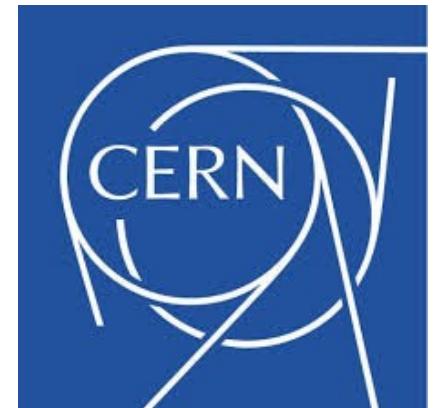




CLIC MUON-SWEEPER DESIGN

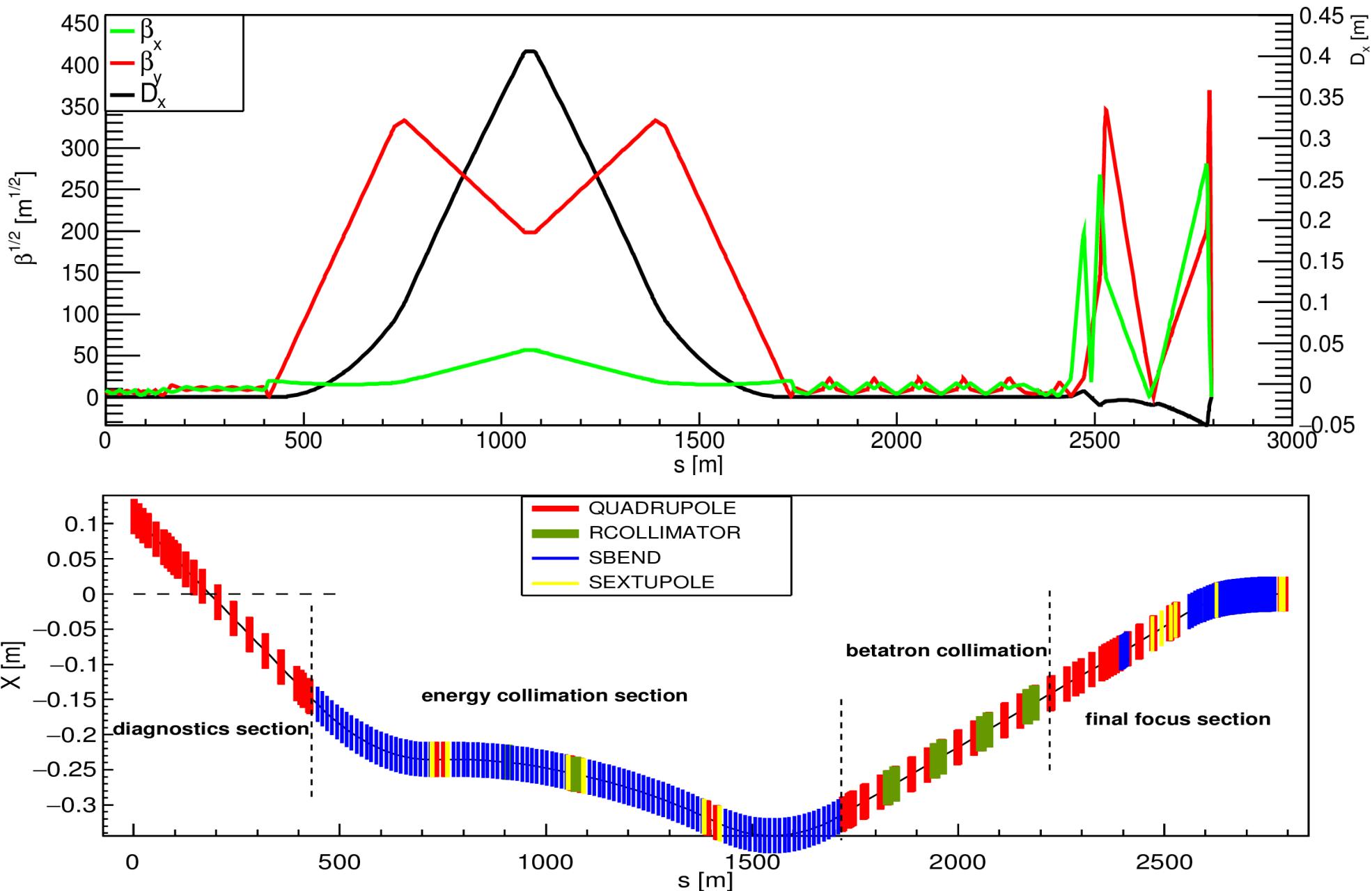
F. Belgin Piliçer, A. Aloev, H. Burkhardt,
L. Gatignon, M. Modena, I. Tapan



CONTENTS

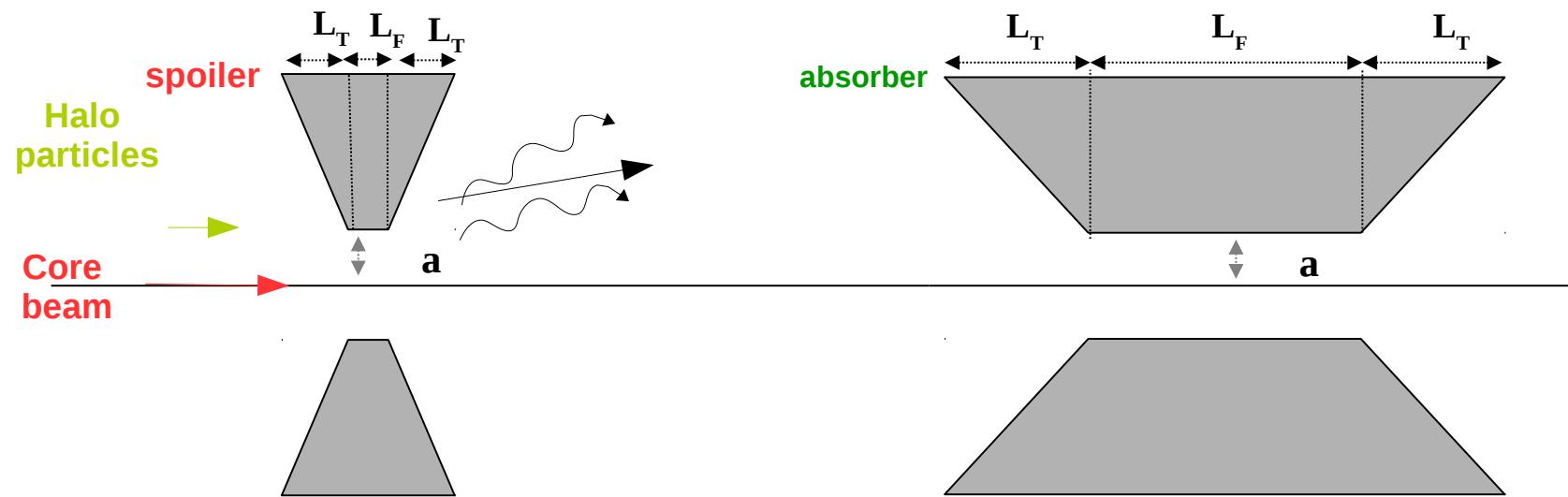
- **MUON BACKGROUND IN BEAM DELIVERY SYSTEM**
- **NEW MUON SWEEPER DESIGN**
- **REDUCTION RATES FOR MUON BACKGROUND**
- **SUMMARY**

CLIC BEAM DELIVERY SYSTEM



WHERE DO MUONS COME FROM?

