


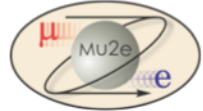
A New High Intensity Muon Beamline at the Paul Scherrer Institut

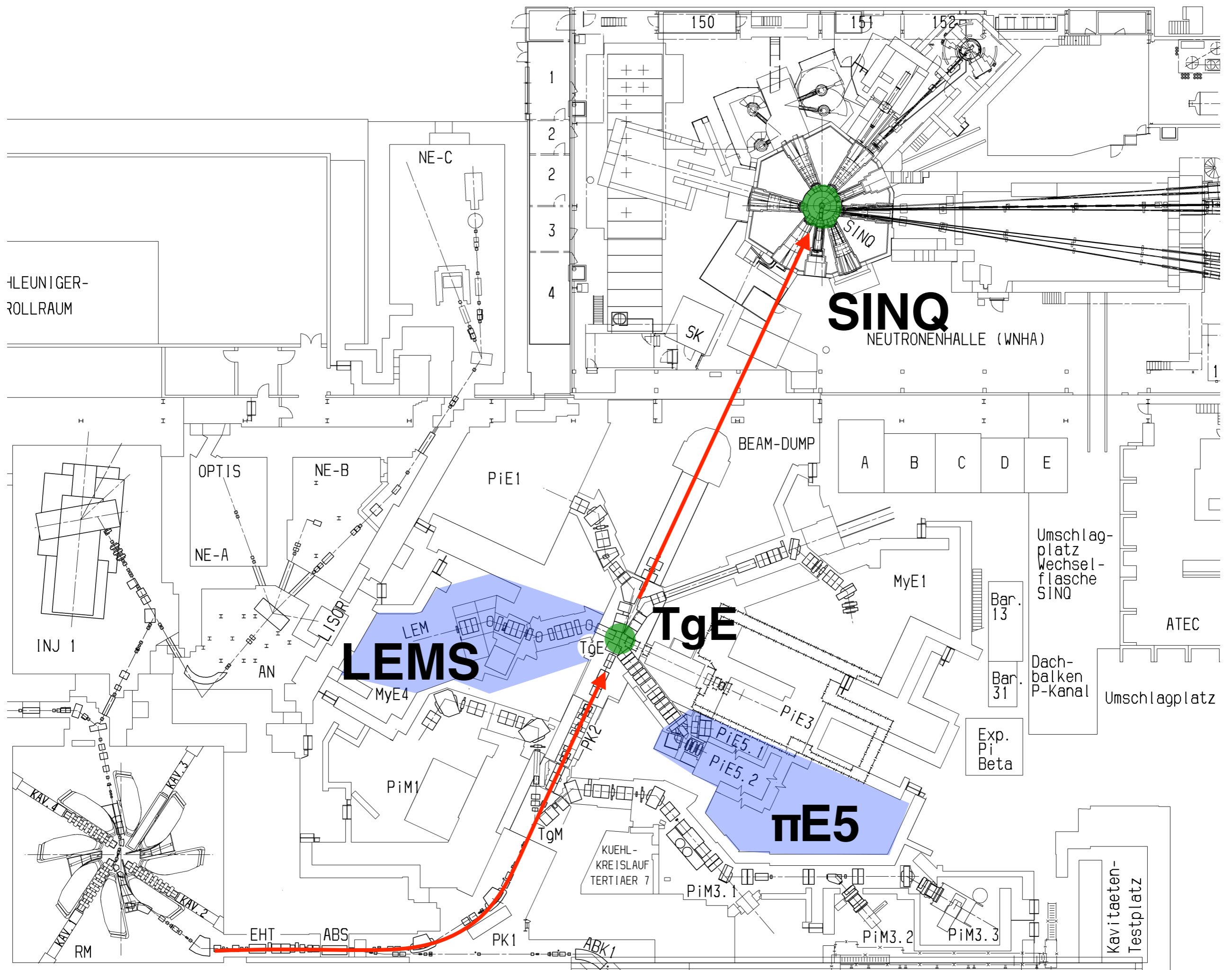
Zachary Hodge
on behalf of the HiMB Project
SPS Annual Meeting 2014, Fribourg
2 July 2014

Intensity Frontier Accelerator Facilities

- PSI home to highest intensity DC μ^+ beam @ $10^8 \mu^+/s$
- New cLFV experiments require significantly higher muon rates to achieve sensitivity goals
MEG: $\mathcal{O}(6 \times 10^{-14})$
Mu3e: $\mathcal{O}(10^{-16})$
- Provide a new μ SR facility
- Maintain PSI leadership in high intensity muons
- Potentially: $10^{10} \mu^+/s$

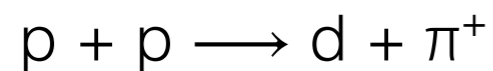
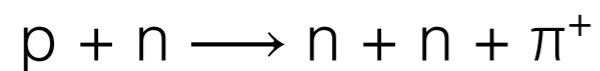
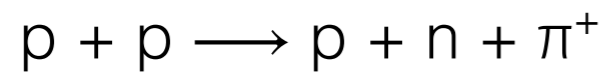
 **J-PARC** $\rightarrow 10^{10} \mu^-/s$
COMET: $R_{\mu e} = \mathcal{O}(10^{-17})$

 **Fermilab** $\rightarrow 5 \times 10^{10} \mu^-/s$
 $R_{\mu e} = \mathcal{O}(10^{-17})$

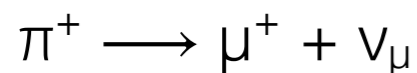


Pion Production and Surface Muons

- 590 MeV proton strikes nucleon in target

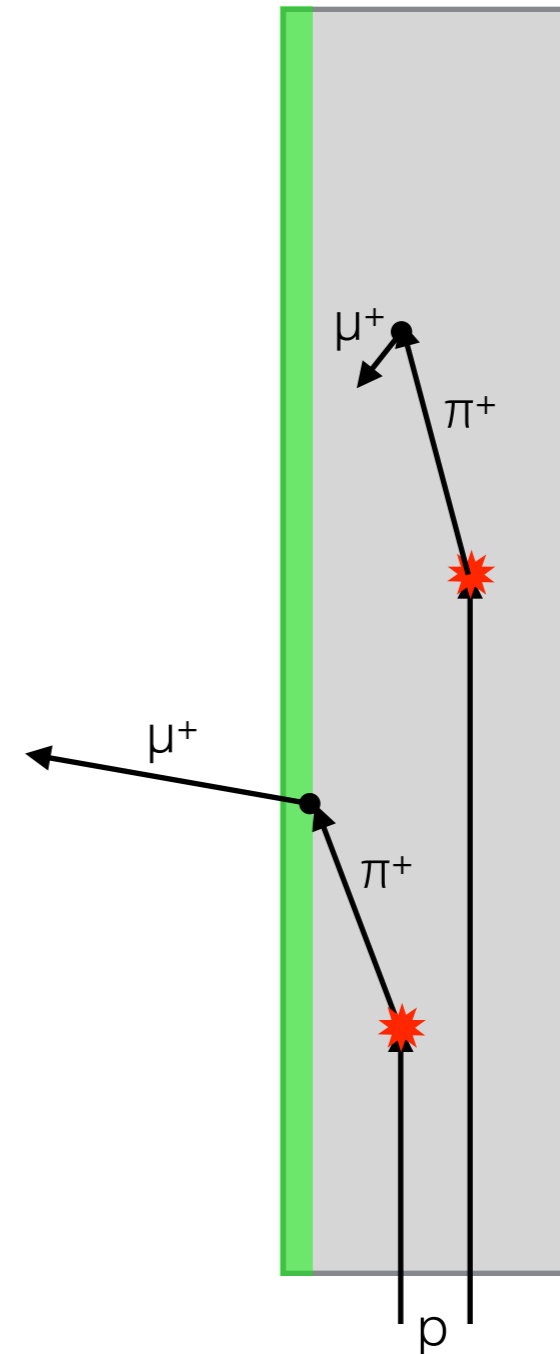


- Pion is stopped in the target material and decays.



