Gamma Factory Low-Emittance Muon Source

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Outline

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- Pion Production
- Muon Production
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Introduction

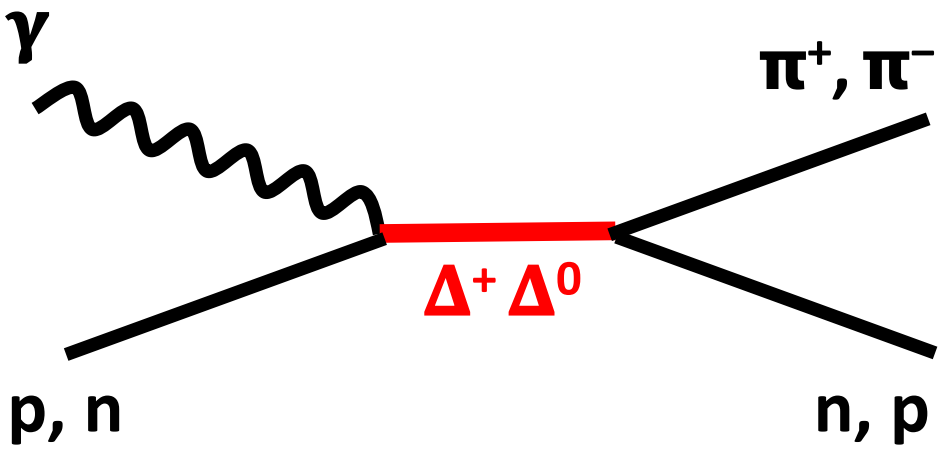
- **Muon collider is the only viable project for the multi TeV lepton collisions.**
- **Being about 200 times more massive than electrons, muons suffer significantly less from synchrotron-radiation losses and therefore can be accelerated efficiently in a circular machine.**
- **But reaching high luminosities is extremely tough owing to short muon lifetime at rest (2.2 μs) and the difficulty of producing large numbers of muons in suitably shaped bunches.**
- **Muon beams are obtained via K or π decays produced in proton interaction to a target.**

- **Muon beams, produced by the proton-beam-driven source, would need to be cooled to be of use for the muon collider.**

This talk presents a new concept of the GF-driven muon beam source for which the beam cooling may no longer be needed.

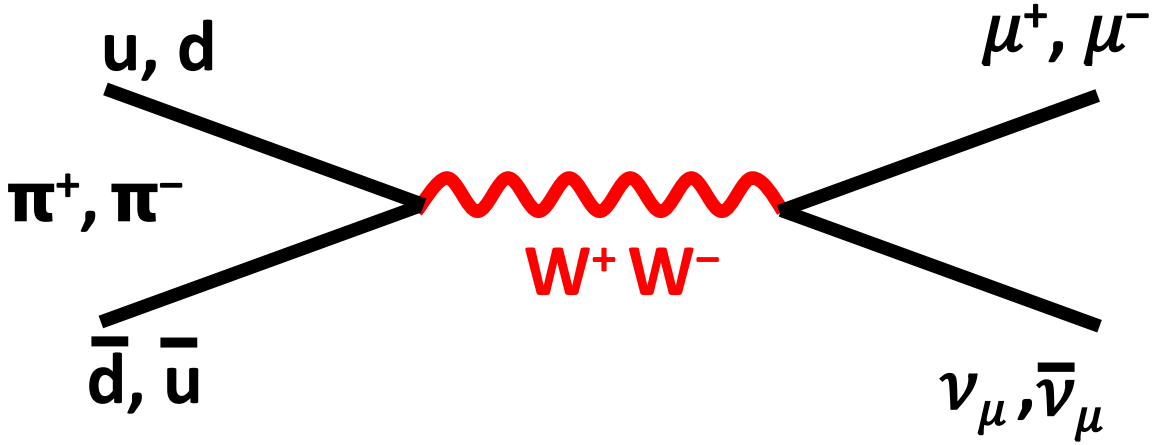
Pion photoproduction

$\gamma + p \rightarrow \Delta^+ \rightarrow n + \pi^+$
$\gamma + n \rightarrow \Delta^0 \rightarrow p + \pi^-$



Charged Pion Decay

$\pi^+ \rightarrow W^+ \rightarrow \mu^+ + \nu_\mu$
$\pi^- \rightarrow W^- \rightarrow \mu^- + \bar{\nu}_\mu$