- Core particles can significantly increase in amplitude and become halo particles around the beam.



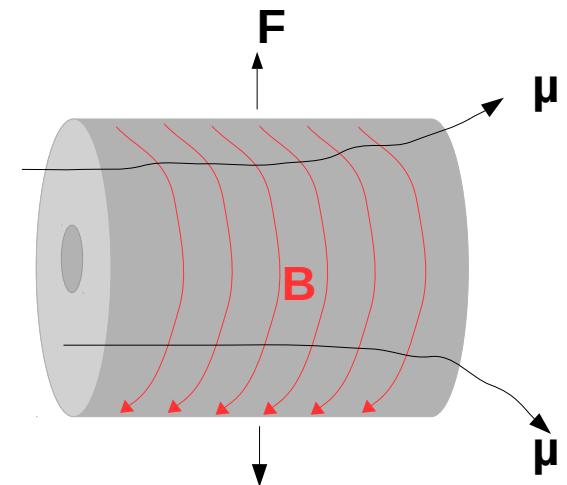
Schematic of collimators

- Halo particles are scattered with spoilers.
- The secondaries reach to the absorber and generate muons as a background particles.

MUON BACKGROUND IN BDS

- Muon sweeper / shielding will be used to prevent muons to reach interaction region.
- Magnetized shielding has a rotationally symmetric (toroidal) magnetic field. (almost no field inside the beam pipe)
- Deflect muons to the tunnel wall.
- The available drift spaces in the betatron collimation section (after absorbers) will be used.

Solenoid Muon Sweeper



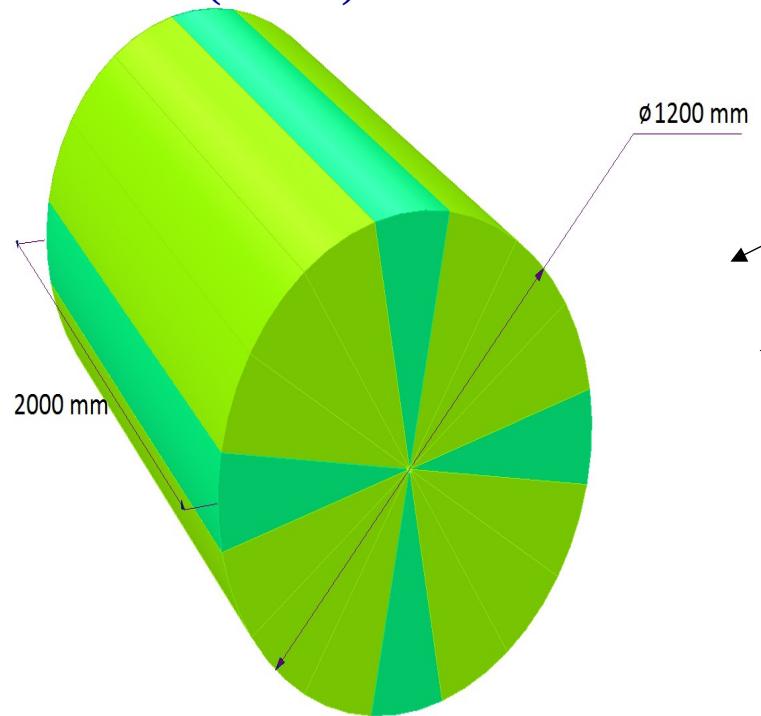
$$R = 3.333 \frac{\beta \cdot p_{inc} [GeV/c]}{B [T]}$$

$$\theta \approx \frac{L}{R}$$

MUON SWEeper / MAGNETIZED SHIELDING DESIGN

done by A. Aloev

A permanent magnet solution
with Samarium-cobalt
(SmCo) blocks



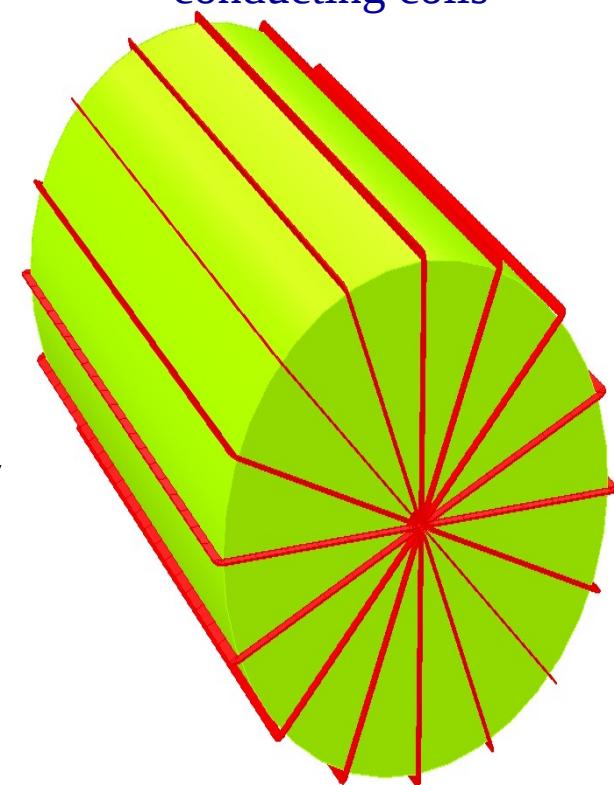
and

Iron
yoke

SmCo
blocks

Normal
conducting
coils

A solution with normal
conducting coils



- “Green” magnet – no power consumption
- Large permanent blocks are difficult to assemble
- Average field level is limited by the remanence of SmCo

Pros & Cons

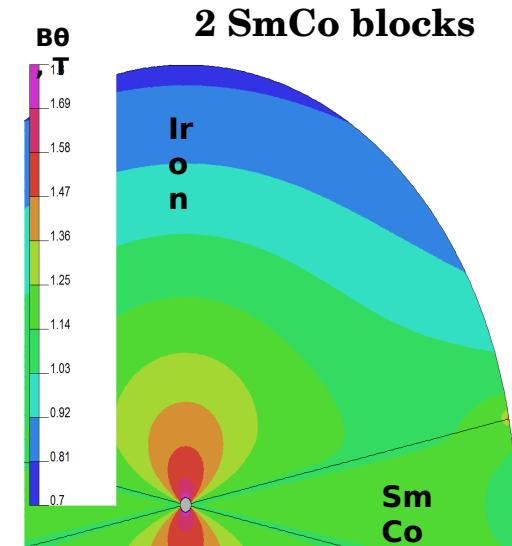
- Field homogeneity is much better than for the permanent magnet solution.
- Power consuming magnet
- A gap between the vacuum chamber and the yoke inner radius is required to accommodate the coils. The field level is low in this gap.

