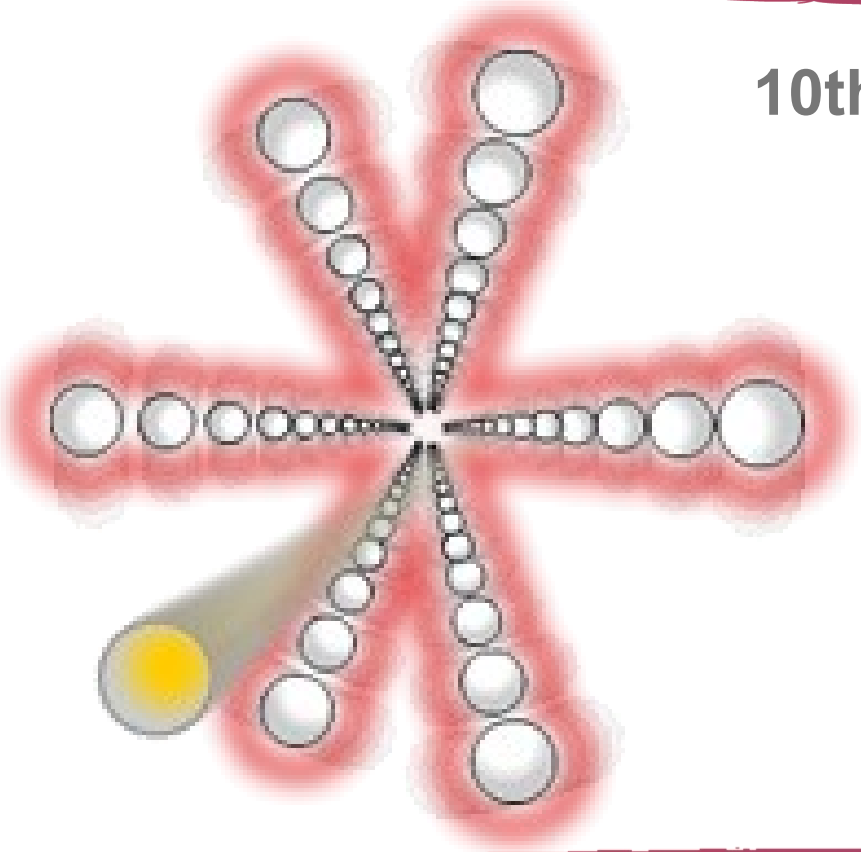


10th International Conference Charged & Neutral Particles Channeling Phenomena, 9th Sept, Riccione, Italy

Crystal assisted steering of muon collider beam

M. Romagnoni
rmgmrc@unife.it

Co-funded by the European Union

Co-funded by the European Union (EU). Views and opinions expressed are however those of the author only and do not necessarily reflect those of the EU or European Research Executive Agency (REA). Neither the EU nor the REA can be held responsible for them.

Outline

- Muon Collider introduction and potential
- Crystal assisted beam collimation
- Axial stochastic deflection and planar channeling at TeV scale
- Planar channeling for 1.5 TeV/c and 5 TeV/c muon
- Conclusion

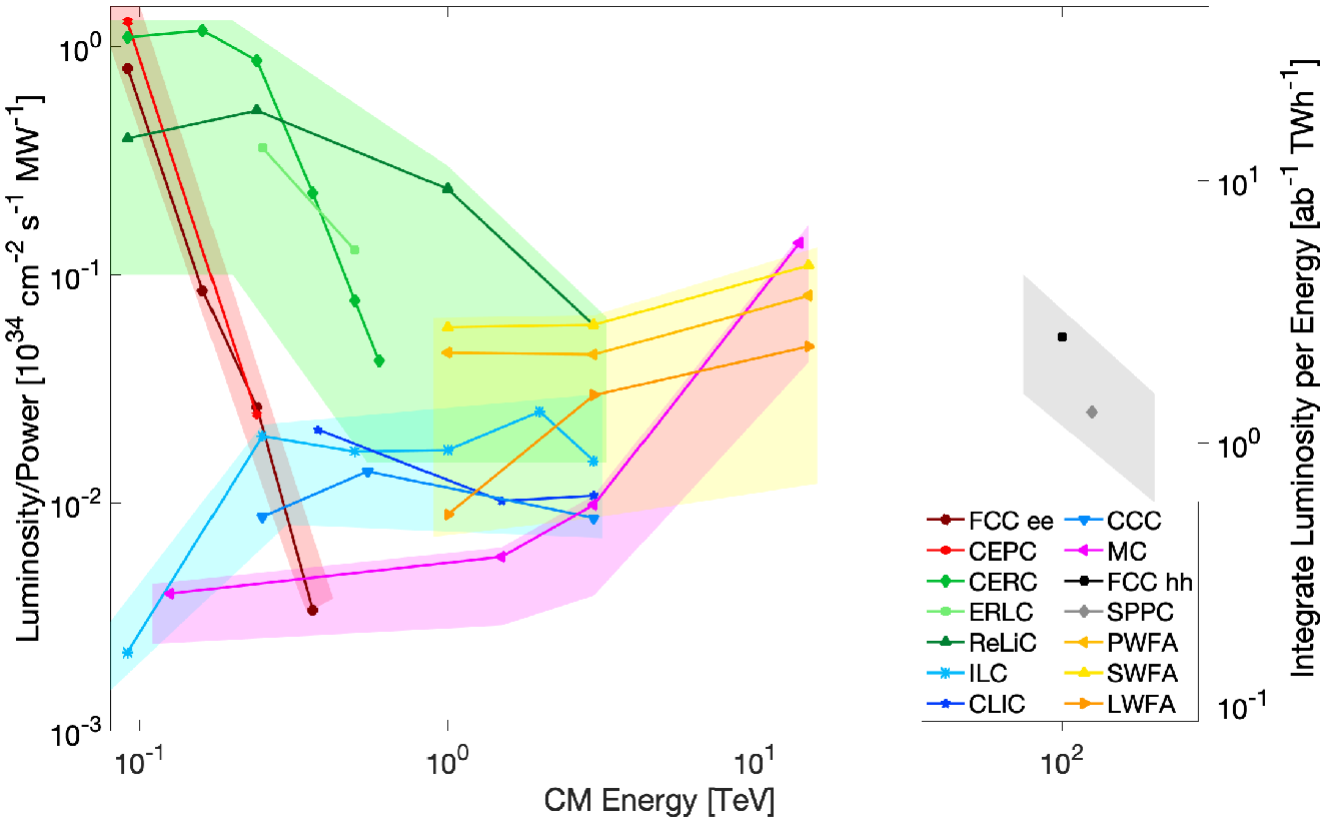
Colliders high energy frontier

- The evolution of high energy collider have exploited electron (positron), proton (anti-proton)
- Electron/positron:
  - Circular Collider: limit on maximum energy (FCCee, CCC)
  - Linear Collider: single pass acceleration and single collision (ILC, CLIC)
- Hadron :
  - Particle Internal structure: E_{cm} divided between partons (LHC,FCC-hh)

Using heavier fundamental particles such as Muon can overcome limitations of both e-/e+ and hadronic machines

