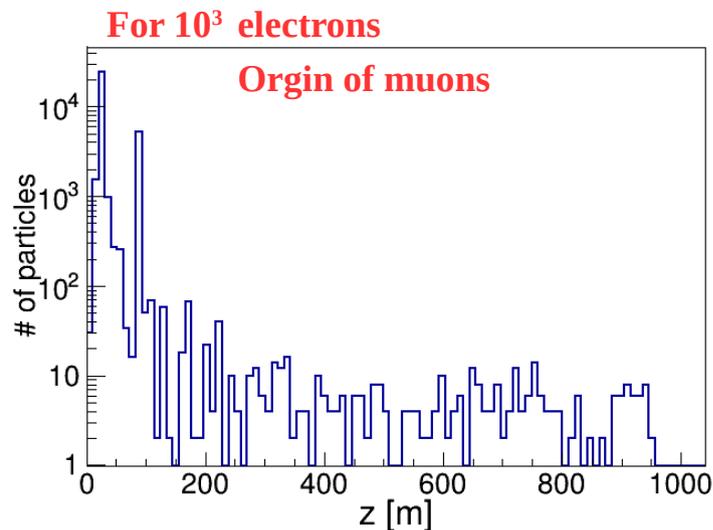


- CLIC-BDS Magnets information CLIC – Note – 984.
- For more information about collimators CLIC CDR.

PRELIMINARY RESULTS FOR MUONS IN BDS



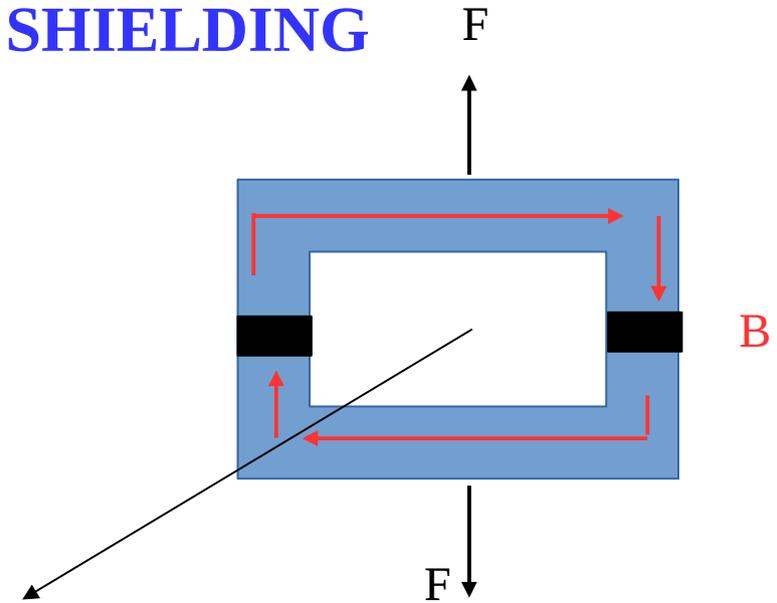
- Muons are created by **GammaToMuPair** process and **AnnihiToMuPair** process.
- Muons loss their energy along beam line with following processes ⁴:
 - Ionization
 - Pair Production
 - Bremsstrahlung
 - Nuclear Interaction