MUON SWEeper / MAGNETIZED SHIELDING DESIGN

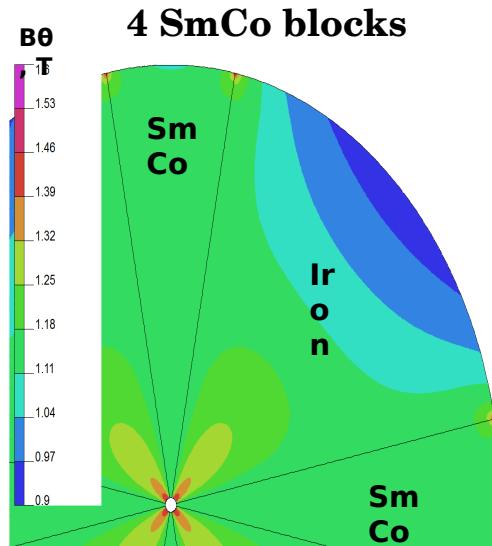
done by A. Aloev

Permanent magnet solution

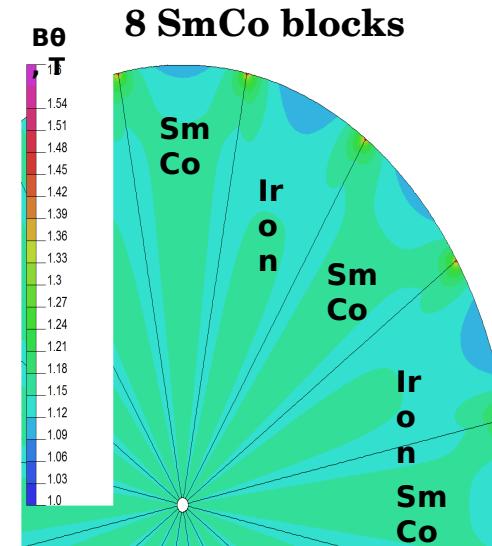
2 SmCo blocks



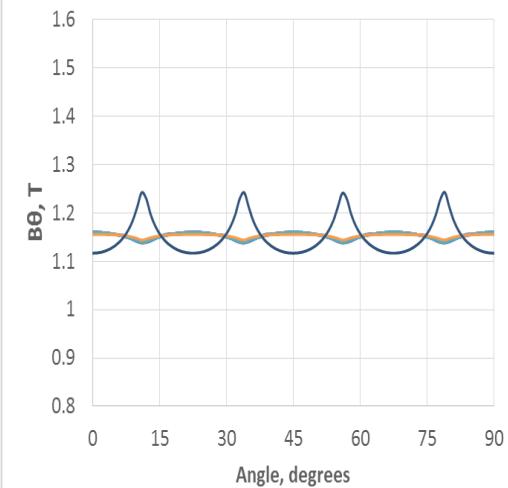
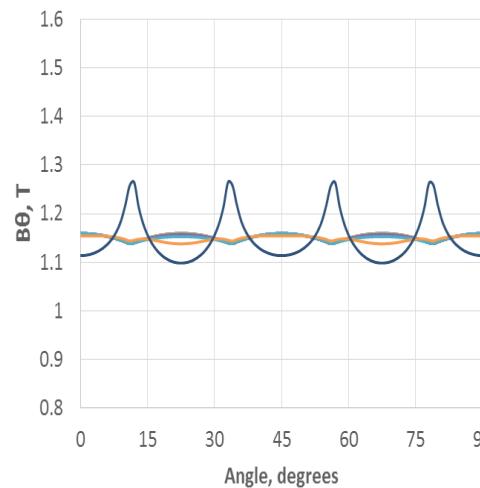
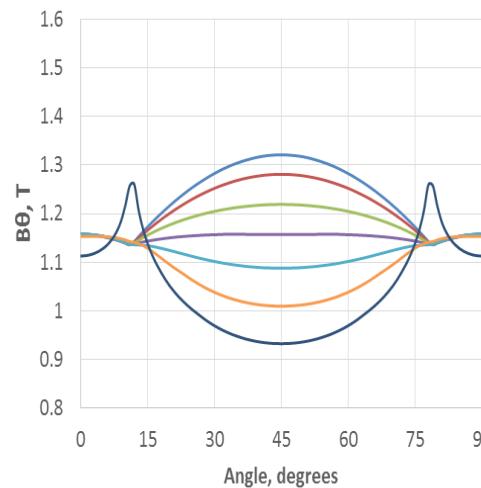
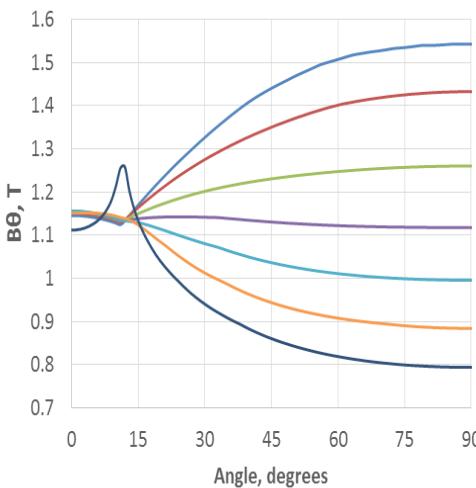
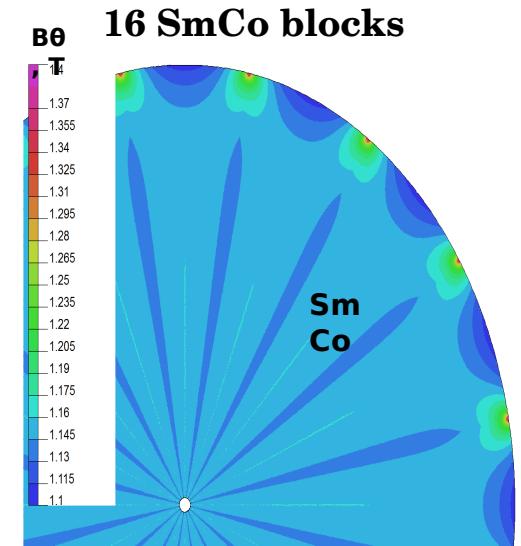
4 SmCo blocks