Muon Collider

- Being more massive than electrons (positrons) radiation losses are reduced by a factor **10^9**
- Being fundamental particle, all E_{cm} energy available in collision
- High potential for physics studies and efficient luminosity vs energy scaling
- More compact collider wrt hadron and e+/e- case

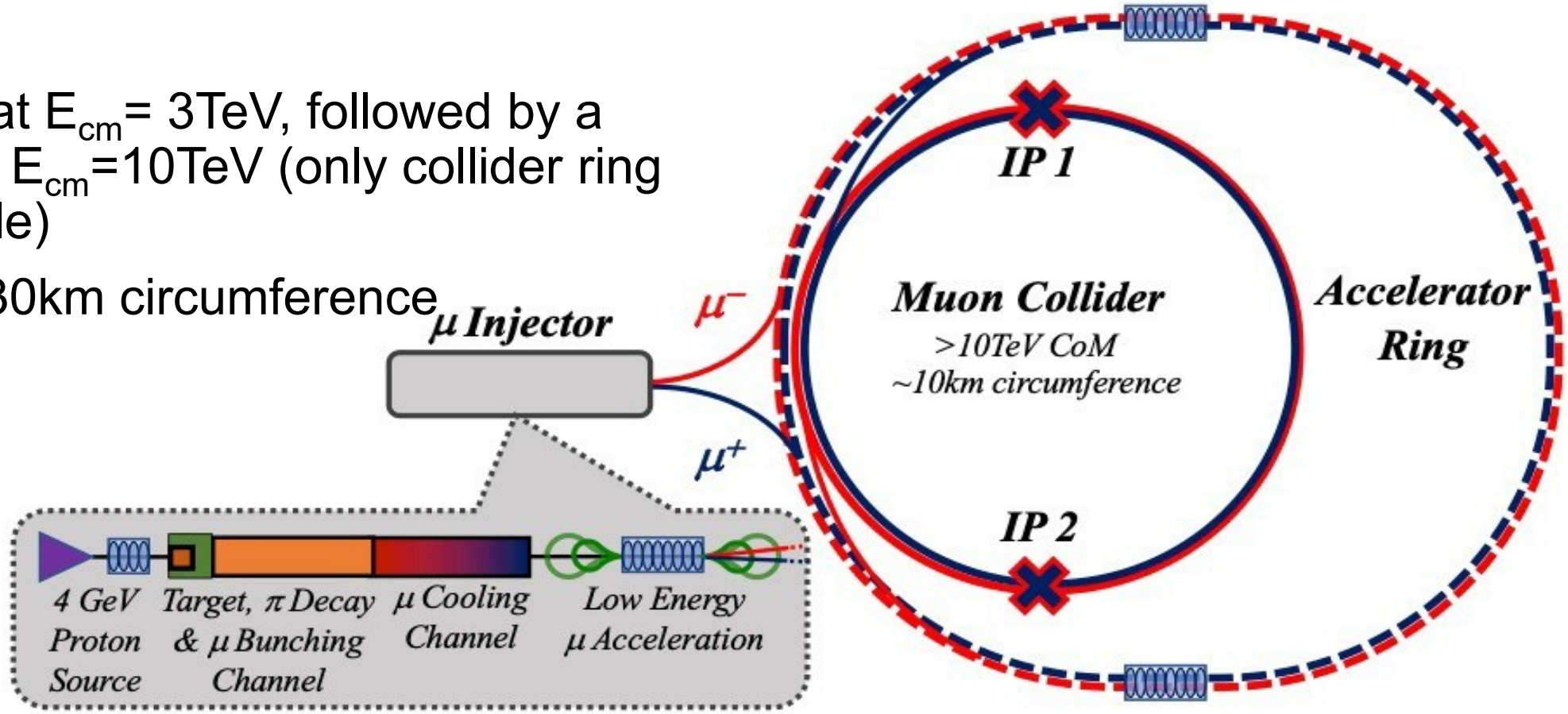


Thomas Roser et al., Report of the Snowmass 2021 Collider Implementation Task Force

Muon Collider Schematic

First stage at E_{cm}= 3TeV, followed by a scale up to E_{cm}=10TeV (only collider ring not re-usable)

Footprint ~30km circumference



Beam Collimation with bent crystals

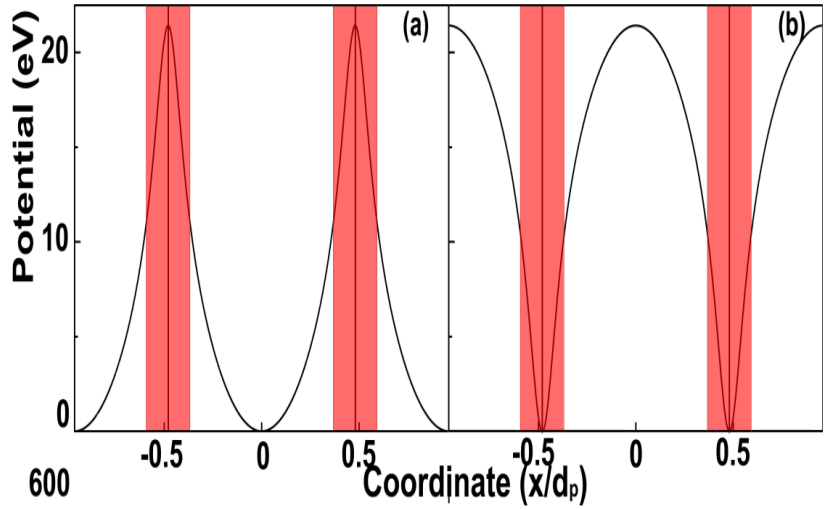
- Bent crystal are powerful tool to deflect high energy particles
- Test at LHC proved effectiveness at TeV scale for positive particles
- Can muon in a future muon collider be efficiently deflected by bent crystal?

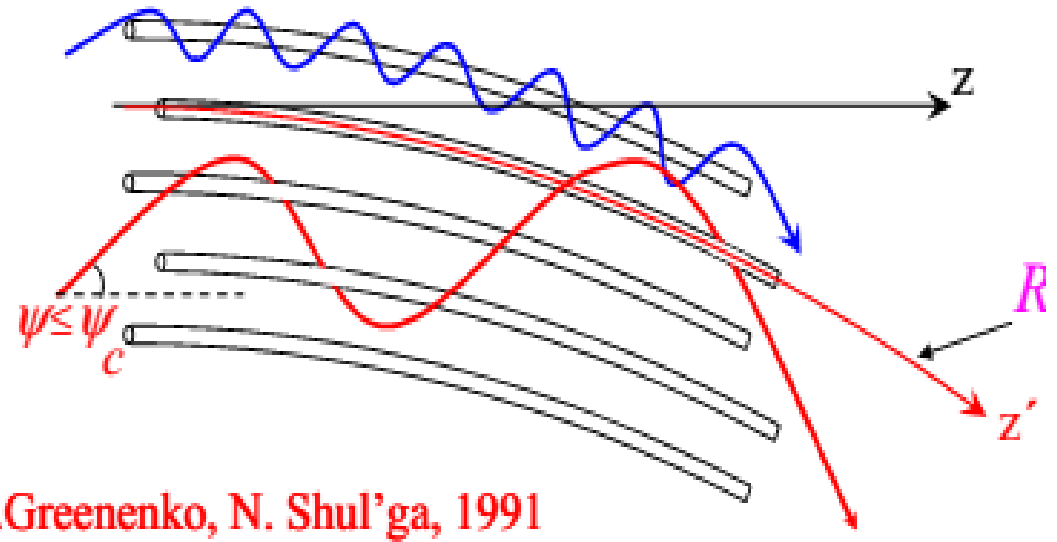
NEW CHALLENGE: STEERING OF NEGATIVE PARTICLE

Negative particle steering

- Planar channeling is significantly less efficient for negative particles, as incoherent scattering with atomic nuclei is enhanced instead of being suppressed.