Novel paradigm: μ and ν sources based on exclusive pion production in photo-excitation of Δ resonances with the Gamma Factory photon beam

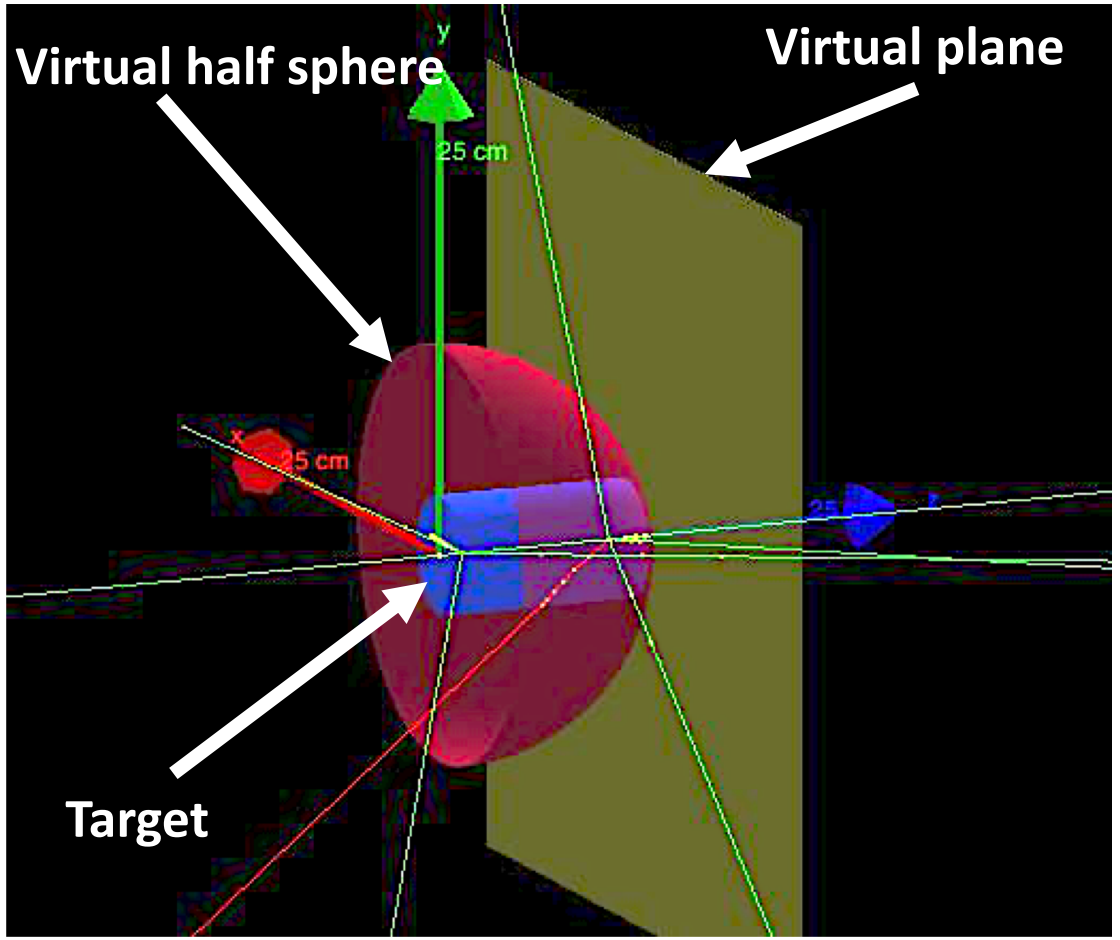
GEANT4 Simulation Layout

Gamma beam energy -- 300 MeV, 350 MeV and 410 MeV.