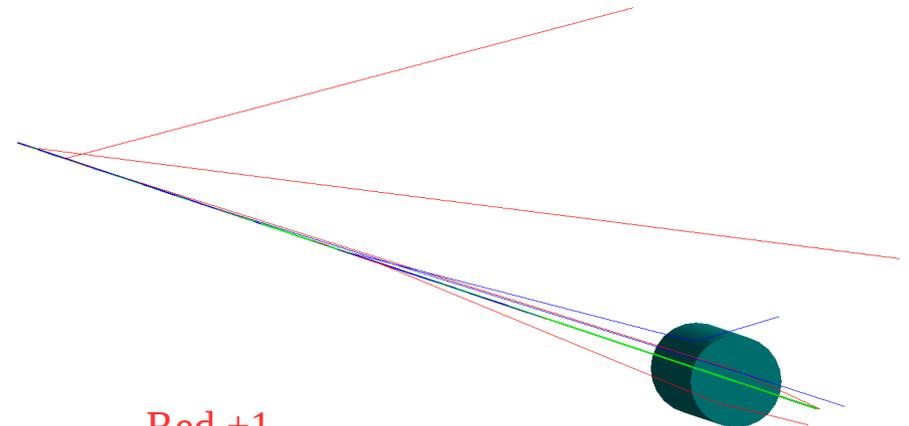
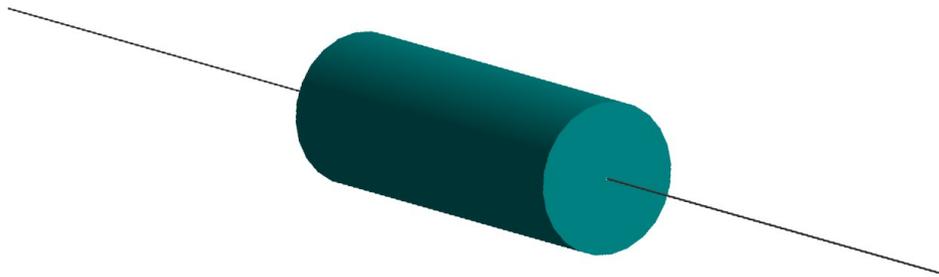
4. A. G. Bogdanov, H. Burkhardt et.al. "Geant4 Simulation of High Energy Muon Interactions", IEEE, 2004.

TUNNEL FILLERS / MASSIVE SHIELDING

- Tunnel fillers will be used to prevent muons to reach interaction region. ([Lau Gatignon.](#))
- Tunnel fillers (magnetized spoiler) have a rotationally (toroidal) magnetic.



zero magnetic field @ center



Red +1
Blue -1
Green 0

CONCLUSION

- Beam Delivery System geometry description
- Beam Tracking
- Muon production with electromagnetic package
- Halo estimate and muon production
- HOW can we sweep these muons?
 - Tunnel Fillers (position and optimization)
Sweep muons **before** the FFS long dipole section.
 - Other ideas ?