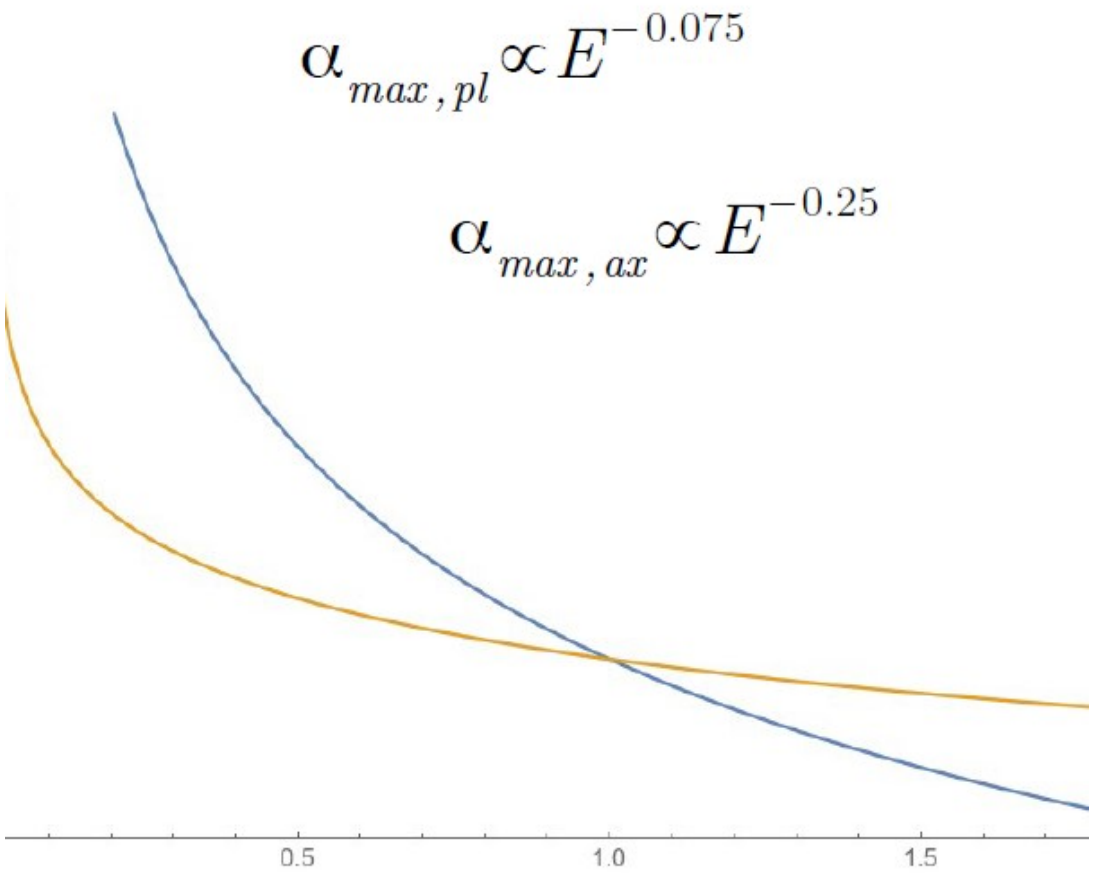
- Axial Stochastic Deflection was first proposed by A.A. Greenenko and N.F. Shul'ga in 1991
- Experimentally observed by H8-RD22/UA9 collaboration at CERN in 2008 for protons and in 2009 for π^- mesons
- The mechanism involve over-barrier motion: particles scattering converge stochastically along the axis direction. Efficient for both positive and negative particles





Axial Stochastic Deflection and Planar channeling

- Negative particles in planar channeling exploit weaker potential and more incoherent nuclear scattering wrt positive case
- Stochastic axial deflection has the potential to steer efficiently both negative and positive particles
- Maximum deflection angle scale with different power law:
  $E^{-0.075}$ (planar) vs $E^{-0.25}$ (axial)