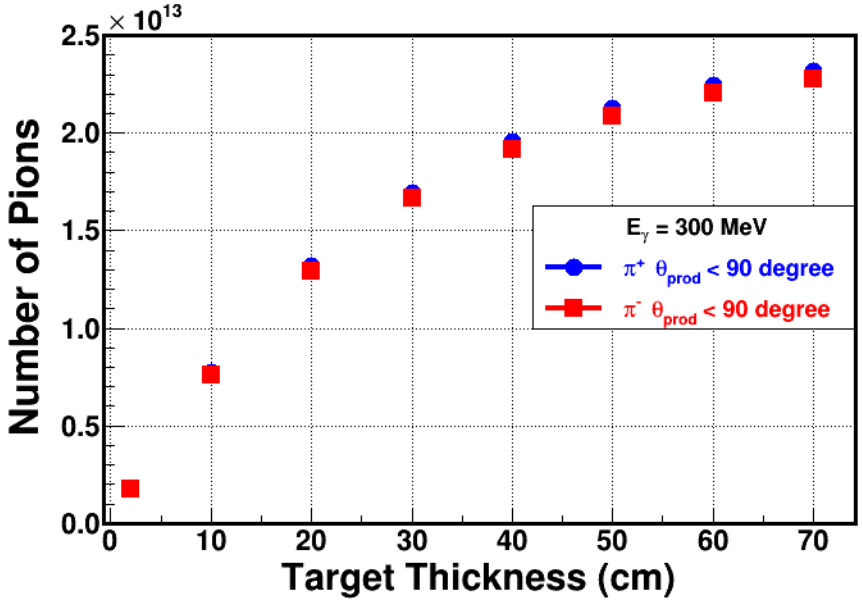
Ideal gamma beam – without energy, angular and spatial distribution (pencil gamma beam).

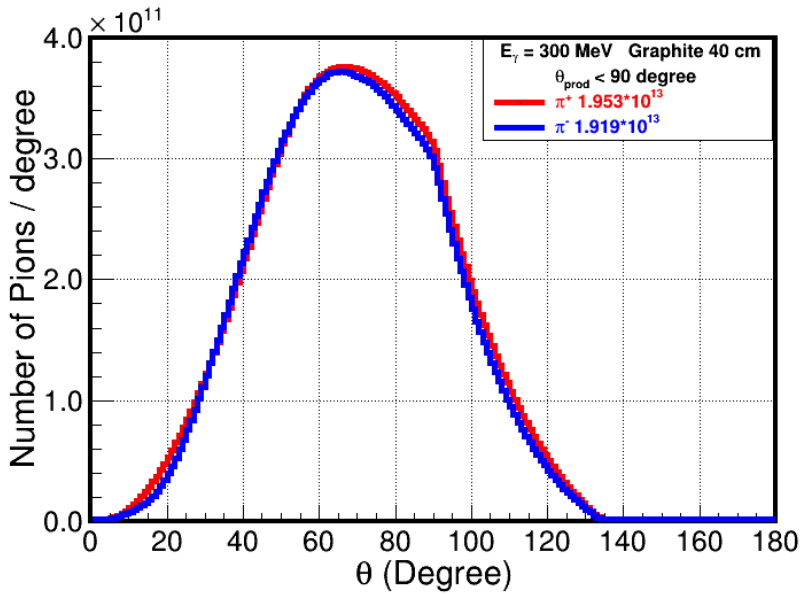
Different materials were investigated as a target candidates - graphite, beryllium, copper, tungsten etc.

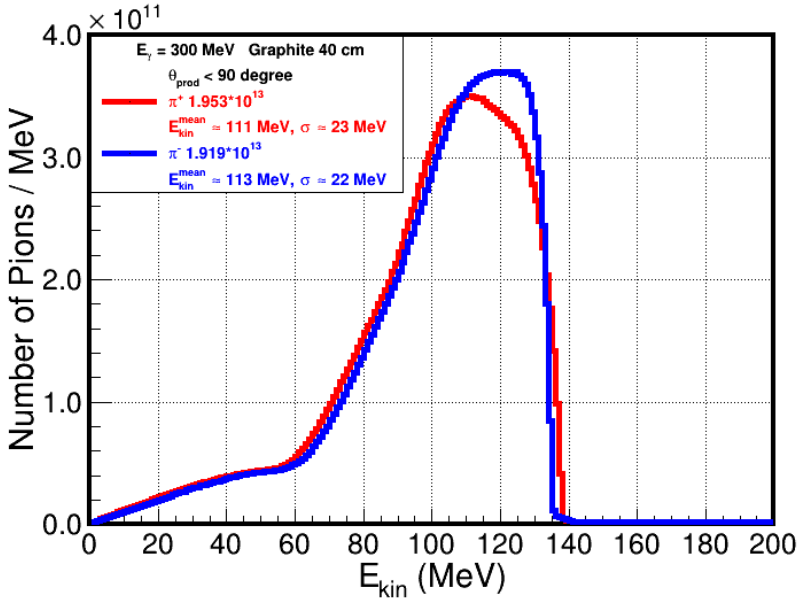
For graphite target we have nearly the same number of π^+ and π^-.