8 SmCo blocks



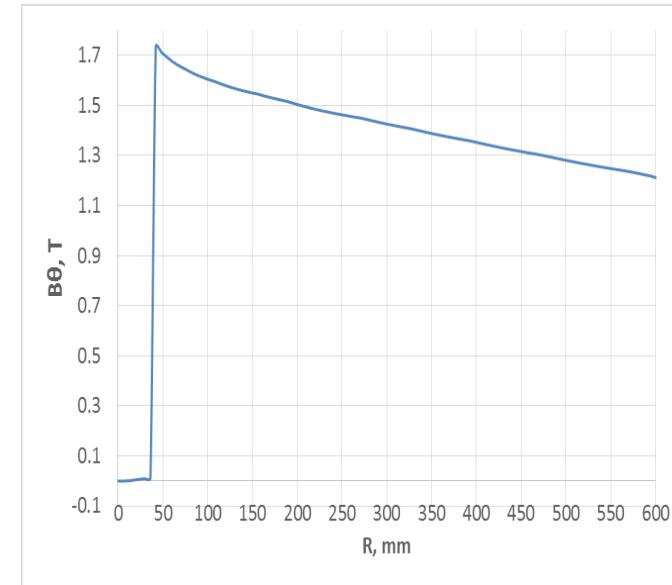
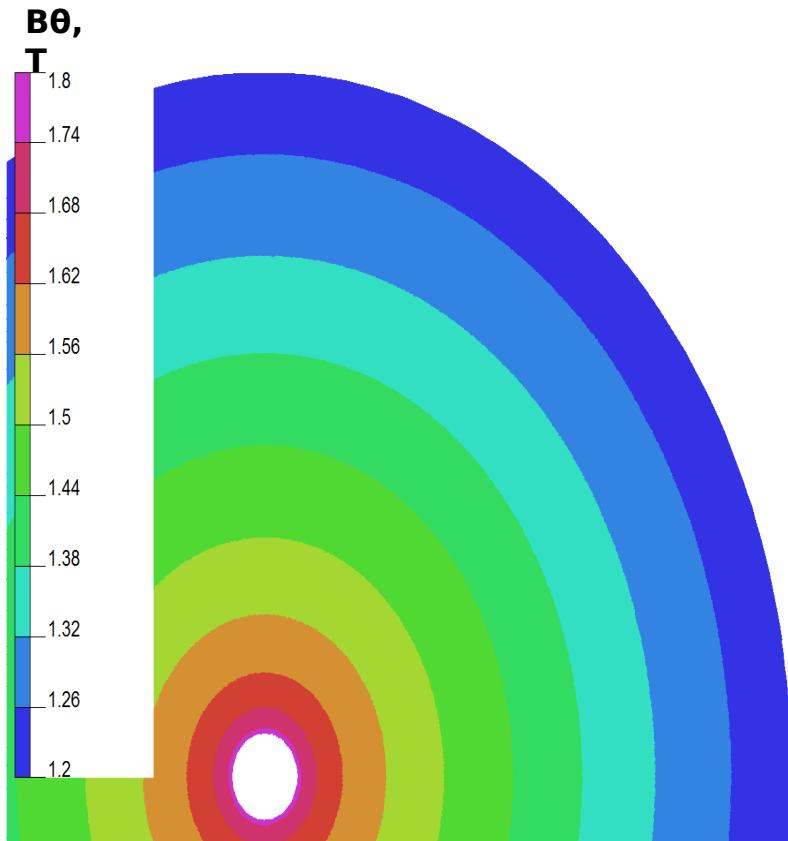
16 SmCo blocks



MUON SWEeper / MAGNETIZED SHIELDING DESIGN

done by A. Aloev

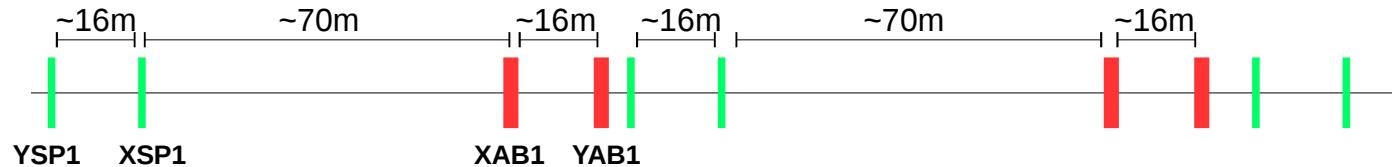
Normal Conducting Coils Solution



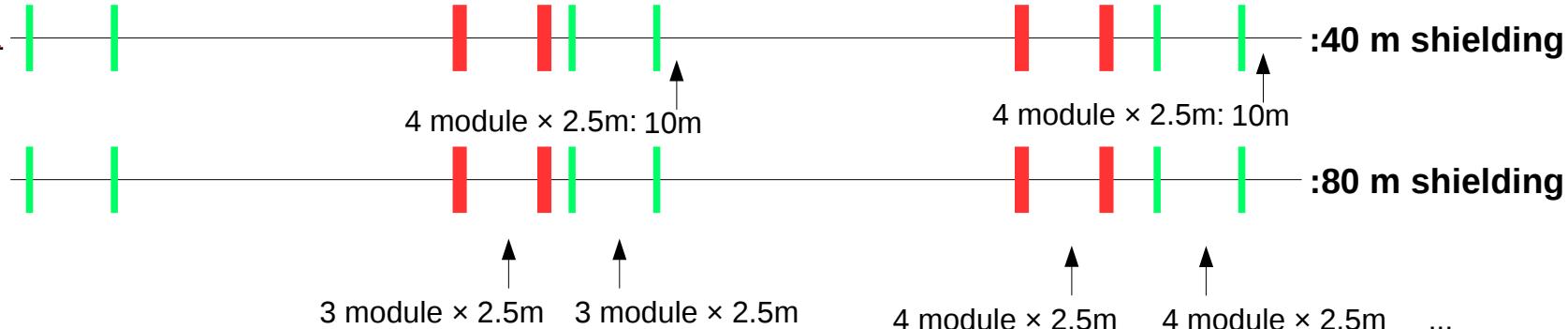
- Azimuthal homogeneity of B_θ is below 10^{-3} for a given radius value.
- Total ampere-turns NI 2.2 kA
- Current density 0.8 A/mm² (allows air cooling)
- Power consumption 120 W (for a single 2 meter section)