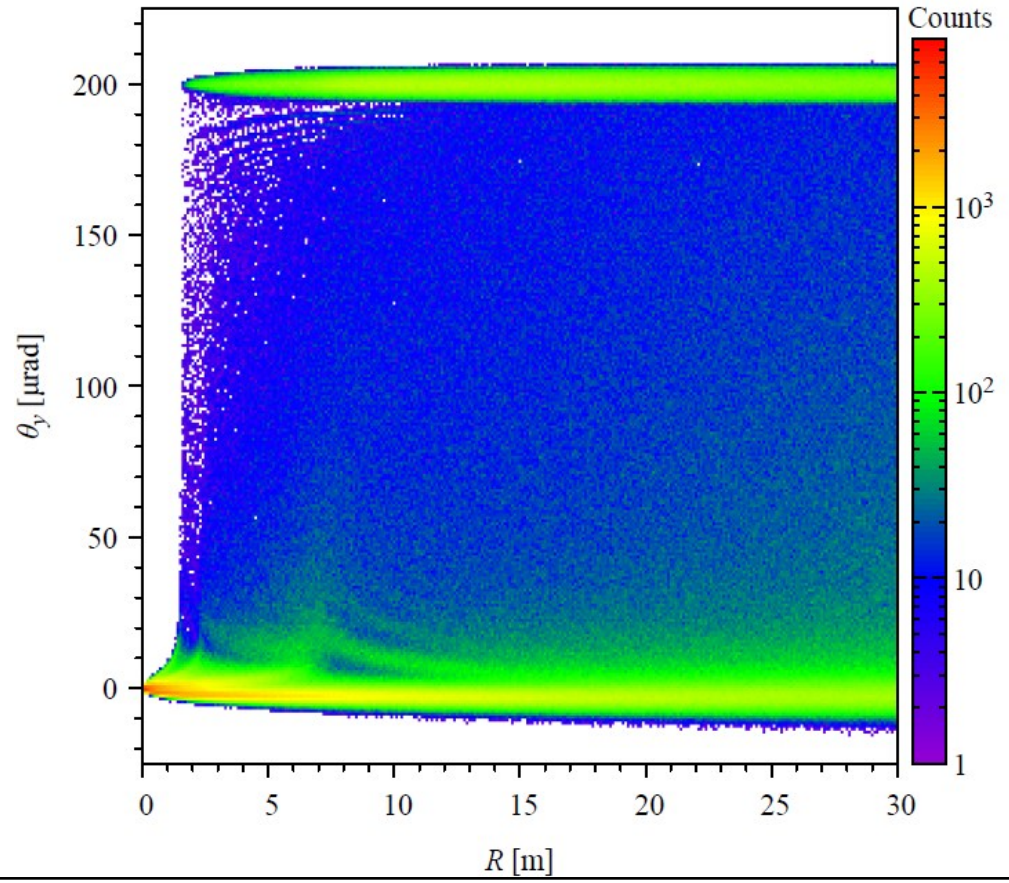


Comparison of planar and axial stochastic deflection at 1 TeV

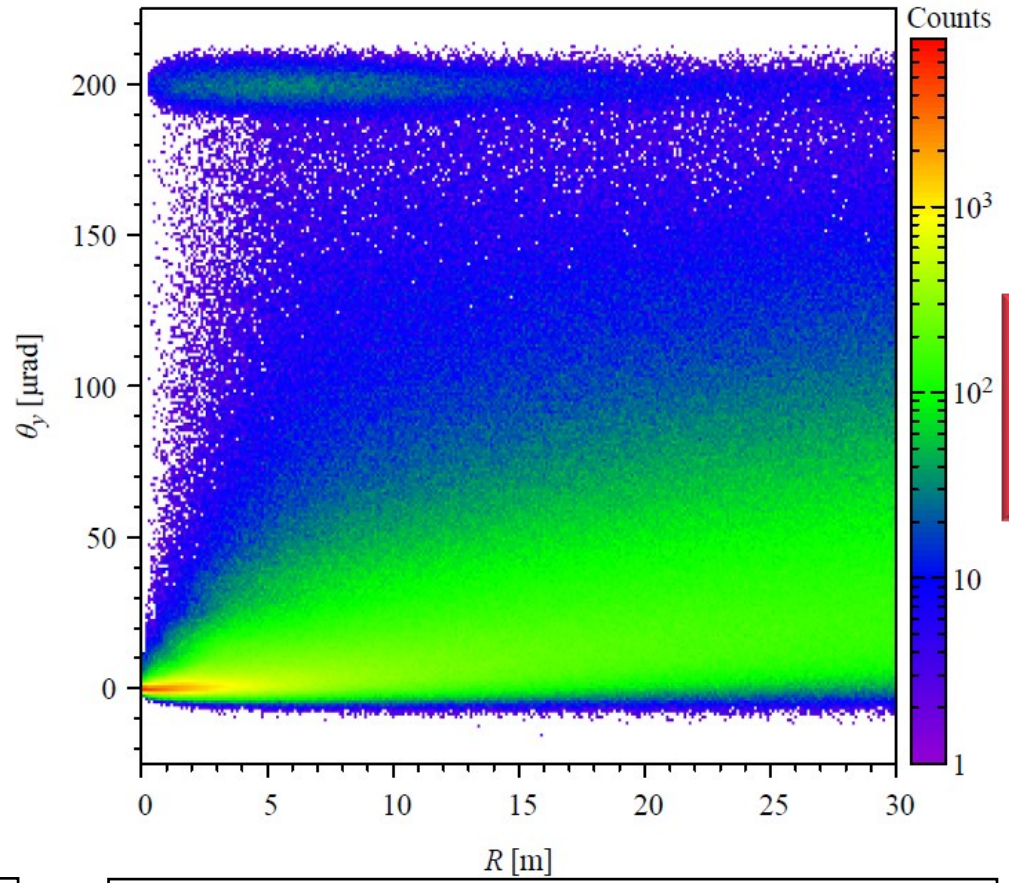
- A large simulation campaign has been carried out with both muon and anti-muon of 1 TeV/c momentum
- Optimal radius of curvature has been obtained for deflection angles from 2 μrad up to 200 μrad
- Cases for 200μrad, 50μrad are presented as example in this work

Large angle deflection μ- (200μrad)