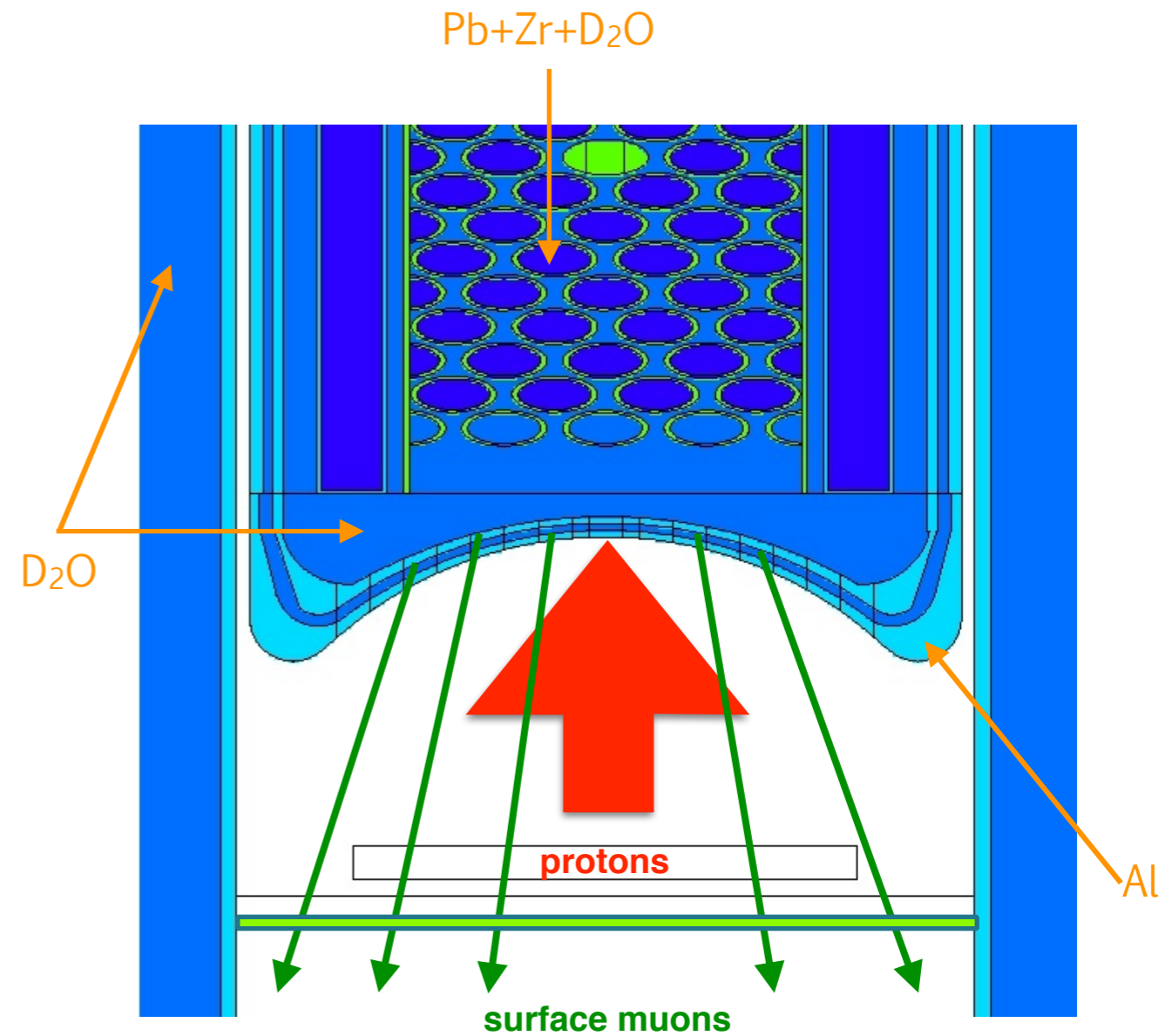
Those near surface of target produce monochromatic “surface muons”.

- $P_\mu = 29.79 \text{ MeV}/c$
 $E_\mu = 4.12 \text{ MeV}$
~100% polarized



HiMB Concept

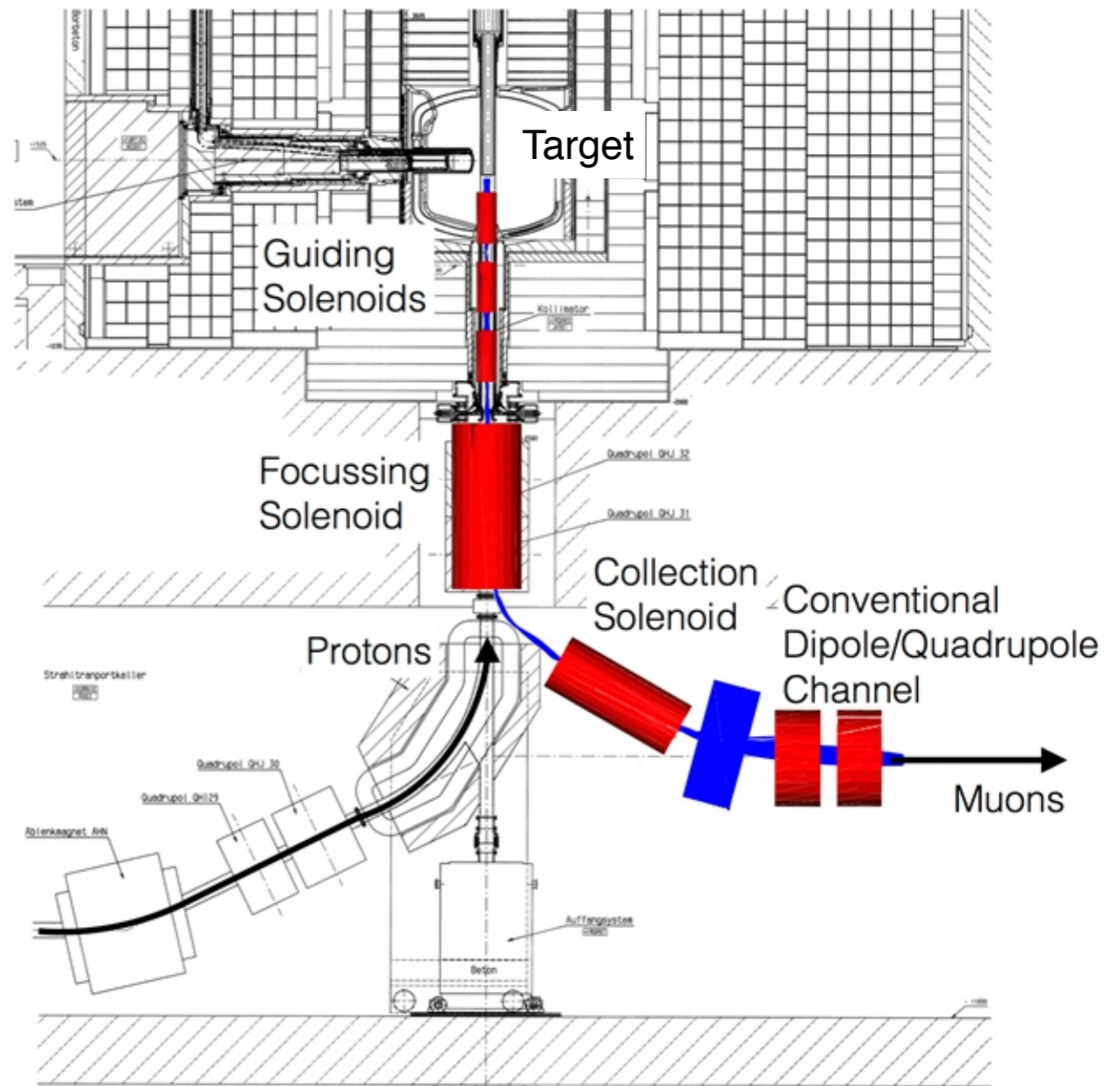
- SINQ spallation neutron source
- Pions produced in SINQ target are stopped in the Al window
- Surface muons that are produced anti-parallel to proton beam are collected



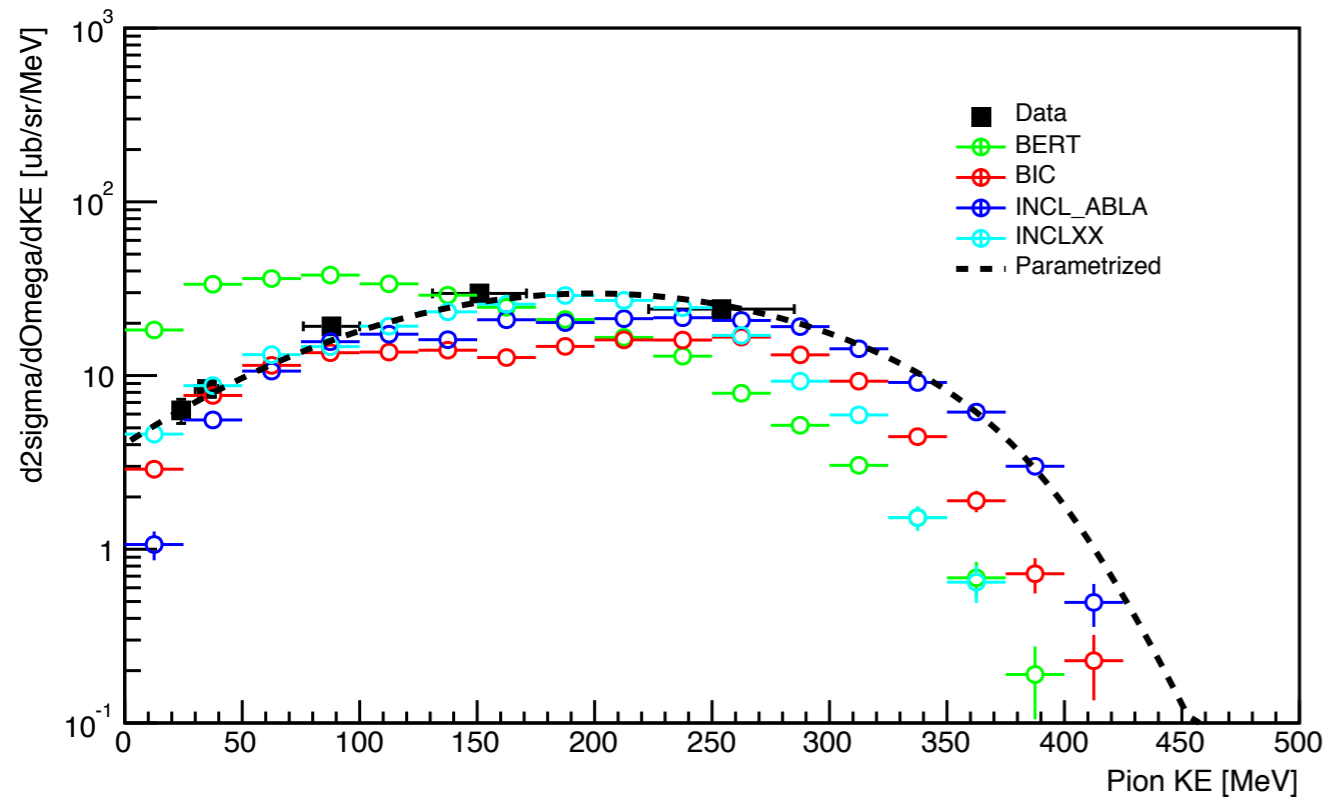
HiMB Concept

- Muons transported opposite to proton beam in solenoid channel. Extracted prior to fringe field of last bending magnet.
- Continue in a conventional beamline to experiment
- Source validation and toolset completed
- Currently studying solenoidal channel acceptance
- $R_{\mu^+} = 1.2 \times 10^{11} \mu^+/\text{s}$ downward below source with $I_p = 1.7 \text{ mA}$ on SINQ