MUON SWEEPER DESIGN

No Shield:

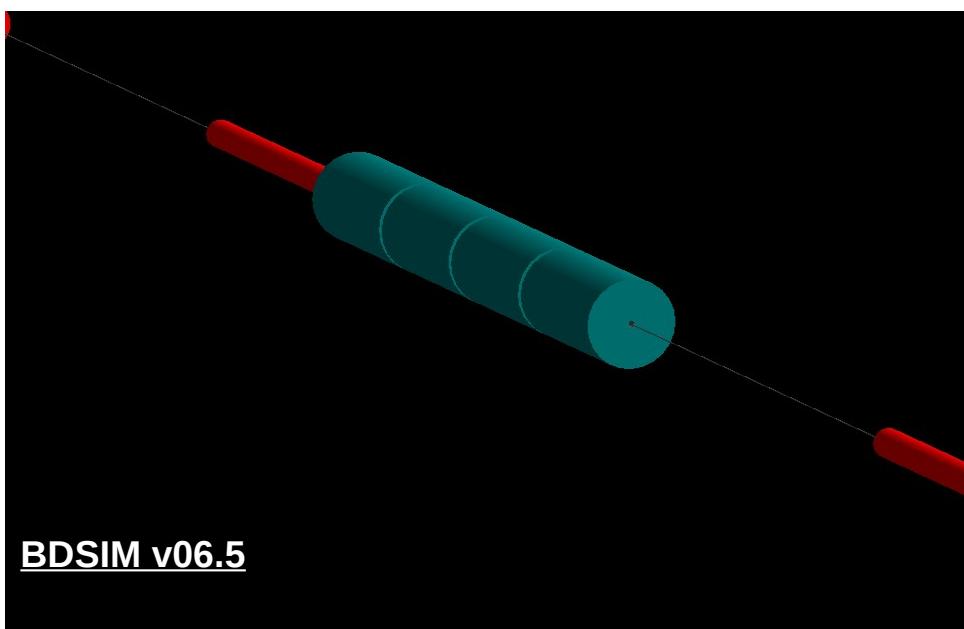


40 m shielding:



L. Deacon:
Updated version

Previous study: Muon Background Reduction in CLIC, EuCARD-CON-2012-001.



BDSIM v06.5

→ Inner radius : 4 cm

→ Outer radius : 60 cm

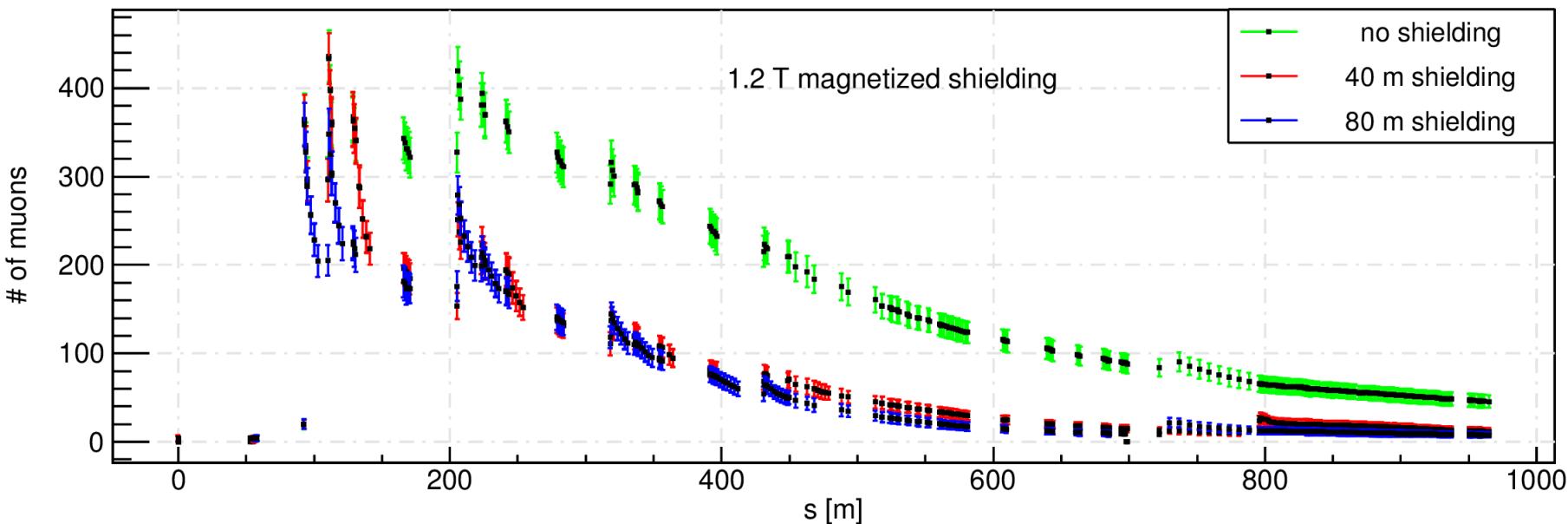
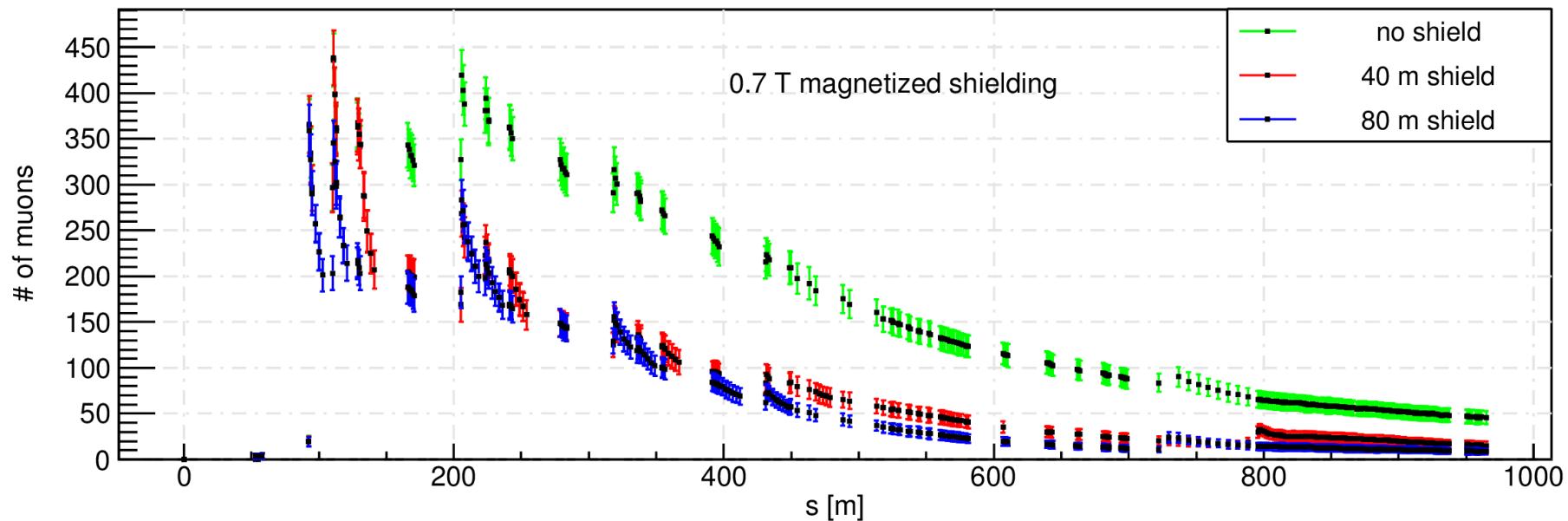
→ Module : 2.5 m