Number of produced π^+ and π^-

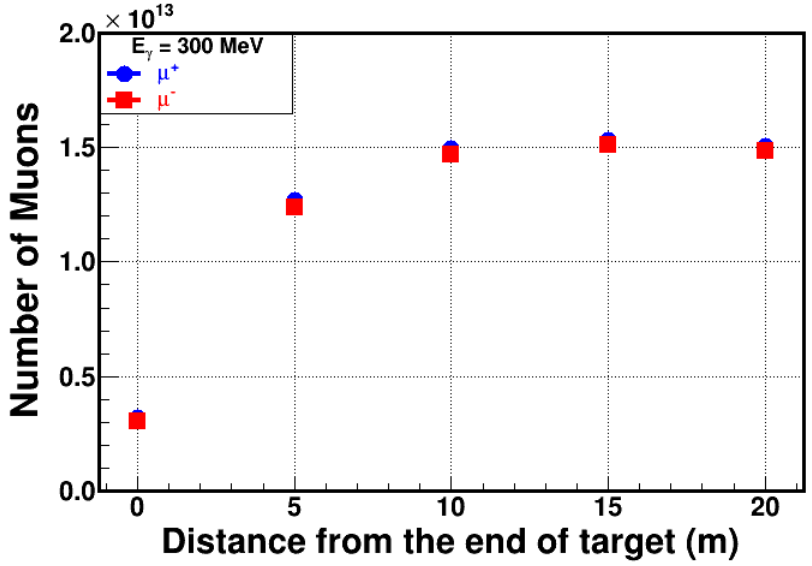


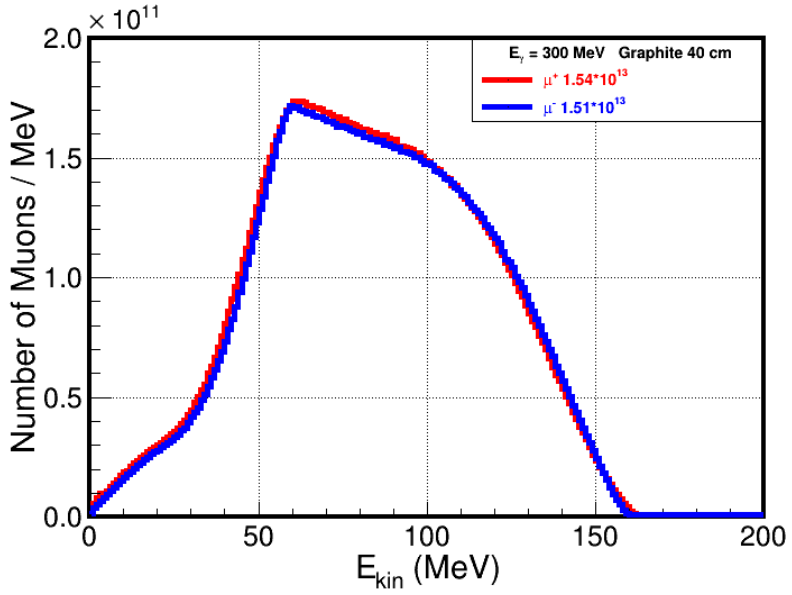




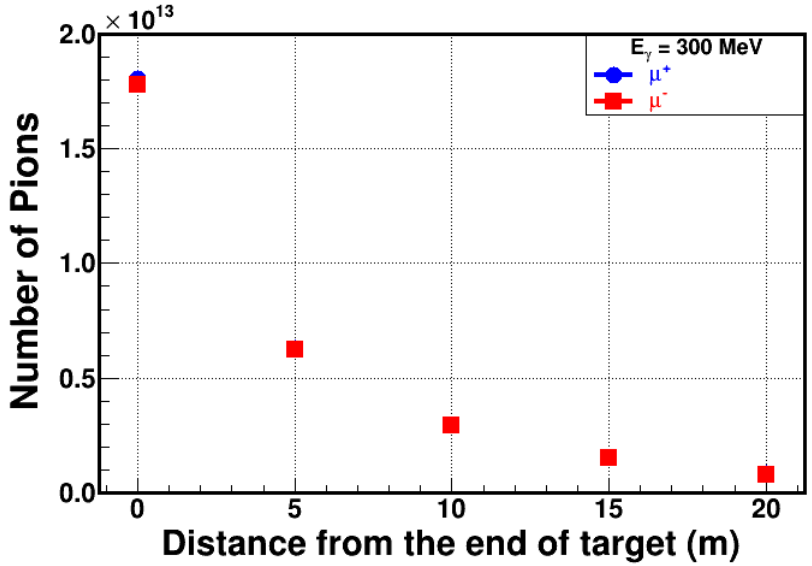
Simulations were done for 1MW photon beam power (2×10^{16} γ / sec).
Number of pions for 40 - 50 cm graphite is about 2×10^{13} pions / sec.