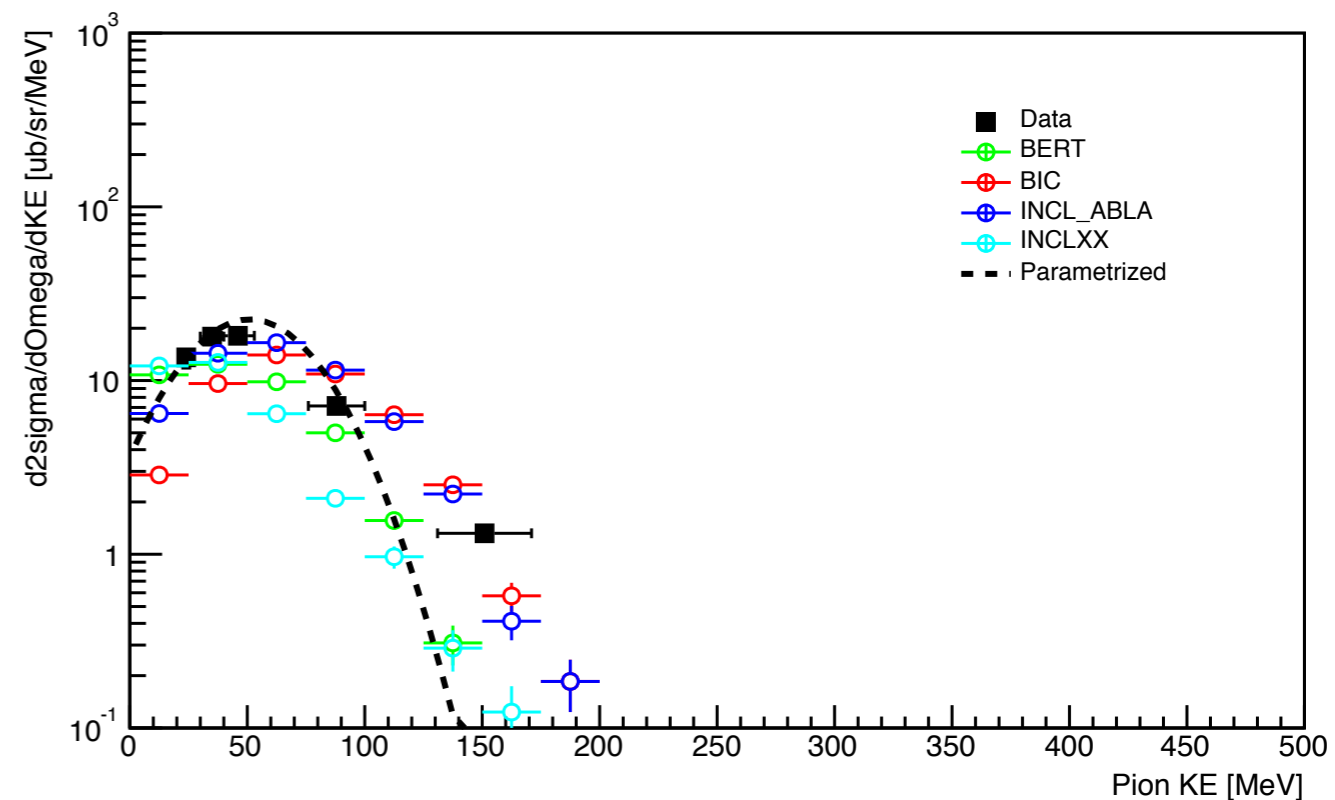
HiMB Conceptual Layout



Cross section on C, 585 MeV, π^+ , $\theta = 22.5^\circ$



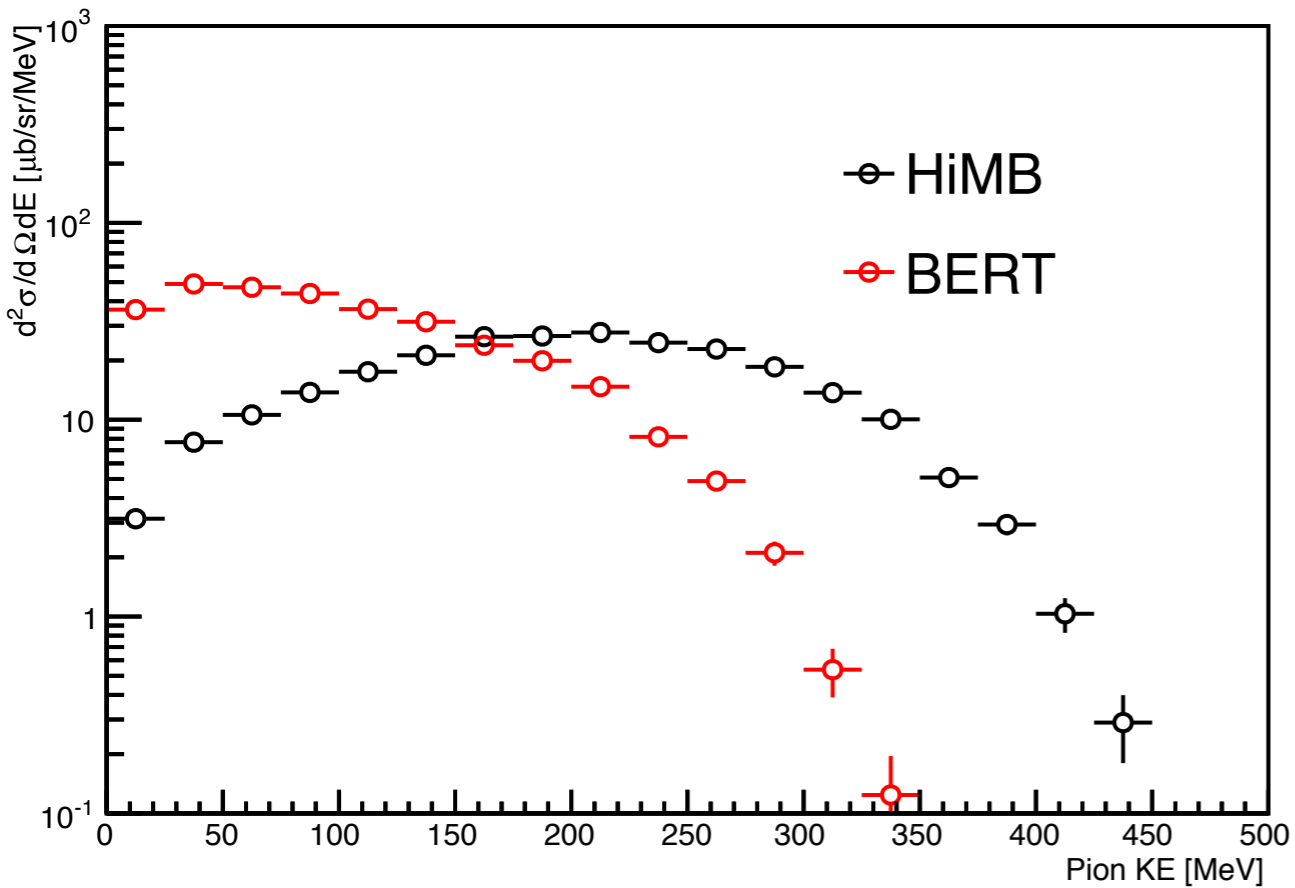
Cross section on C, 585 MeV, π^+ , $\theta = 135^\circ$