→ Distance between modules : 10 cm

→ Magnetic Field: 0.7 T , 1.2 T

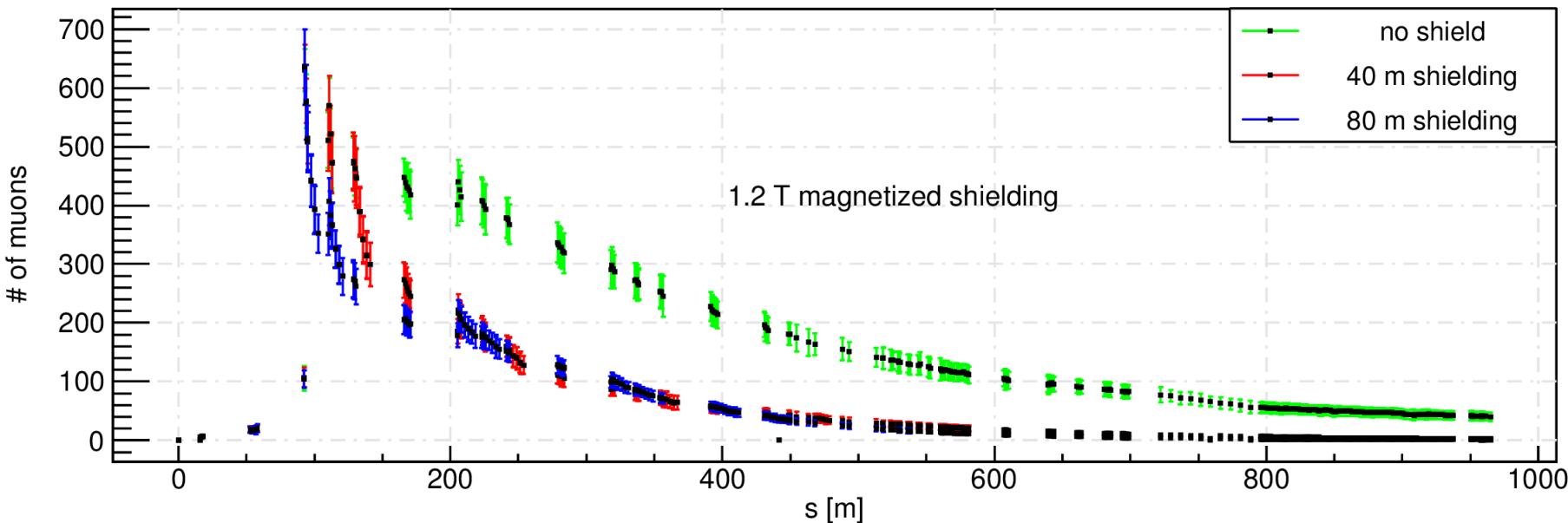
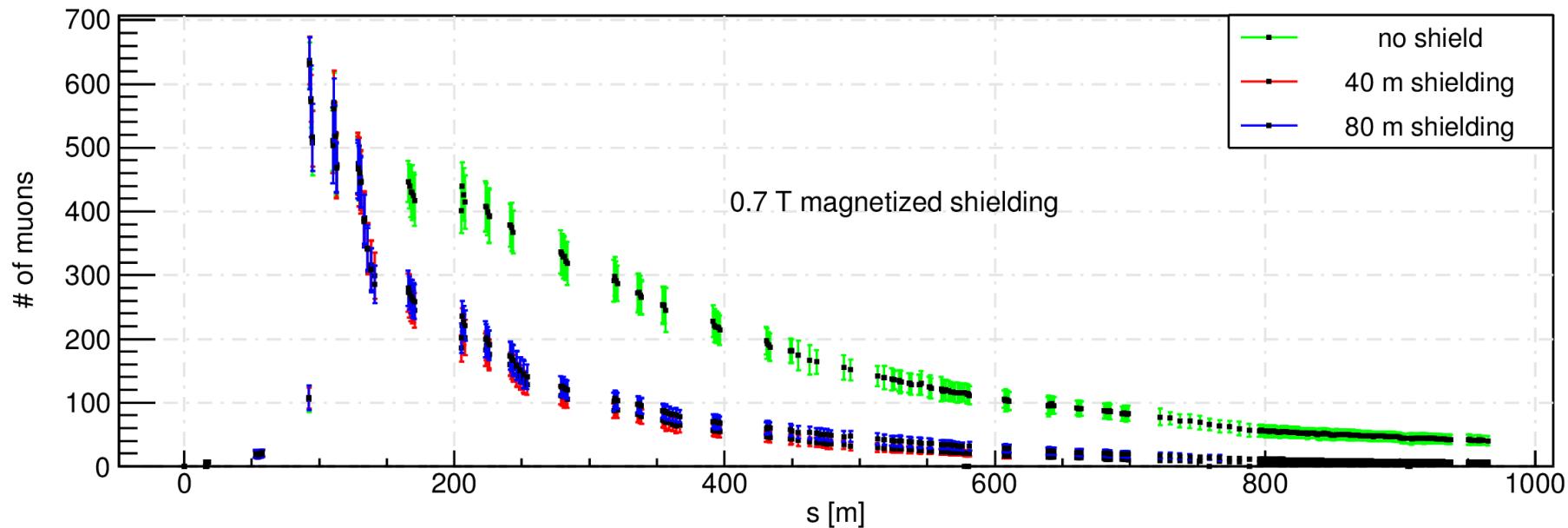
MUON REDUCTION RATE