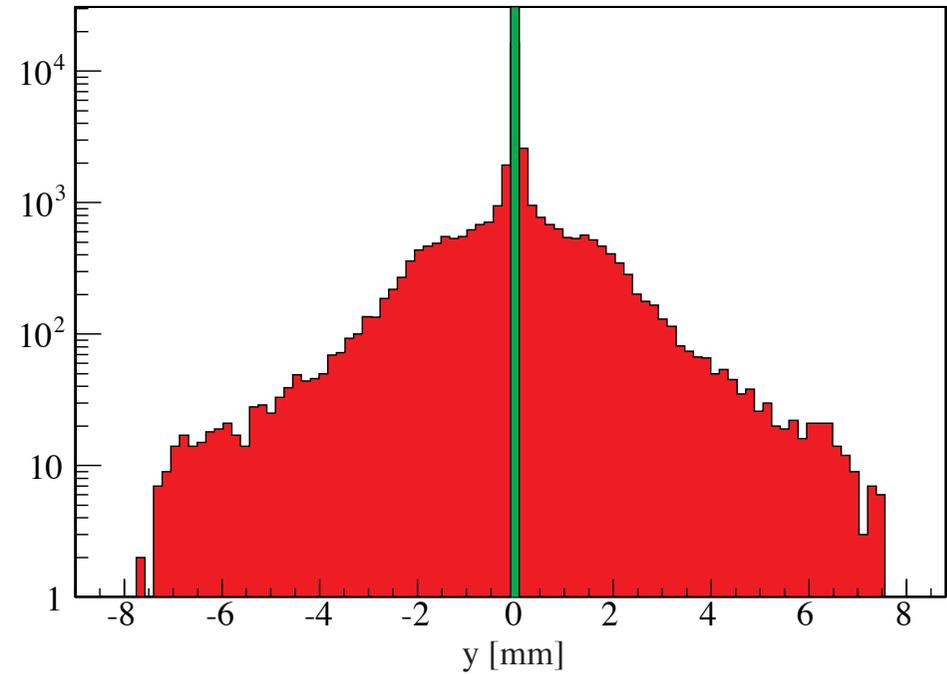
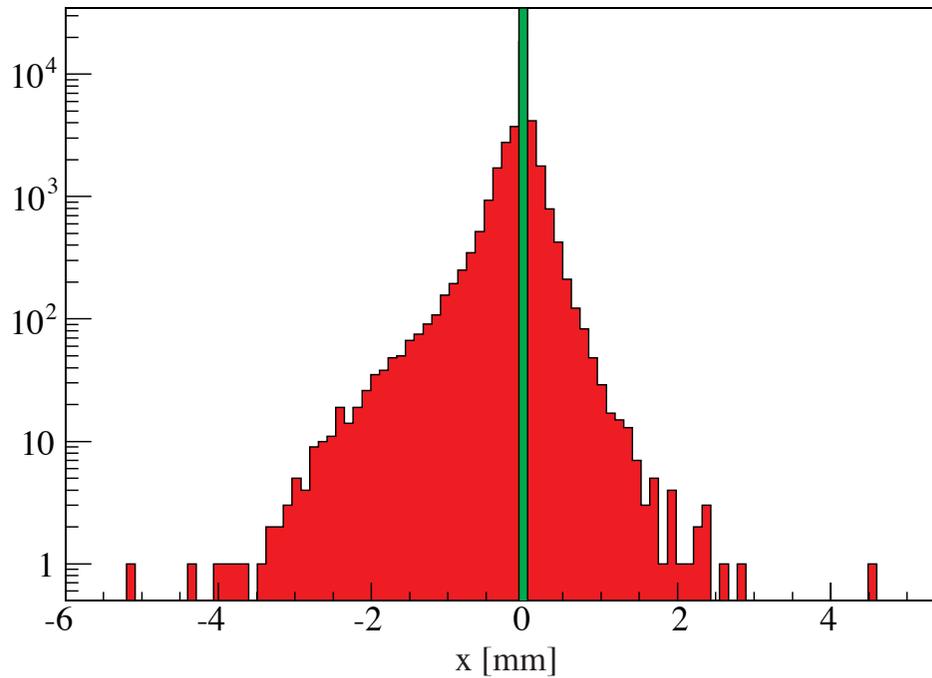


**THANKS
FOR YOUR ATTENTION... :)**

BACKUP SLIDES

Some slides courtesy of Helmut Burkhardt and Lau Gatignon

HTGEN + PLACET, at XSP1, YSP1



Interaction in the spoiler, tracking of secondaries ---> BDSIM

Basic approach to reduce muon halo: **Toroidal fields in Iron**

Magnetised Iron has three main effects on muons:

❑ Energy loss: $dE/dx \sim 1.5 \text{ GeV/m}$

❑ Multiple Coulomb scattering:
$$\theta_{scatt} [mrad] = \frac{14}{p[GeV/c]} \sqrt{L/X_o} = \frac{14}{p\sqrt{0.0176}} \sqrt{L} = \frac{106}{p} \sqrt{L}$$

❑ Magnetic deflection:
$$\theta_{defl} [mrad] = \frac{300}{p[GeV/c]} BL[Tm] = \frac{300 \times 1.5}{p} L = \frac{450}{p} L$$