Number of produced μ^+ and μ^-

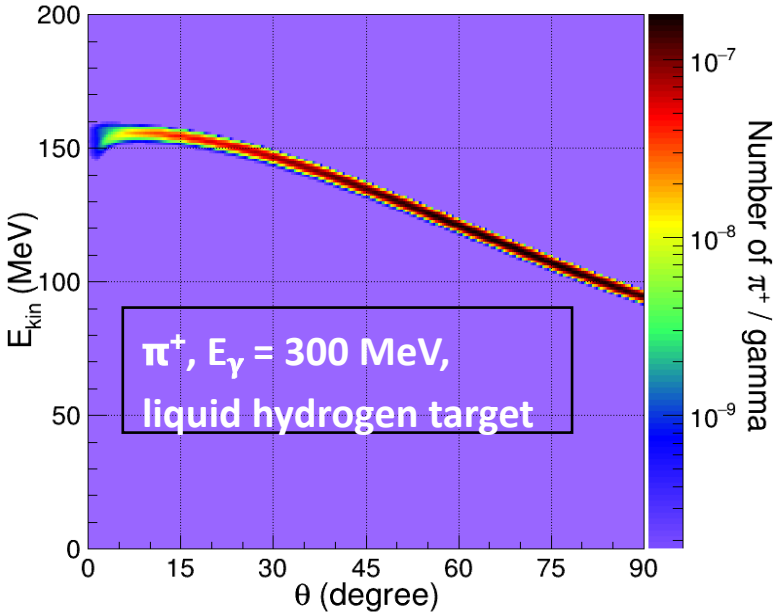




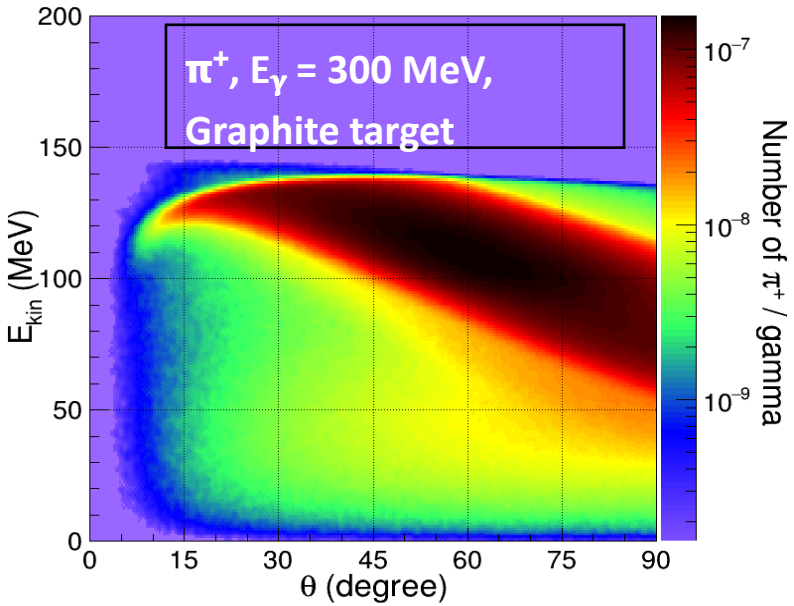
Pions mean lifetime - 26 nsec

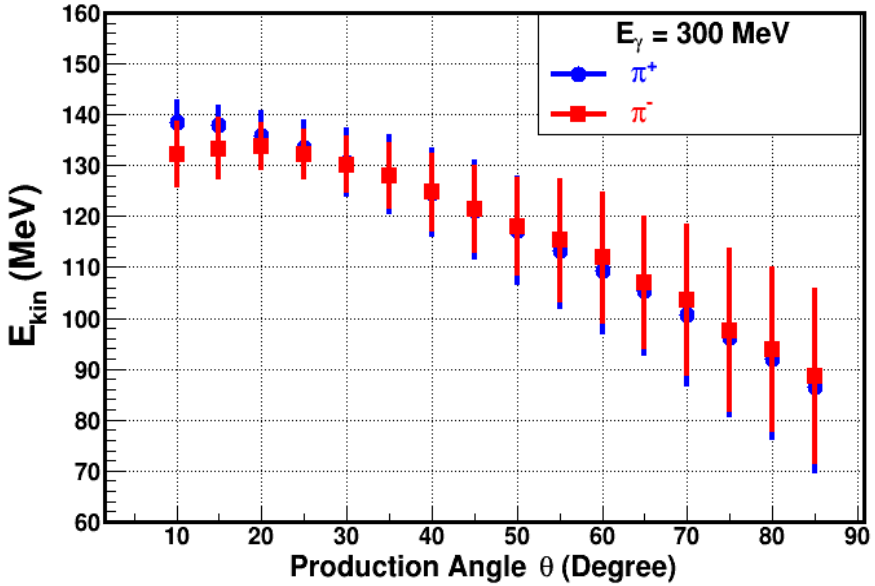


Dist (m)	π^+ x 10^{13}	μ^+ x 10^{13}
0	1.81	0.32