Artificial hit → First Spoiler



MUON REDUCTION RATE

Estimated Halo Distribution → First Spoiler



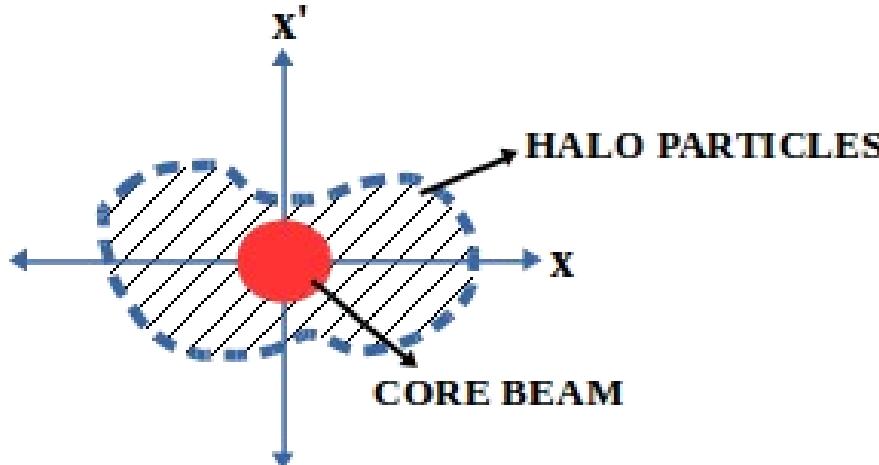
SUMMARY

- Permanent magnet solution has been compared with normal conducting coils.
- Field intensity has been simulated for different # of SmCo blocks.
- The muon sweeper parameters have been updated for BDS.
- 0.7 T (min) and 1.2 T (optimum) as permanent magnet option have been simulated with BDSIM.
- The simulation results showed roughly factor of ~10 reduction at 1.2 T for muons at the end of the BDS.
- The remaining muons comes dominantly from last dipole section.

**THANKS FOR
YOUR PATIENCE...**

BACKUP SLIDES

HALO GENERATION

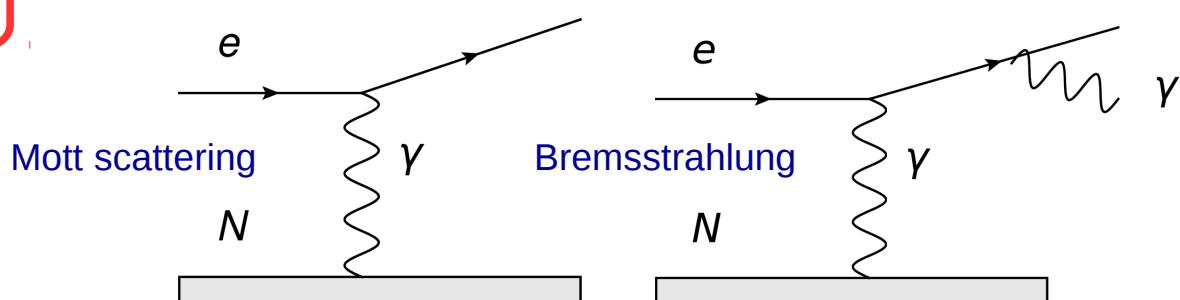


Core particles can significantly increase in amplitude and become halo particles around the beam by following **particle processes** [1, 2, 3];

- Beam-Gas Elastic Scattering (Mott Scattering)
- Beam-Gas Inelastic Scattering (Bremsstrahlung)
- Scattering off Thermal Photons
- Intrabeam Scattering
- Synchrotron Radiation
- **Optics Related Effects**
- **Other Sources**

}

- Known dominate processes
- Scattering from residual gas nucleus
- HTGEN generates halo particles.



- → No energy loss
- → Only change trajectory of the scattered particles.

- → Significant amount of energy loss

1. H. Burkhardt et. al., "Halo Estimates And Simulations For Linear Colliders", Proceedings of PAC07, Albuquerque, New Mexico, USA.

2. H. Burkhardt et. al., "Halo and Tail Generation Computer model and Studies For Linear Colliders", EUROTeV Report-2008-076.

3. M. Fitterer, "Modelling of Halo and Tail Generation in Electron Beams", Phd Thesis, CERN-THESIS-2009-239.

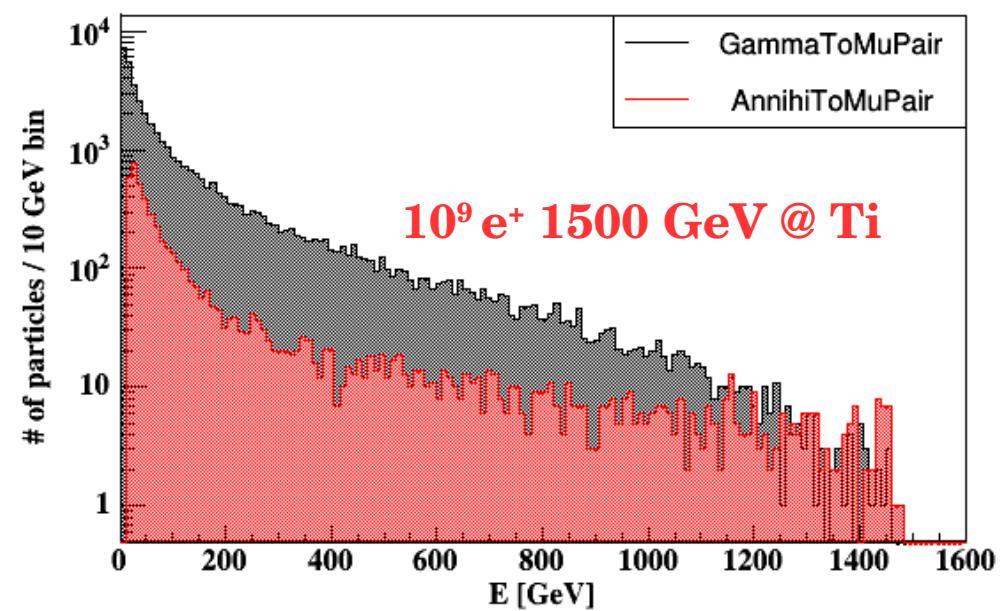
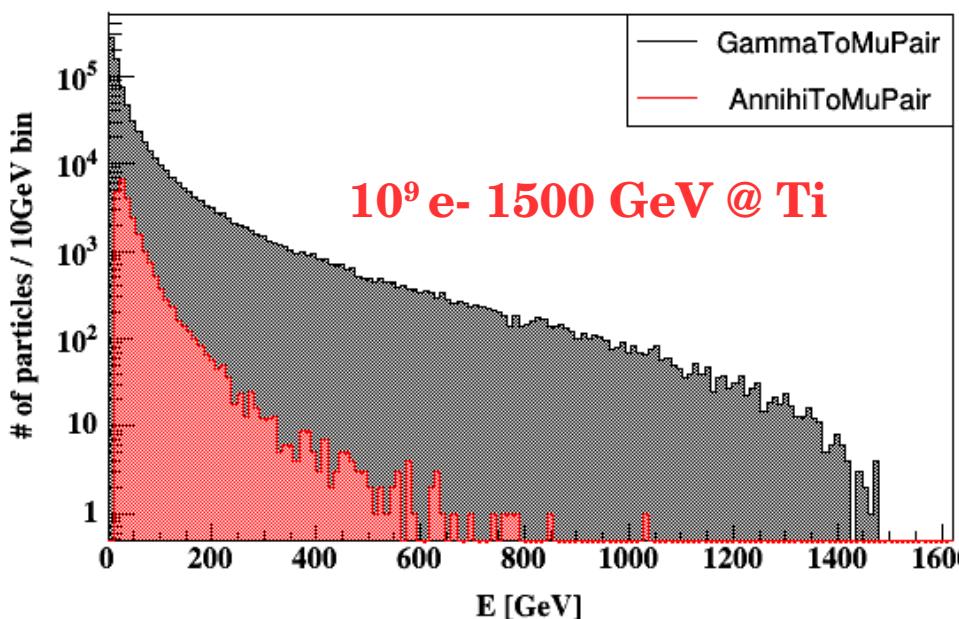
MUON PRODUCTION