(111) plane



<110> axis



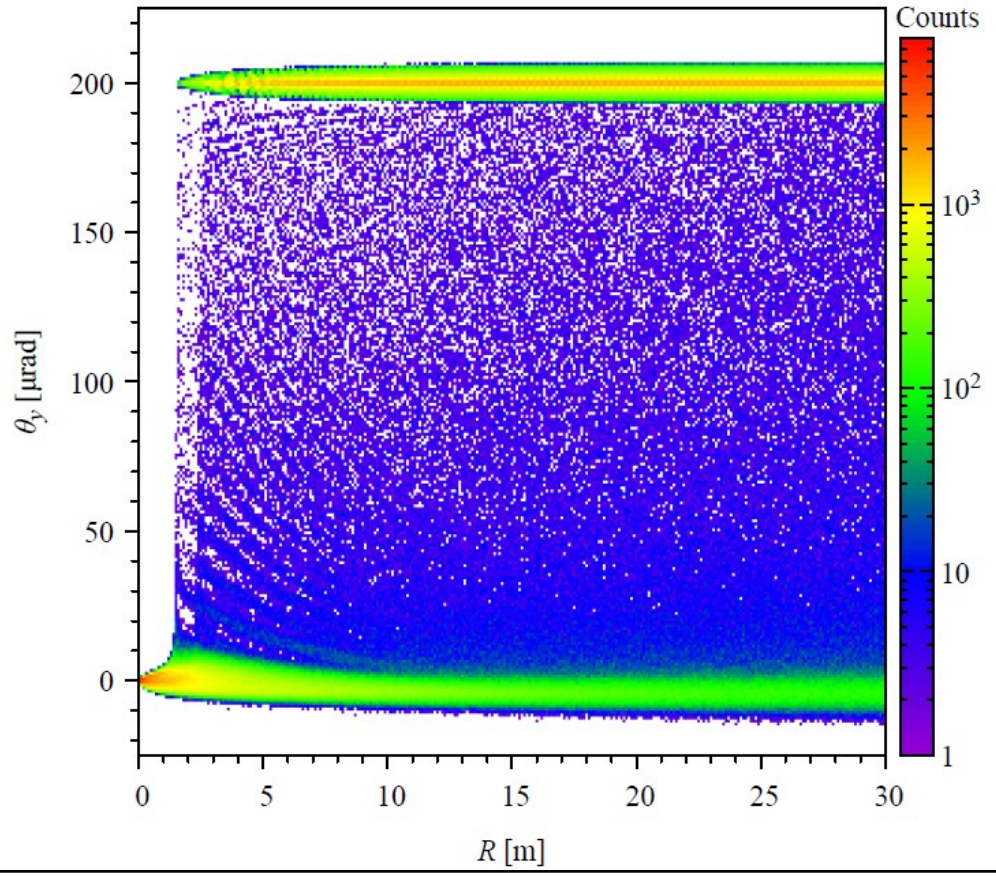
Courtesy of I. Kyryllin

Better single pass efficiency with planar channeling

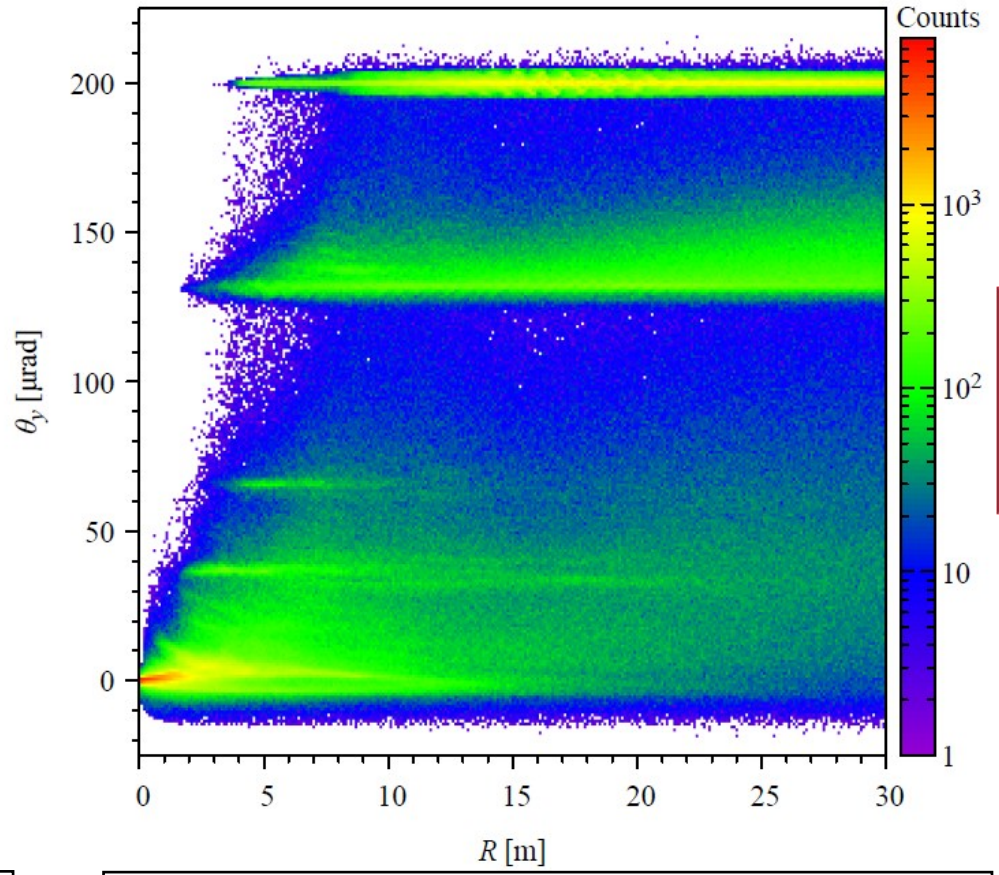
Optimal radius of curvature for R ~6-7m

Large angle deflection μ+ (200μrad)