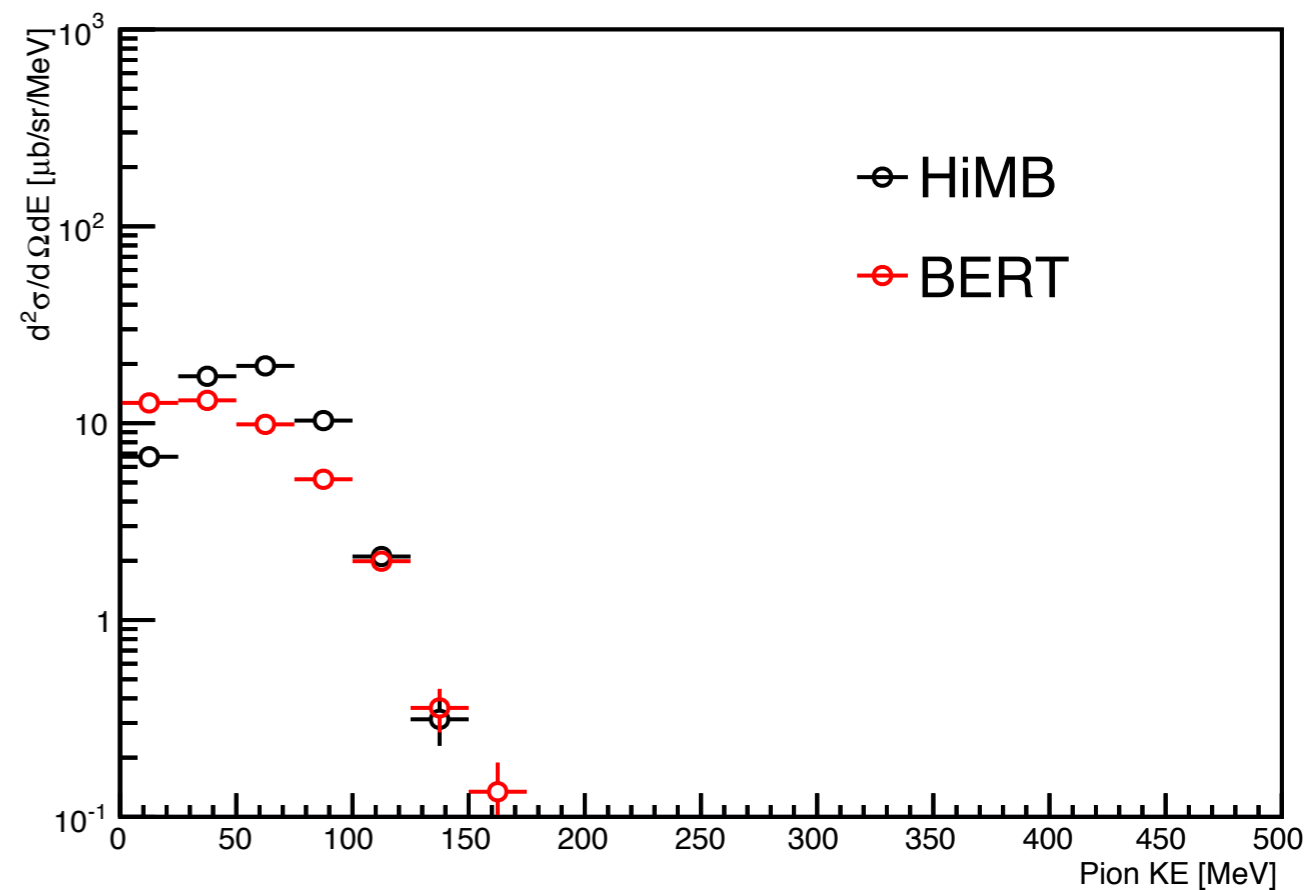
Comparison of Geant4 Models

585 MeV protons on Carbon target

Cross Section π^+ at $\theta = 22.5^\circ$, 585 MeV protons on Target



Cross Section π^+ at $\theta = 135^\circ$, 585 MeV protons on Target



R. L. Burman and E. S. Smith, Los Alamos Tech. Report LA-11502-MS

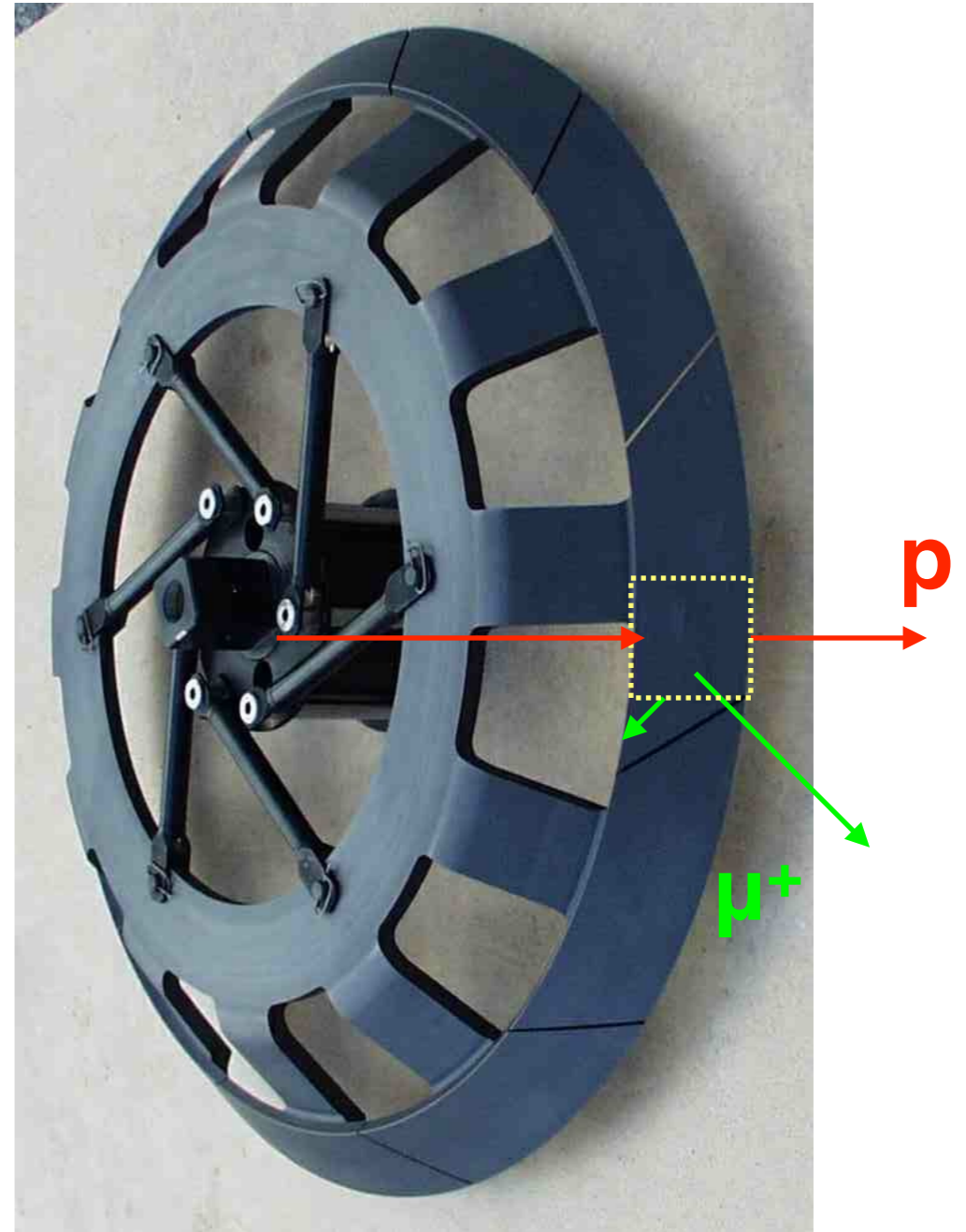
R. Frosch, J. Löffler, and C. Wigger, PSI Tech. Report TM-11-92-01

HiMB Parameterized Model

Combined parameterization of data collected at PSI and LAMPF, across all production energies and angles

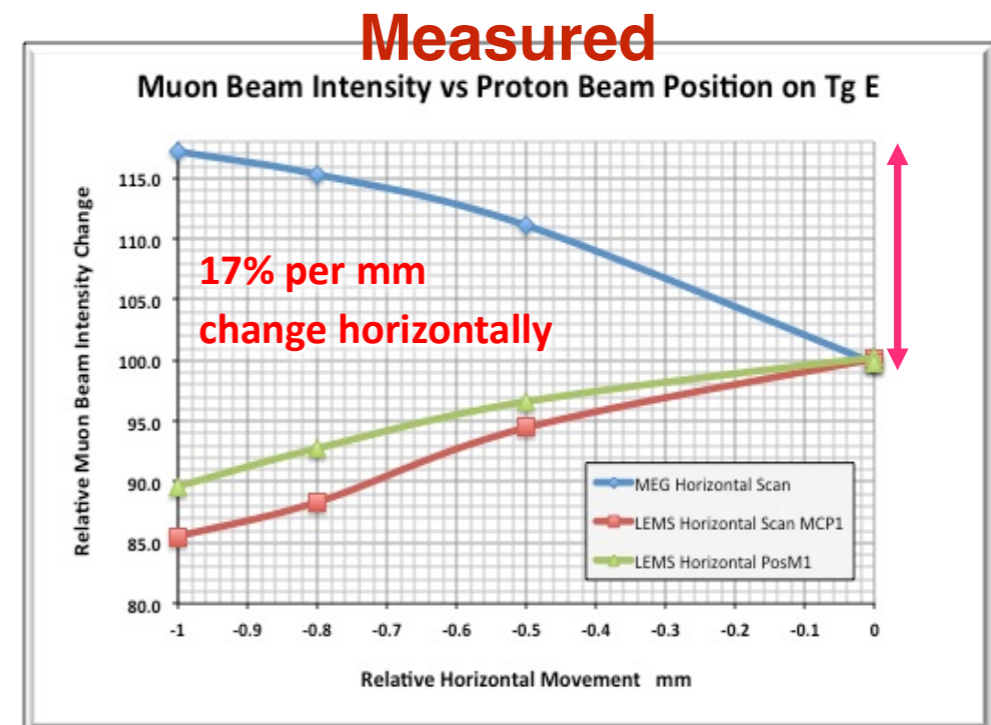
Target E at PSI

- Provides a normalization to HiMB and a validation of sim toolset
- Target E is a graphite truncated hollow cone
 - Approximated as a rectangular section in G4BL
 - Length = 40.0 mm
 - Height = 40.0 mm
 - Width = 6.0 mm



Horizontal Proton Beam Offset

- Horizontal proton beam offset from target center
- Surface muon rate measured simultaneously on opposite sides of TgE
- Higher rates as beam is brought closer to target surface
- HiMB shows better agreement between G4BL and measured rates in LEMS