5	0.63	1.27
10	0.30	1.49
15	0.15	1.54
20	0.08	1.51



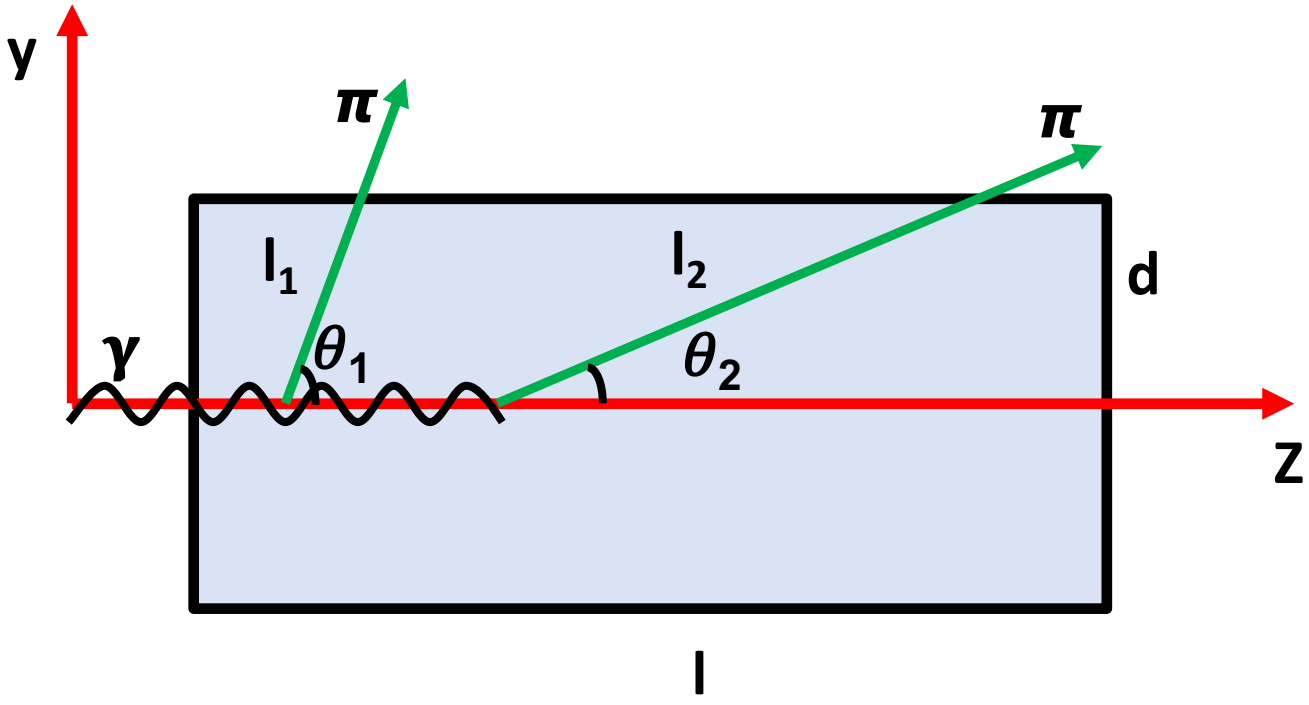
- ***Pion energy and transverse momentum no longer random***
- ***Fully specified by one parameter: the pion emission angle, θ***