(111) plane



<110> axis



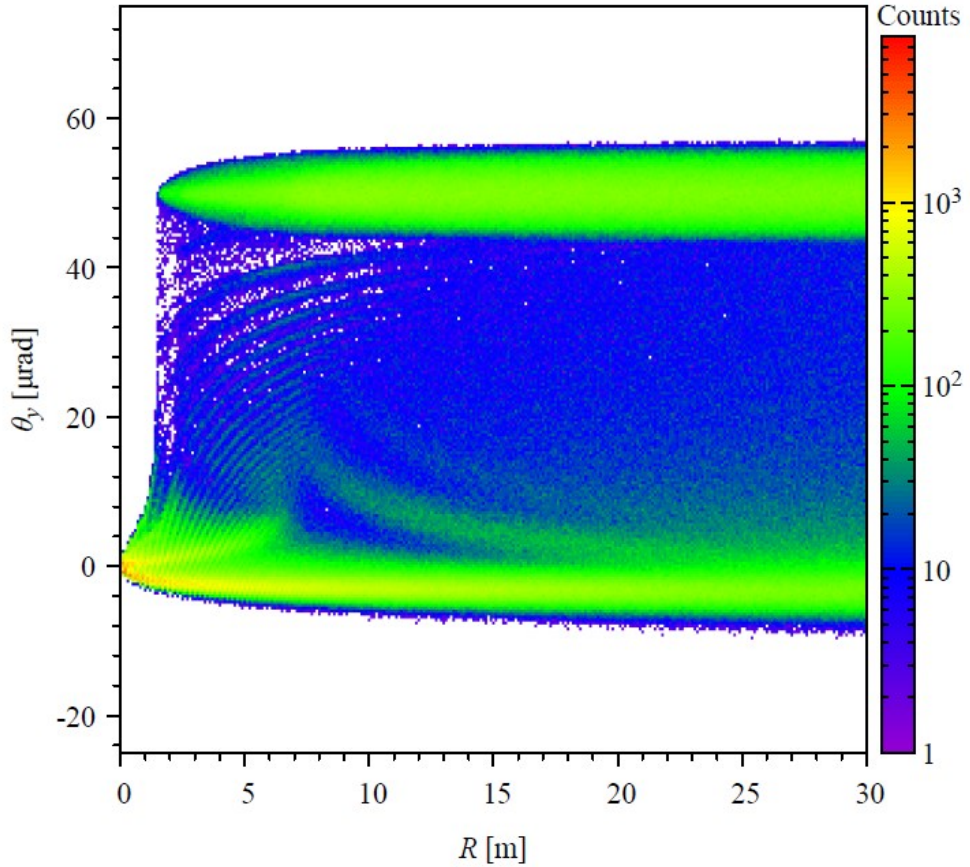
Courtesy of I. Kyryllin

Better single pass efficiency with planar channeling

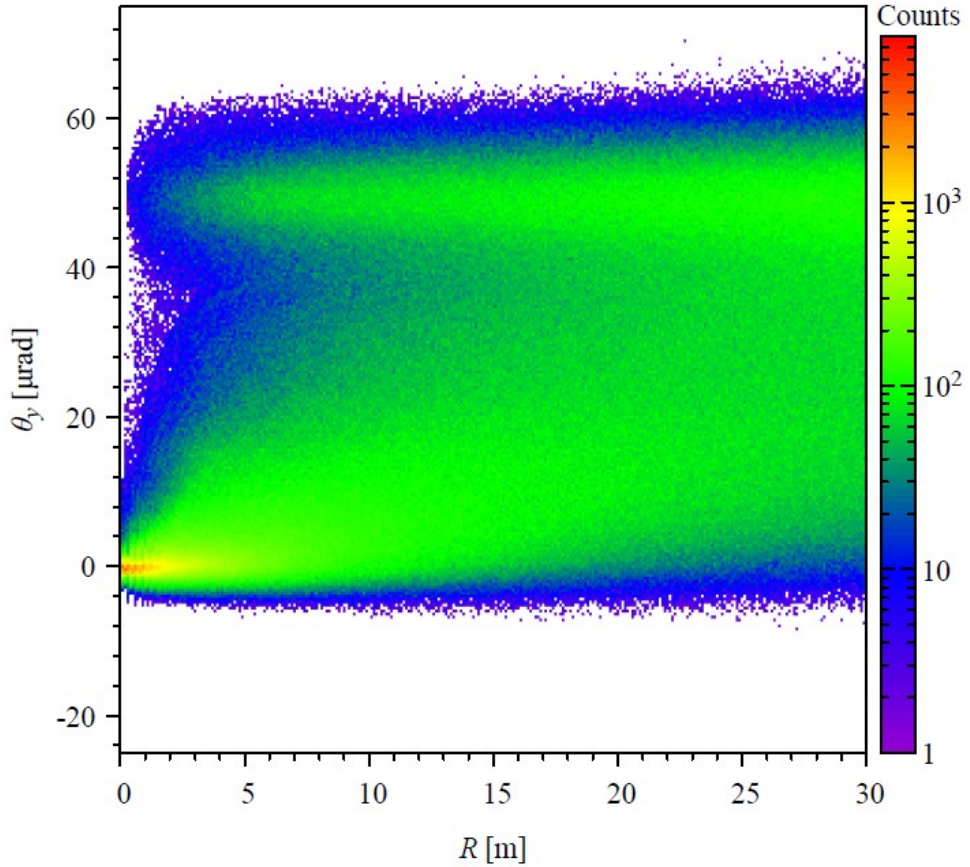
Optimal R between 15-20m

Small angle deflection μ- (50μrad)

(111) plane



<110> axis



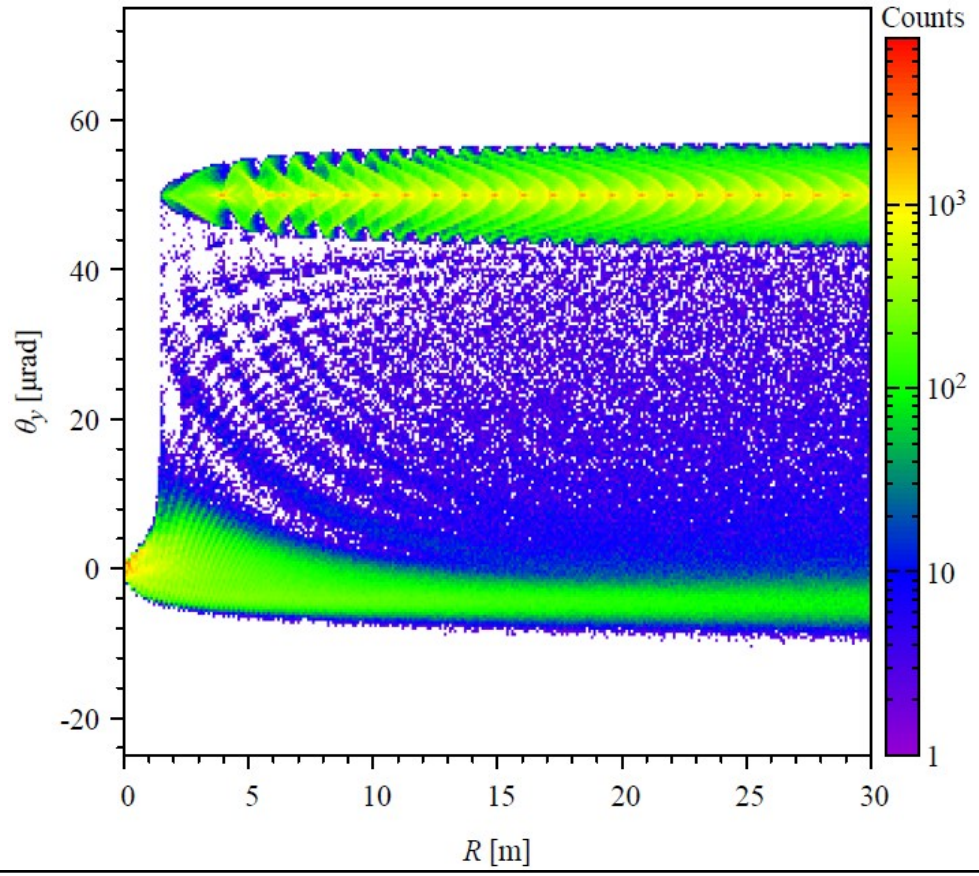
Courtesy of I. Kyryllin

Better single pass efficiency with planar channeling

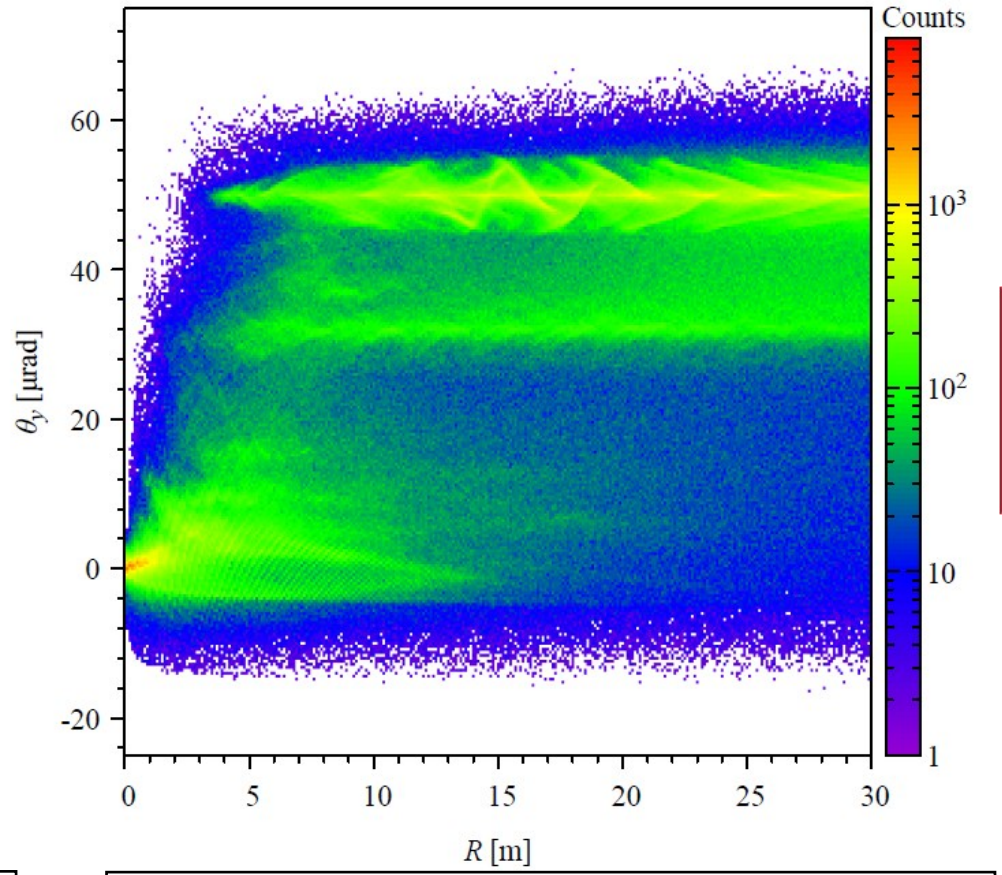
Optimal R between 20-25m

Small angle deflection μ+ (50μrad)