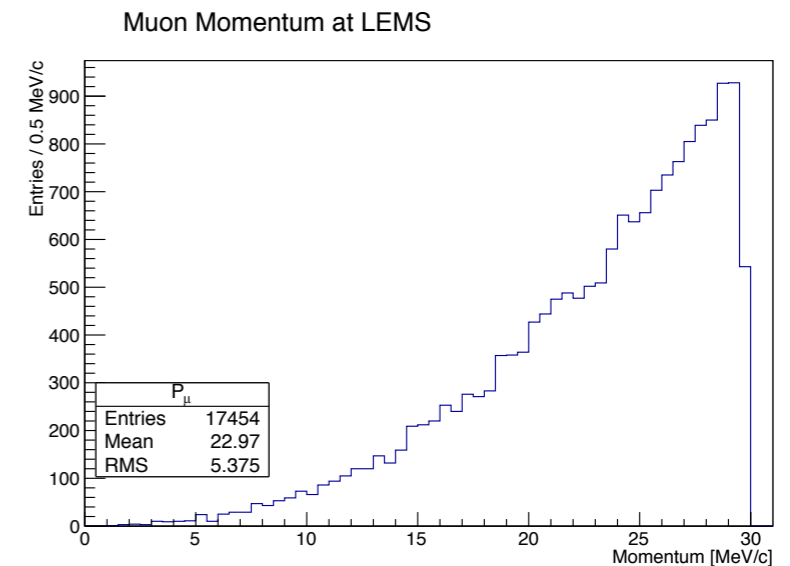
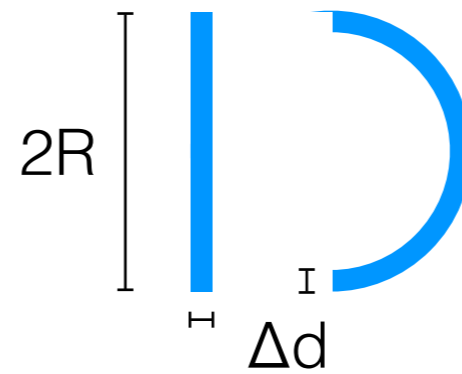


RATIO TO CENTERED BEAM

	LEMS BERT	LEMS HiMB	LEMS Data	PiE5_Full BERT	PiE5_Full HiMB	PiE5 Data
0.5 mm	0.87	0.95	0.95	1.12	1.05	1.11
1.0 mm	0.77	0.89	0.87	1.25	1.09	1.17

Radial Grooved Target

- Increasing the surface area/volume should increase the surface muon production
- Grooves along the proton beam direction can provide this increase in surface volume



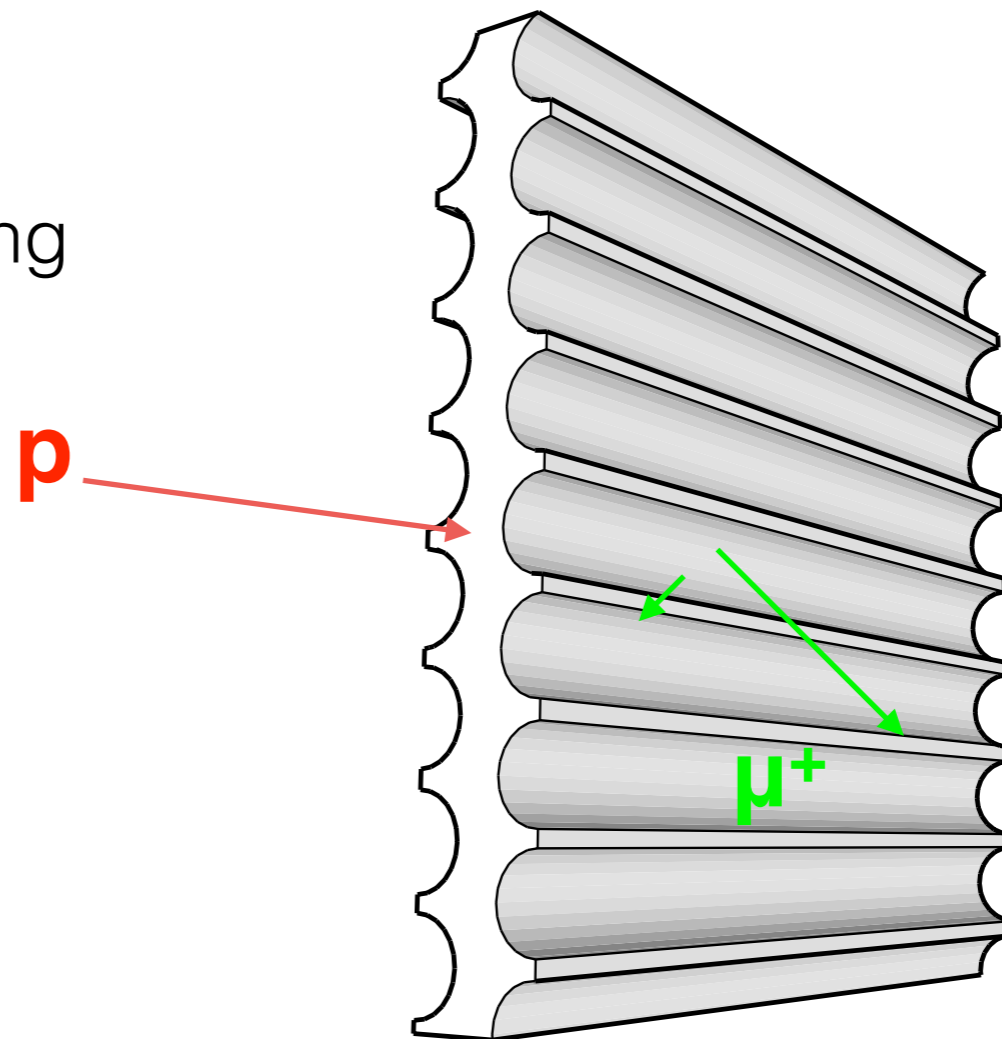
Groove
Radius
[mm]

Enhancement Ratio

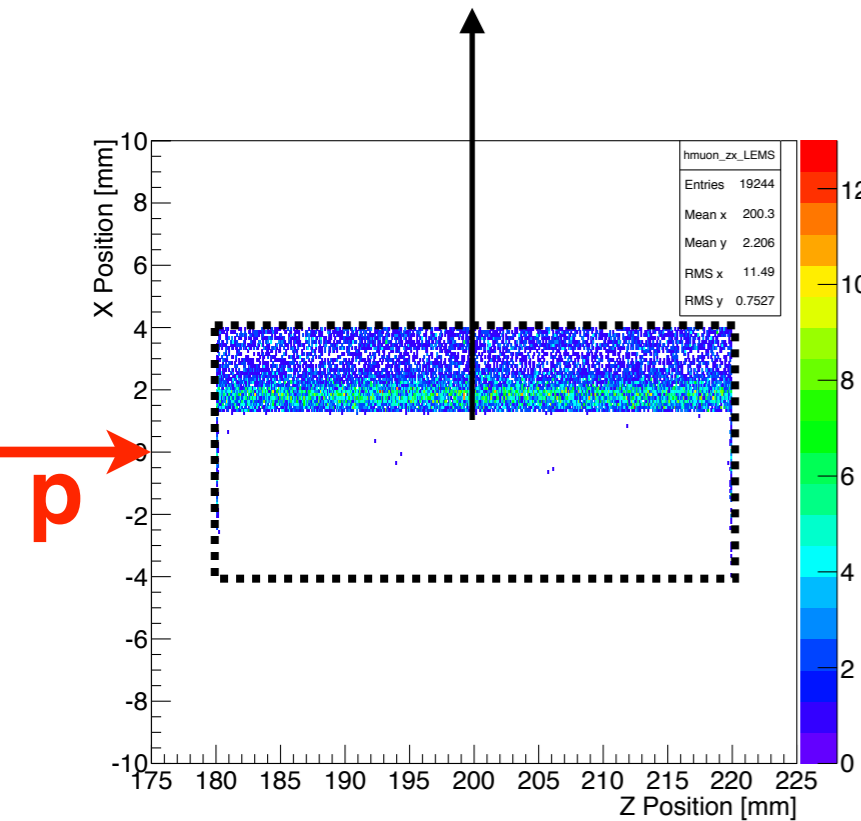
1.0	1.35
1.5	1.40
2.0	1.45

Radial Grooved Target

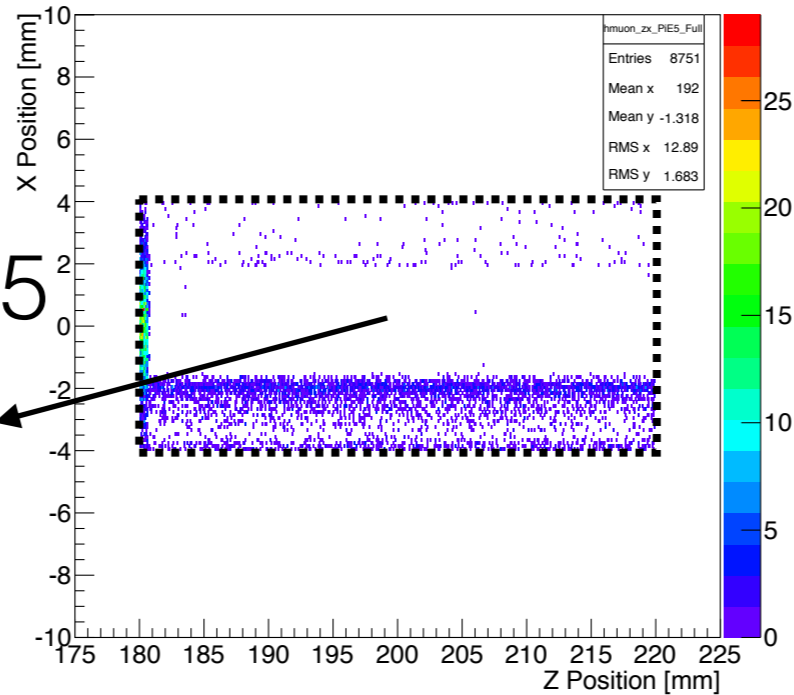
- Alternate design for increasing surface muon production
- Grooves are staggered to maintain a standard target width
- Width = 6.0 mm + R_g