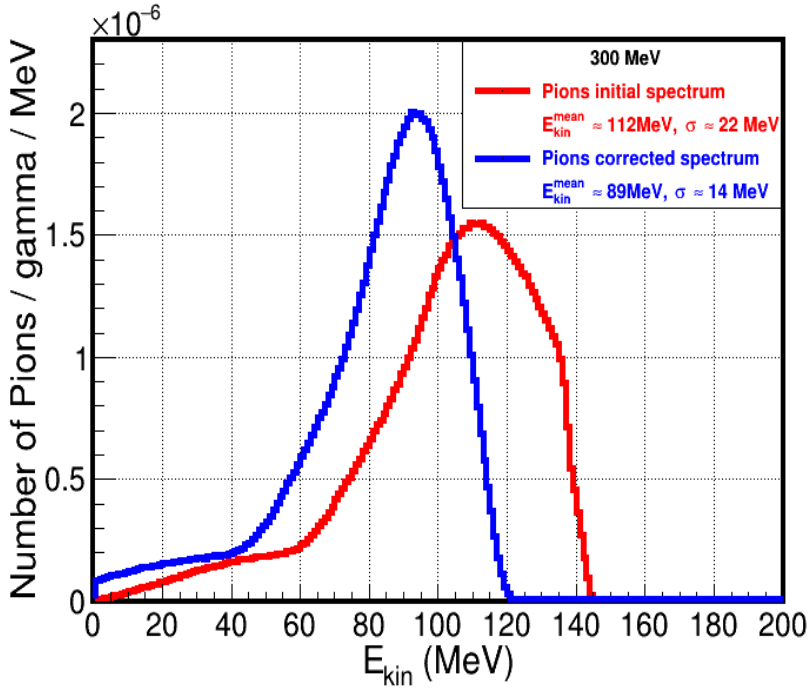
Symmetry of π^+ and π^- production for isoscalar target (e.g. graphite) ***(the cost: Fermi smearing - error bars)***

Further "Monochromatisation" of the pion kinetic energy by a suitable choice of the target radius



$\frac{dE}{dx} = \varepsilon \sim 5$ MeV / cm Energy loss

l = d / sinθ Distance in target



Energy and p_T parametrization:

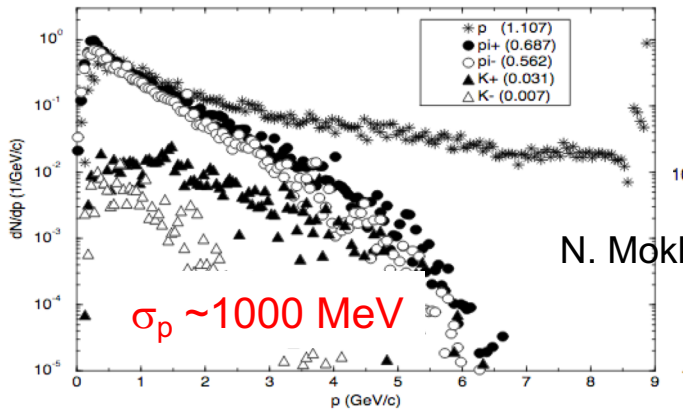
$$E_{corr}^{kin} = E_{0}^{kin} - \varepsilon \frac{d}{sin\theta}$$

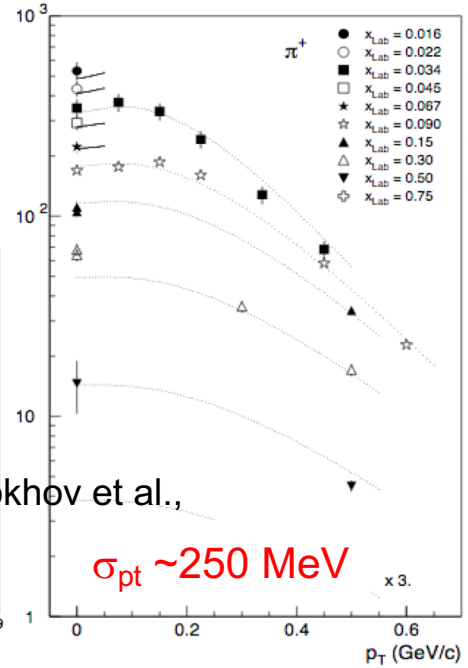
Pion production rate and spectra: proton versus GF γ–beams