(111) plane



<110> axis



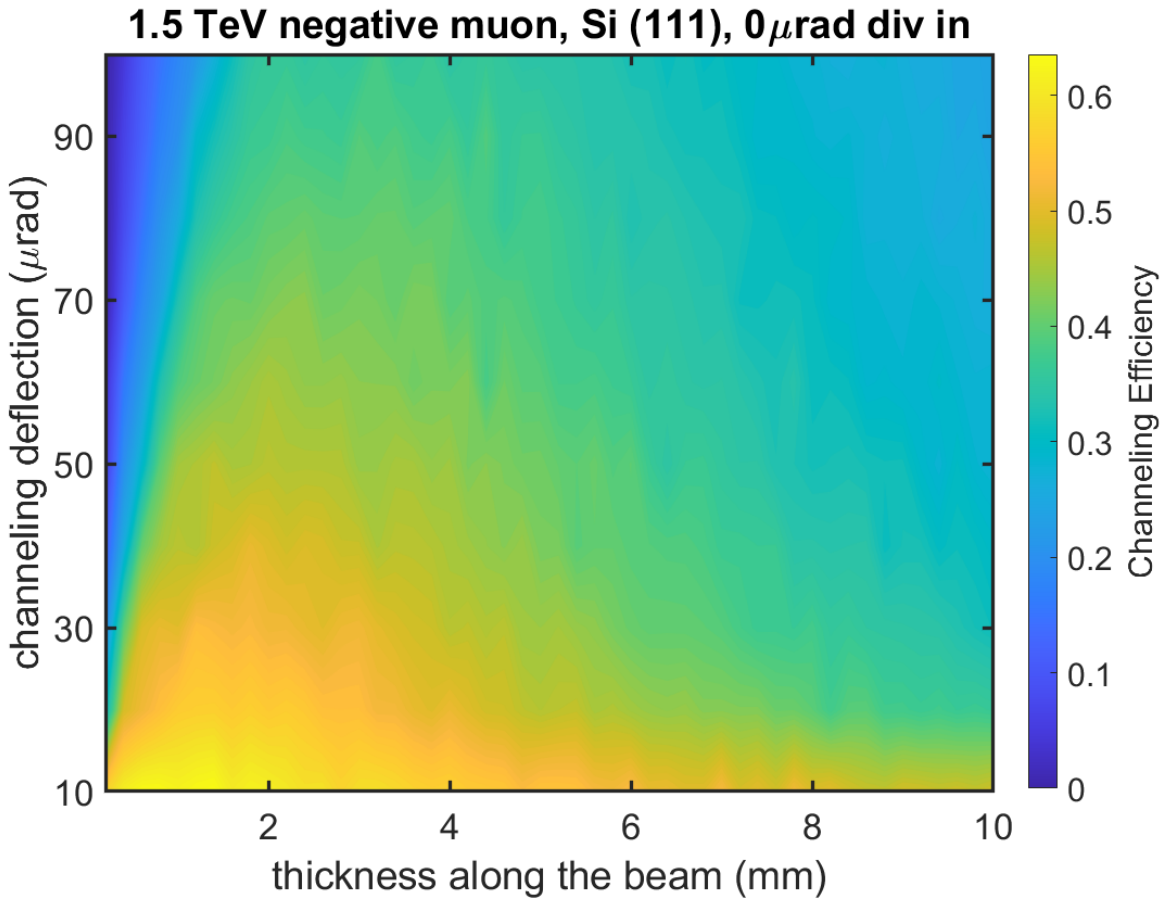
Courtesy of I. Kyryllin

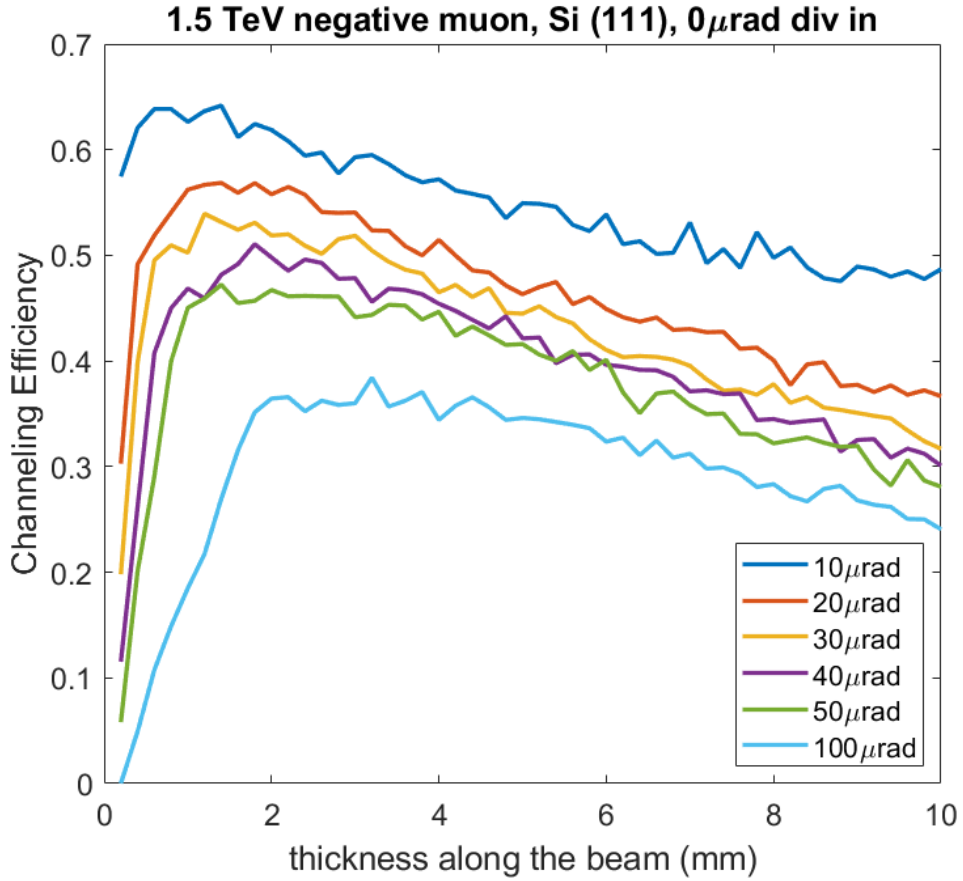
Better single pass efficiency with planar channeling