LEMS



PiE5



Ratio to Standard

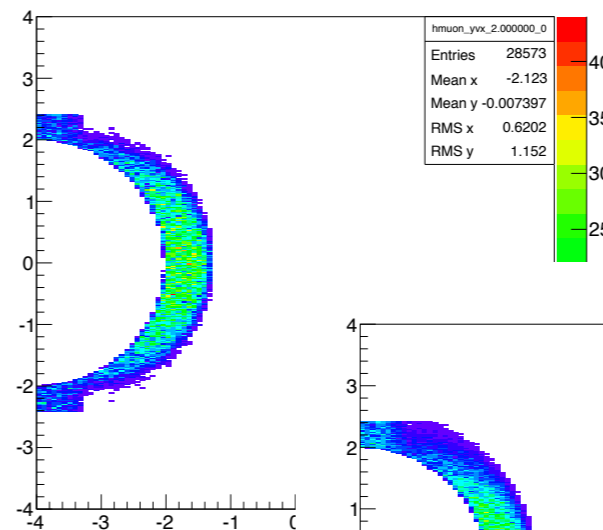
Groove Radius [mm]	LEMS	PiE5
1.0	1.02	1.01
1.5	1.08	1.02
2.0	1.14	1.05

Grooved Targets

Approximately 14% enhancement for 2.0 mm groove configuration

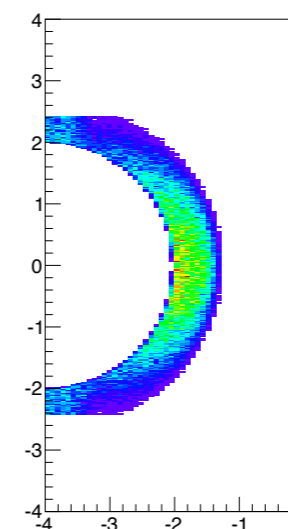
Acceptance Depth

- The acceptance depth in a groove is at the maximum where the groove is closest to the target center
- This depth tapers near the max target width
- Has a crescent shape for small acceptance angles (realistic for beamlines)
- Not the full surface volume expected