- Halo particles can be stopped by collimators but this time secondary muons may be potentially dangerous as a background.
- Geant4 includes a set of high energy processes of muon production inside the **Geant4 Standard Electromagnetic Package** [4, 5].

Two **direct** muon production processes

- Gamma Conversion into Muon Pair
- Annihilation into Muon Pair

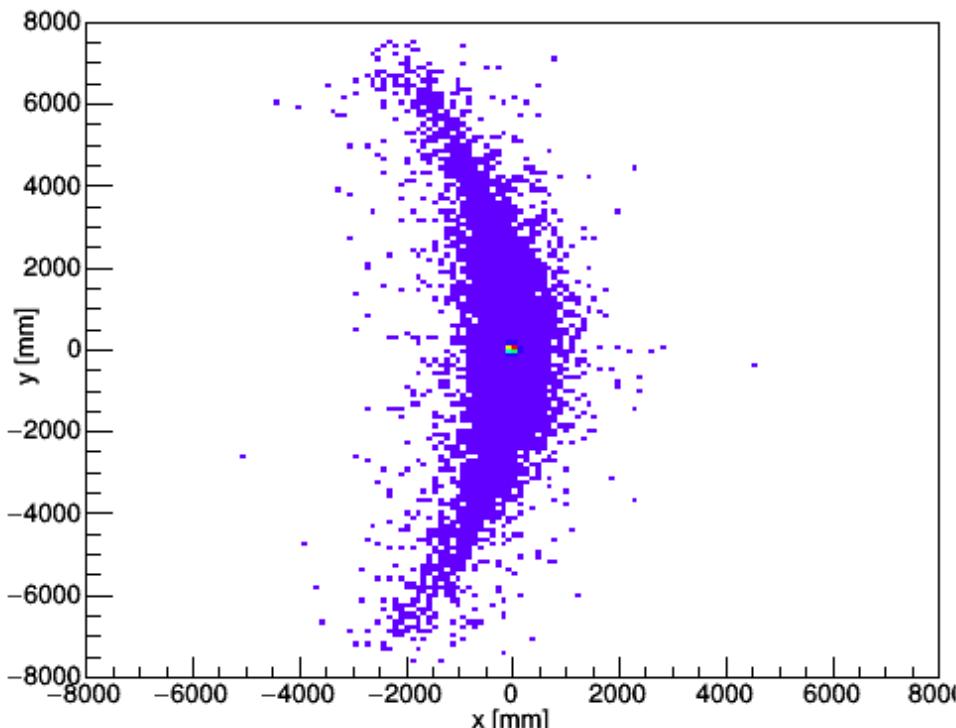
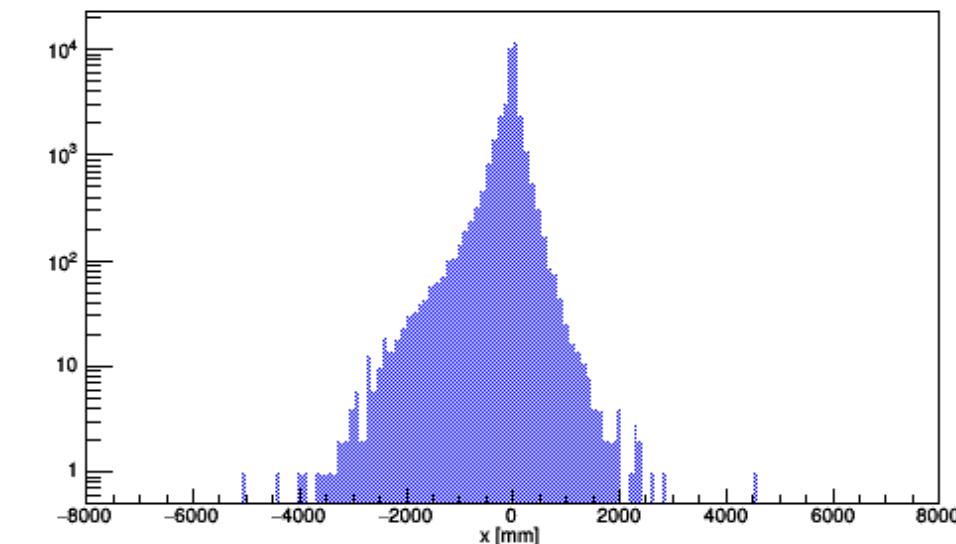
GEANT4.10.01.p02



4. Physics Reference Manual, Geant4 10.1 (5 December 2014).

5. A. G. Bogdanov et. al., "Geant4 Simulation of High Energy Muon Interactions", IEEE Trans. Nucl. Sci., 53, 513-519, 2006.

ESTIMATED HALO DISTRIBUTION



Halo distribution @ YSP1

YSP1 is the first spoiler in the betatron collimation section.

The distribution is provided by H. Burkhardt with HTGEN, includes Beam Gas Scattering processes.

halo distribution @YSP1