Optimal R between 15-20m

μ- planar channeling efficiency 1.5TeV

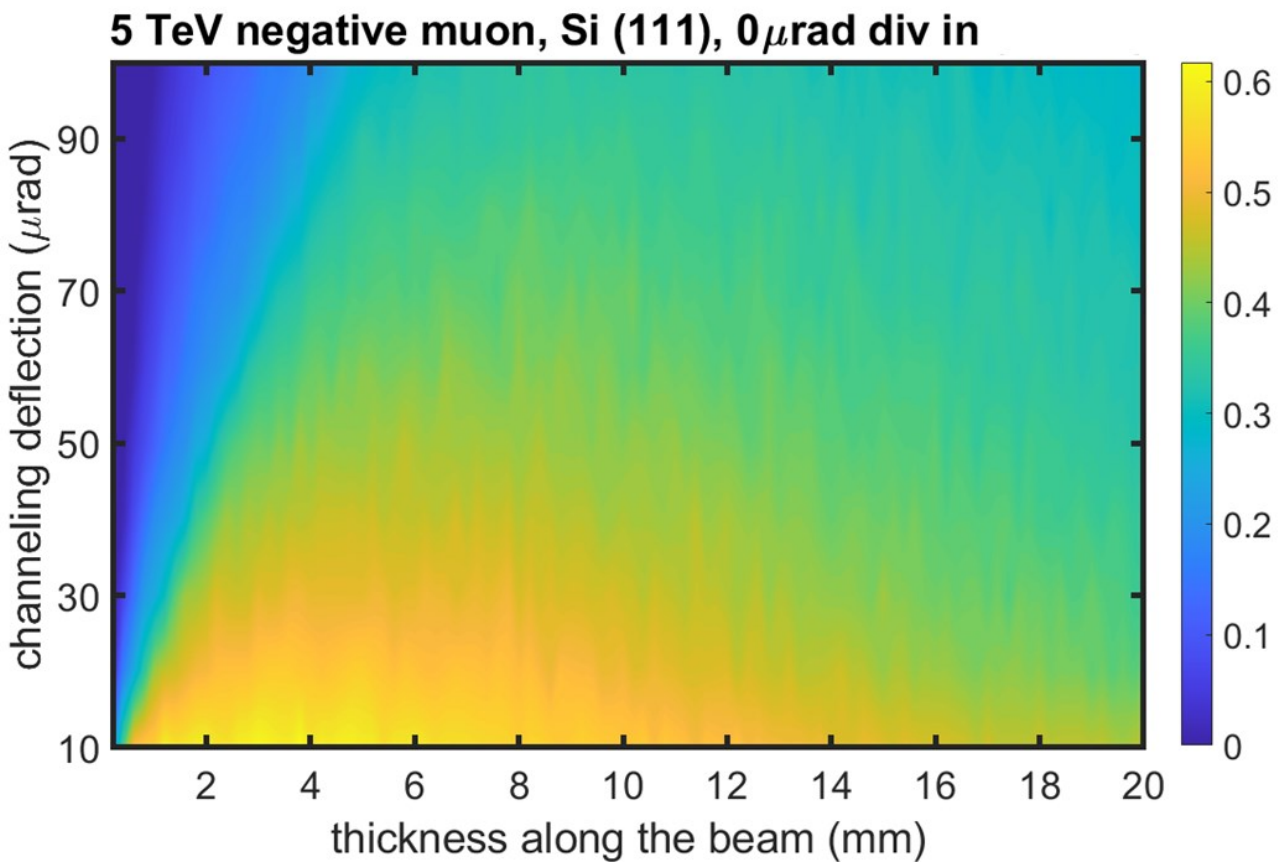
1mm<Optimal crystal length <2mm, possible increase with multi-turn efficiency

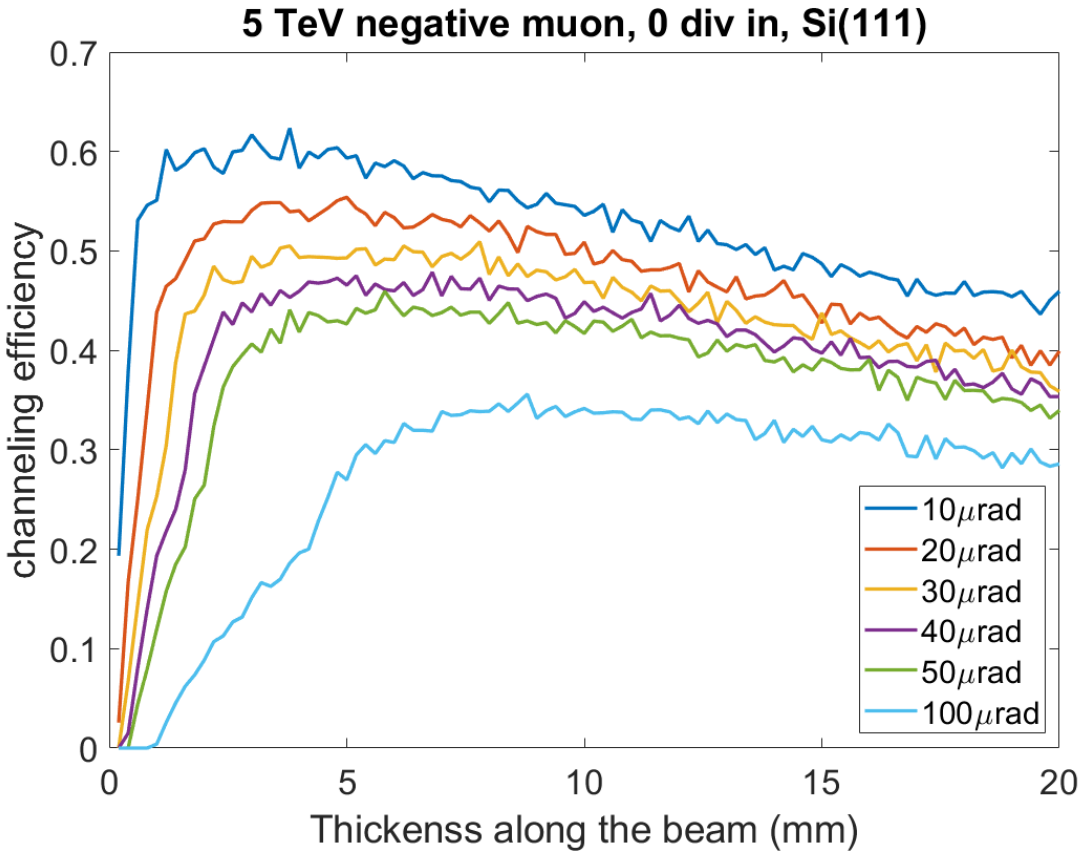




μ- planar channeling efficiency 5TeV

2mm<Optimal crystal length <5mm, possible increase with multi-turn efficiency





Conclusion

- Comparison of axial stochastic deflection and planar channeling as steering mechanism for TeV muon was carried out. Planar channeling was more efficient option as we reach multi-TeV scale

- Optimal single pass efficiency condition was obtained for 1.5 TeV and 5 TeV negative muon case.

- Future study of volume reflection phenomena such as Multiple Volume Reflection in One Crystal and Multiple Volume reflection in a series of aligned bent crystals.

List of Authors

- Marco Romagnoni (University of Ferrara)
- Igor Kyryllin (Kharkiv Institute of Physics and Technology)
- Laura Bandiera (INFN Ferrara)
- Nicola Canale (INFN Ferrara)
- Vincenzo Guidi (University of Ferrara)
- Lorenzo Malagutti (INFN Ferrara)
- Andrea Mazzolari (University of Ferrara)
- Riccardo Negrello (University of Ferrara)
- Gianfranco Paternò (INFN Ferrara)
- Melissa Tamisari (University of Ferrara)
- Alexei Sytov (INFN Ferrara)

Thank you

Co-funded by the European Union (EU). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the EU or European Research Executive Agency (REA). Neither the EU nor the REA can be held responsible for them.

Back-up slides