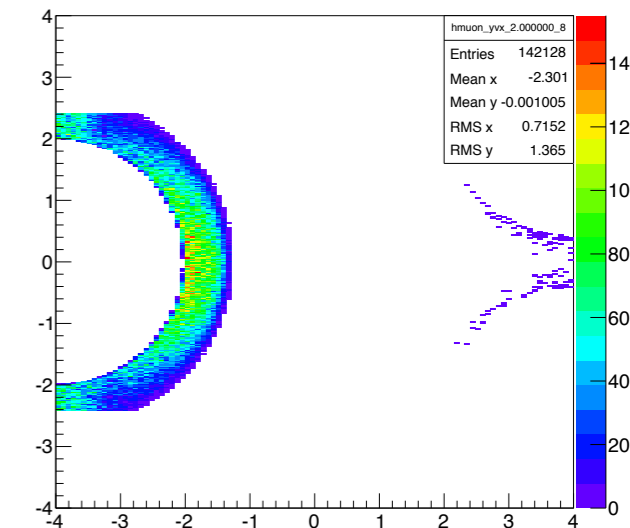


$\Phi < \pm 10^\circ$

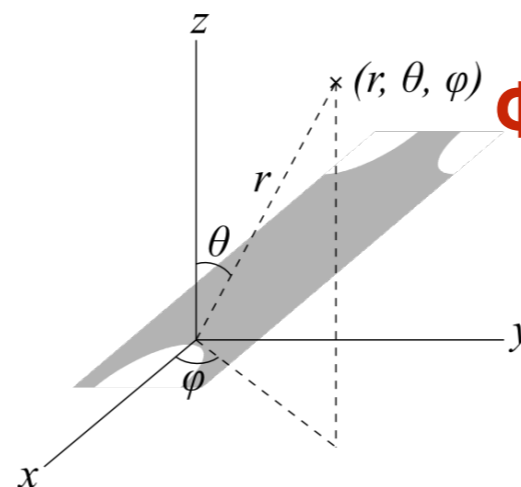
Initial μ^+ position



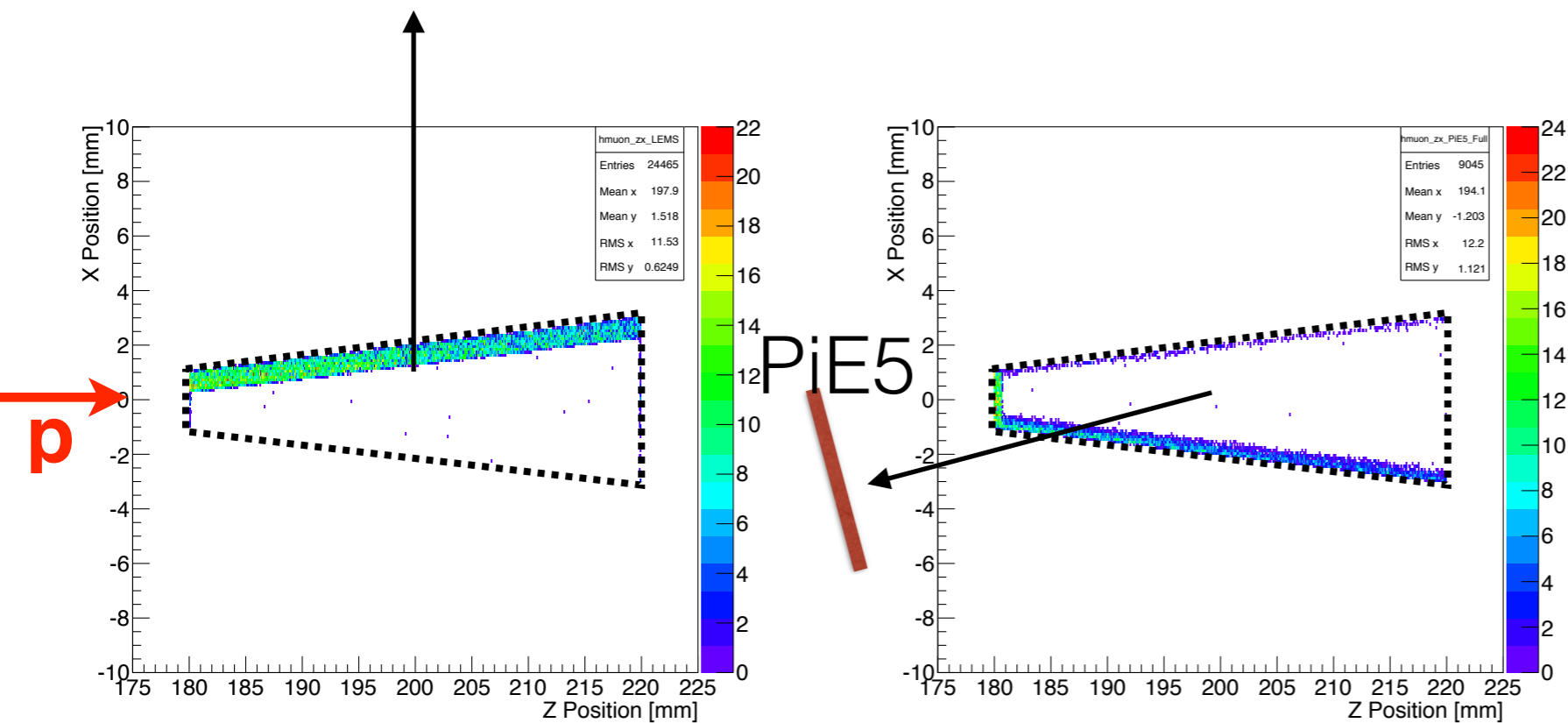
$\Phi < \pm 50^\circ$



$\Phi < \pm 90^\circ$



LEMS



Ratio to Standard

Front Face Width [mm]	LEMS	PiE5
4.0	1.16	1.05
3.0	1.29	1.09
2.0	1.42	1.11

Trapezoidal Target

Approximately 42% enhancement for 2.0 mm front face target configuration

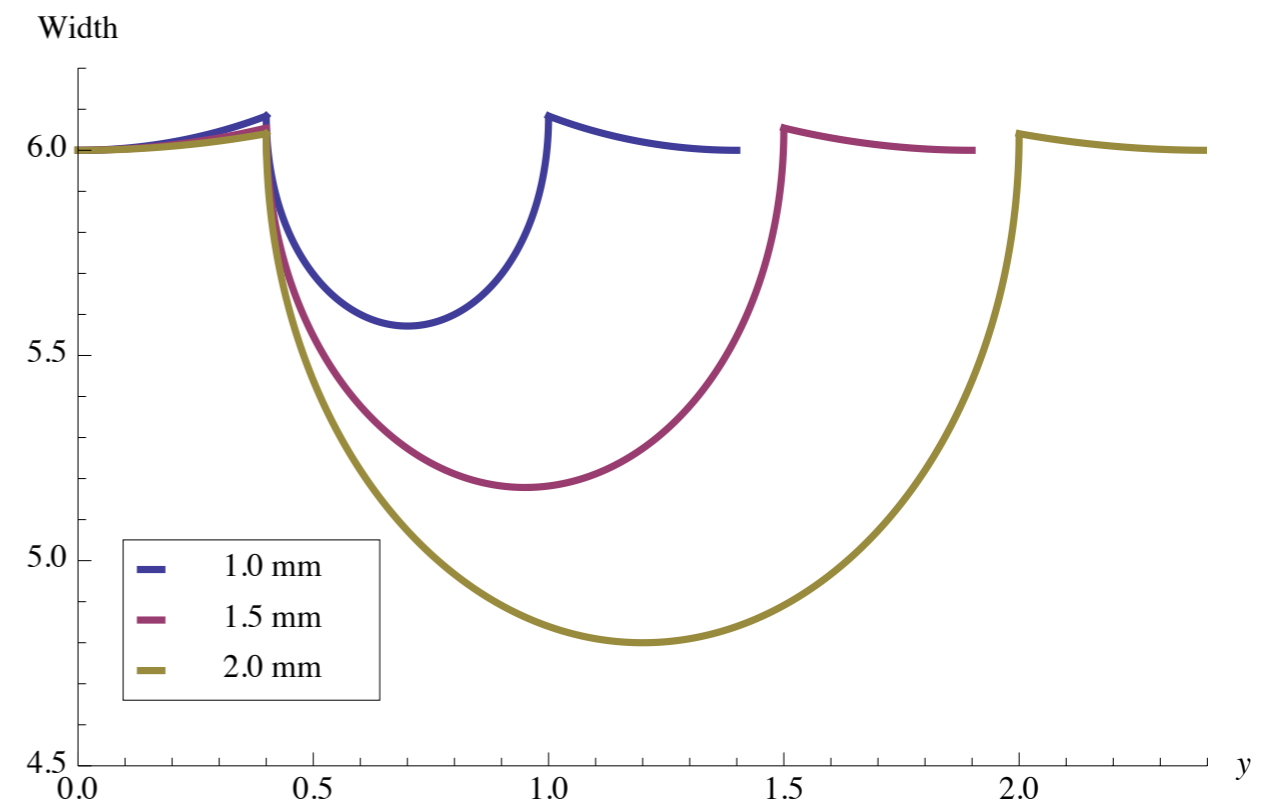
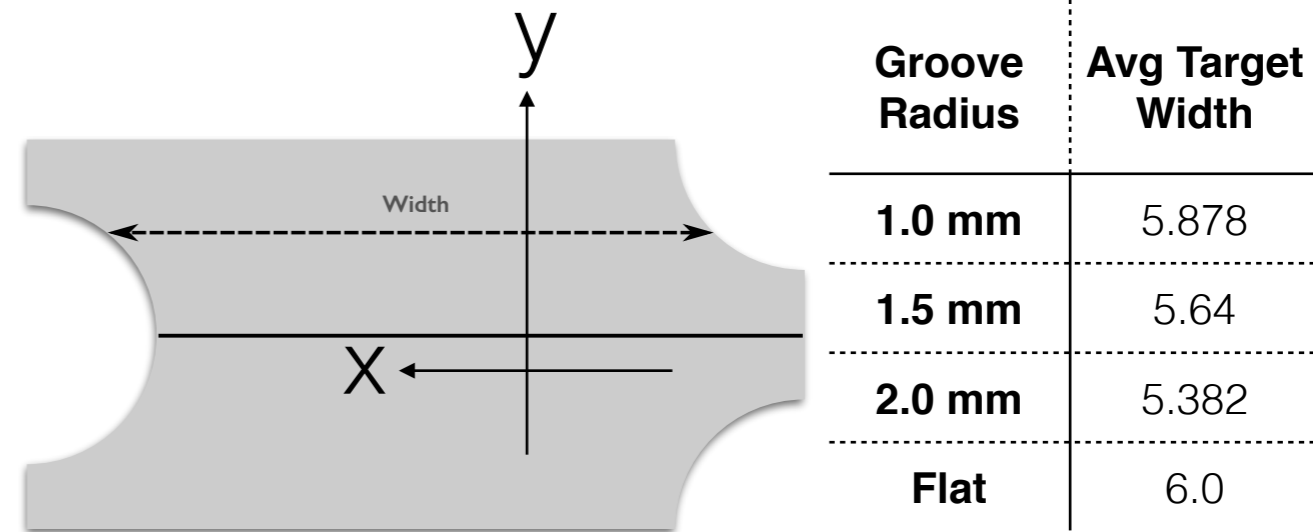
Conclusions

- HiMB project in 2-year feasibility study
 - Muon rate: 1×10^{11} μ /s from source downward
 - Currently evaluating solenoidal collection
- Parameterized π^+ cross section implemented
- Target E used as validation of G4BL
 - Possible improvements to TgE leading to higher muon rates

Backup Slides

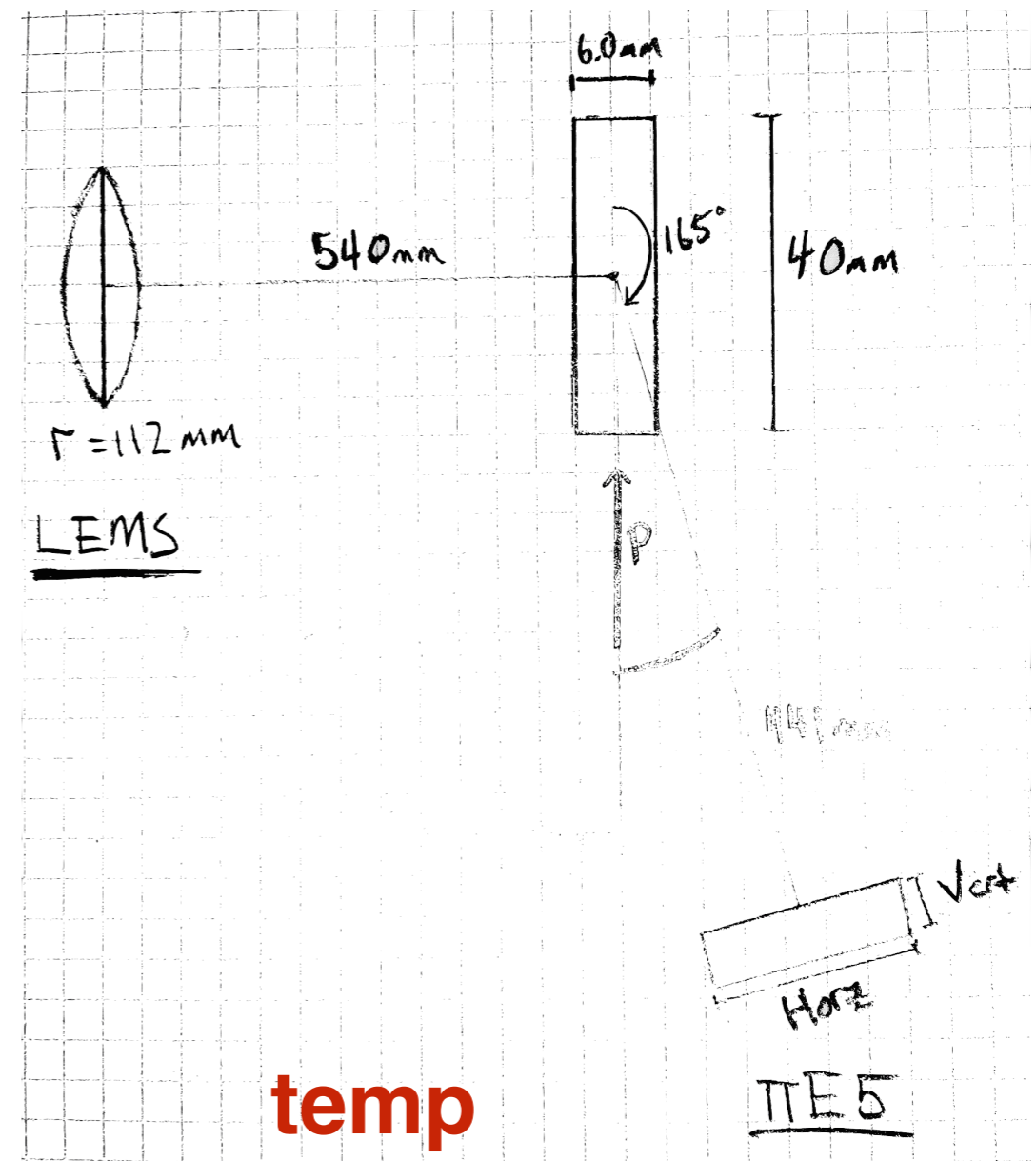
Target Width

- The Target width (x-axis) varies along the y-axis
- This creates an effective width of the target that is less than the standard 6.0 mm



Detector Dimensions

- LEMS:
 - 540 mm from c.o.t.
 - $r = 112$ mm
- PiE5_Full:
 - 441 mm from c.o.t.
 - $v = 79$ mm, $h = 353$ mm



PARAMETERIZATION OF PION PRODUCTION
AND REACTION CROSS SECTIONS
AT LAMPF ENERGIES

by

R. L. Burman and E. S. Smith

ABSTRACT

A parameterization of pion production and reaction cross sections is developed for eventual use in modeling neutrino production by protons in a beam stop. Emphasis is placed upon smooth parameterizations for proton energies up to 800 MeV, for all pion energies and angles, and for a wide range of materials. The resulting representations of the data are well-behaved and can be used for extrapolation to regions where there are no measurements.

Inclusive π^+ Production from Carbon ($T_p = 585\text{MeV}$)

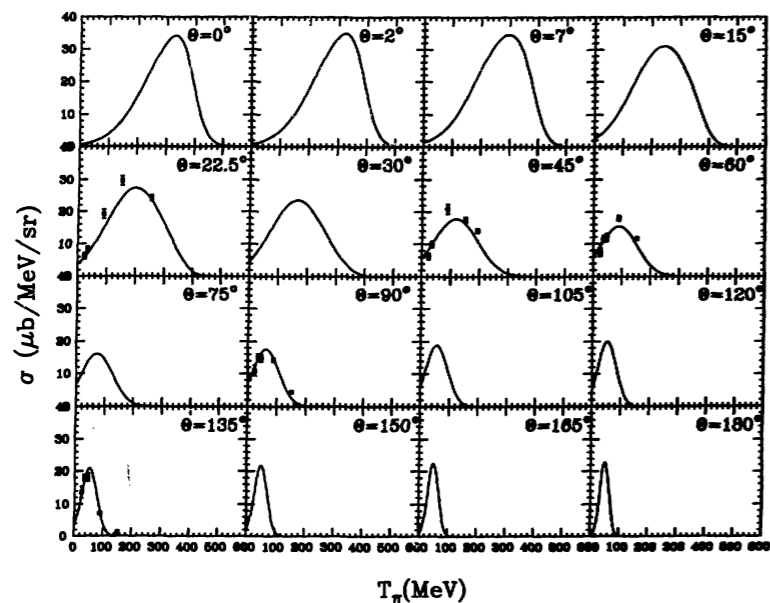



Fig. 7. The parameterization for π^+ production from carbon is compared with the data from Ref. 4.