8 GeV proton beam

For λ_i = 1.5 **graphite** target:
~ 4.1 x 10^{14} π^+/s and ~ 2.6 x 10^{14} π^-/s for 1 MW p beam

1 MW photon beam deposits ~ 6 times less energy in the λ_i = 1.5 graphite target! …in addition ~20% muons lost in the cooling channel

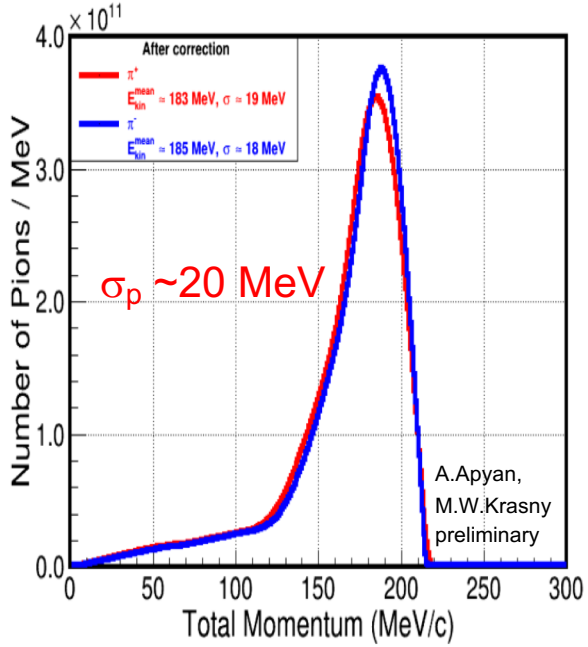


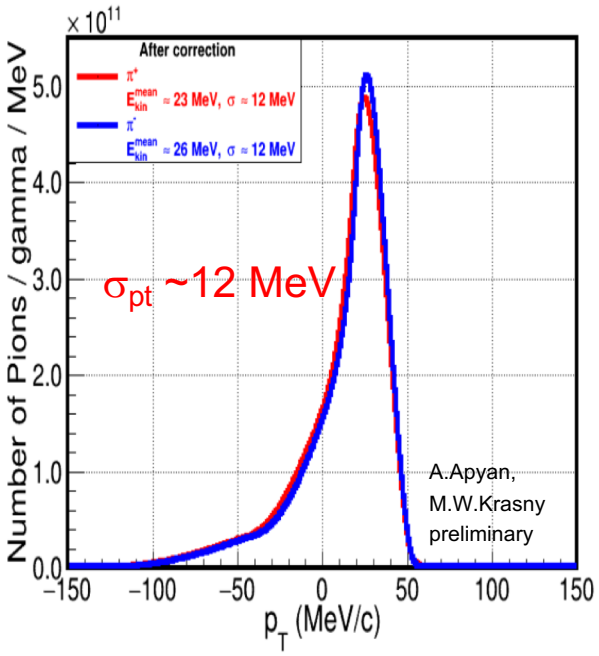


N. Mokhov et al.,

300 MeV GF γ-beam

For λ_i = 1 **graphite** target :
~ 2 x 10^{13} π^+ and π^- /s for 1 MW γ beam (2 x 10^{16} γ/s)





$\varepsilon_{T(x,y)} \sim (\sigma_T \sigma_{pt})/mc^2$
$\varepsilon_L \sim (\sigma_z \sigma_p)/mc^2$

Expected **reduction** of the **transverse pion-beam emittance** (x,y) by a factor of > **10** and **longitudinal emittance** by a factor of > **20**. If preserved while forming μ-beam (under study), no cooling necessary!

Potential advantages of the Gamma Factory photon-beam-driven muon sources

- *Replacing the high-power proton Linac beam by the **LHC-driven GF photon-beam** may turn out to be an exciting, cost-optimising option for the future **muon collider**.*
- ***Producing** and **handling** of **> 1 MW photon beams** may turn out be **easier** than > 1 MW proton beams (less power deposited in the target).*
- ***GF** source could produce **low-emittance muon beams** for which the **muon-cooling** phase may be **avoided.***
- *The almost exact **symmetry** of the π^+ / π^- and μ^+ / μ^- is **assured** (contrary to the proton driven sources).*
- *The above two merits may **facilitate** the design of the **muon collider**.*

Thank you for your attention