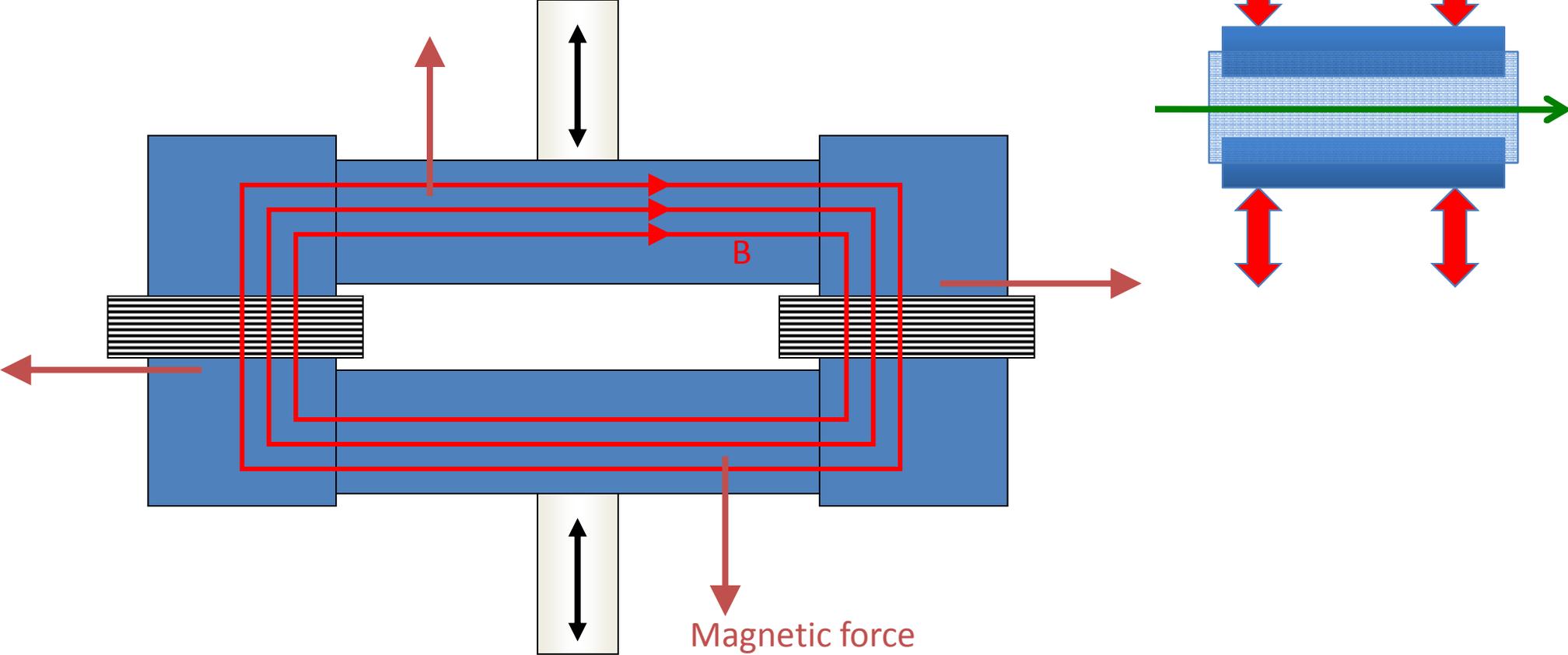
For a useful effect, require $\theta_{defl} \gg \theta_{scatt}$, i.e. $450 L \gg 106 \sqrt{L}$ or $L \gg 0.05 \text{ m}$

e.g. for $\theta_{defl} > 10 \theta_{scatt}$ one requires **$L \geq 5 \text{ m}$**

In the M2 beam we use two types of toroids:

1. SCRAPERS: adjustable gap, no vacuum (?), smaller outer coverage, expensive
2. MIBS: fixed gap, large coverage, cheap, vacuum tube can go through

SCRAPERS (Magnetic Collimators)



Have to get polarity right....