	PAUL SCHERRER INSTITUT Labor für Kern- und Teilchenphysik	Registrierung TM-11-92-01
	Titel Decay of pions trapped in graphite	Ersetzt —
Autor / en R. Frosch, J. Löffler, C. Wigger	Erstellt 27.10.1992/FR11	

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Abstract

This report is concerned with calculations needed for the analysis of the $p_\mu A$ experiment, in which the momentum of muons from the decay $\pi^+ \rightarrow \mu^+ \nu_\mu$ of stopped pions is measured in an 'Arizona' surface muon beam. The experimental muon spectra are consistent with the assumption that the pions stopped in the graphite production target are trapped in a potential well of the form $V(r) = V_0 + \frac{1}{2}k_s r^2$, with $k_s \approx 1.0 \cdot 10^{17} \text{ eV/cm}^2$. This potential well agrees with that recently derived by Y. Shirasu et al. for hydrogen and deuterium atoms dissolved in graphite.

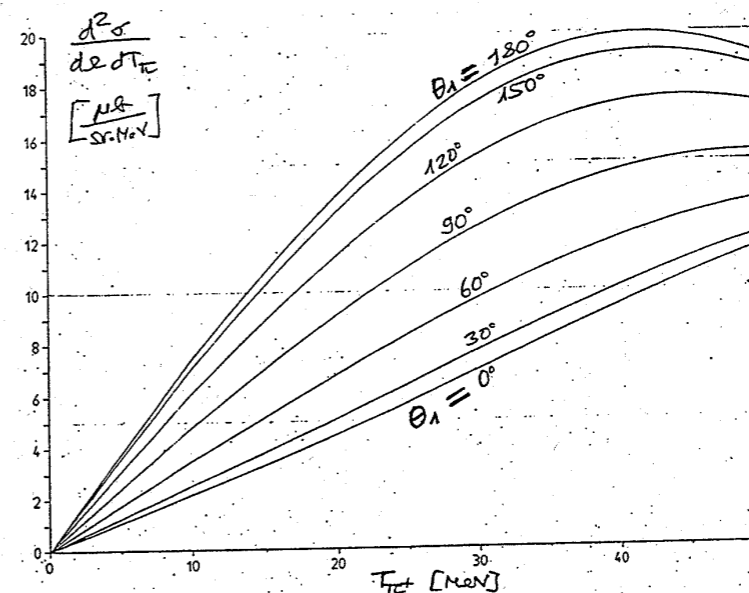
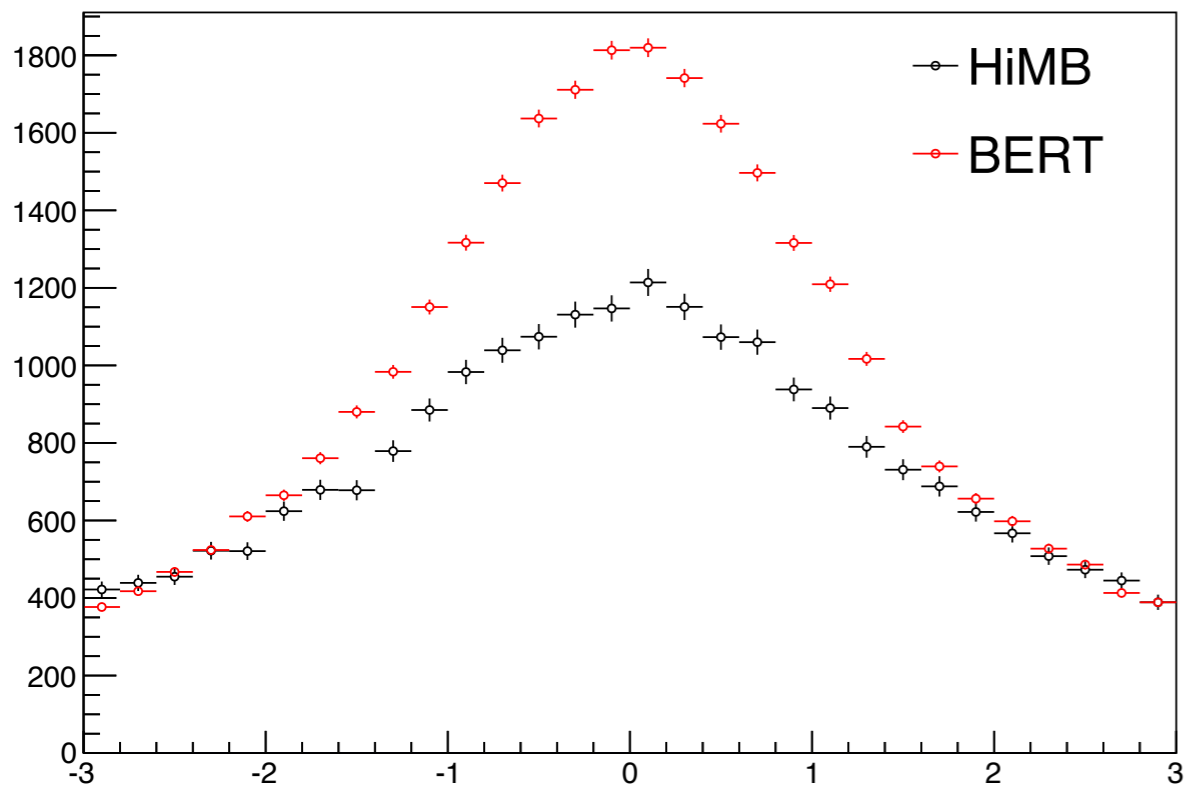


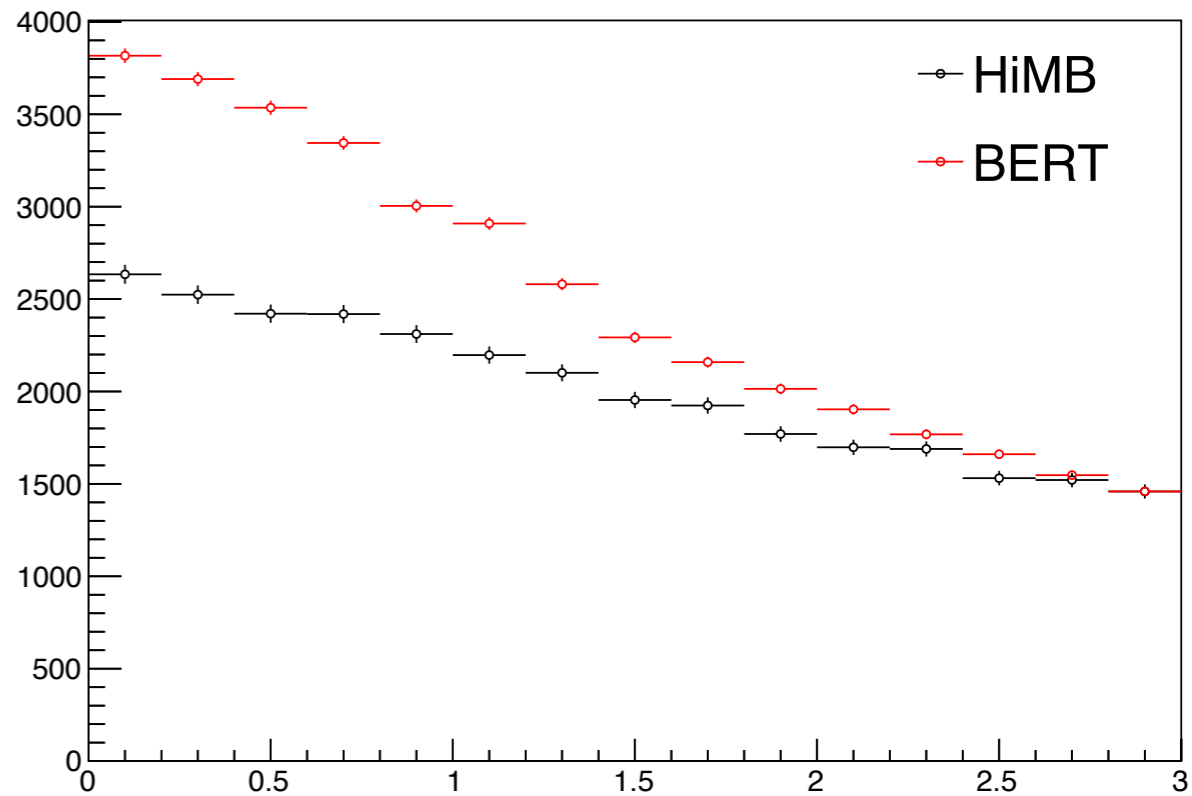
Figure 10: Differential π^+ -production cross-sections according to Eq. (31), for 580MeV-protons in ^{12}C . T_{π^+} : laboratory kinetic energy of produced π^+ ; Θ_1 : laboratory angle between proton and pion momentum vectors.

Pion production parameterization

Pion Stop Distribution - X



Pion Stop Distribution - X



Pion Stop Distributions

Comparison between HiMB and BERT