Jefferson Lab
Thomas Jefferson National Accelerator Facility

Pion ALL experiment

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Twist-3 contributions to wide-angle photoproduction of pion

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(Received 26 February 2018; published 23 April 2018)

We investigate wide-angle π^0 photoproduction within the handbag approach to twist-3 accuracy. In contrast to earlier work both the 2-particle as well as the 3-particle twist-3 contributions are taken into account. It is shown that both are needed for consistent results that respect gauge invariance and crossing properties. The numerical studies reveal the dominance of the twist-3 contribution. With it fair agreement with the recent CLAS measurement of the π^0 cross section is obtained. We briefly comment also on wide-angle photoproduction of other pseudoscalar mesons.

DOI: 10.1103/PhysRevD.97.074023

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DOI: 10.1103/PhysI

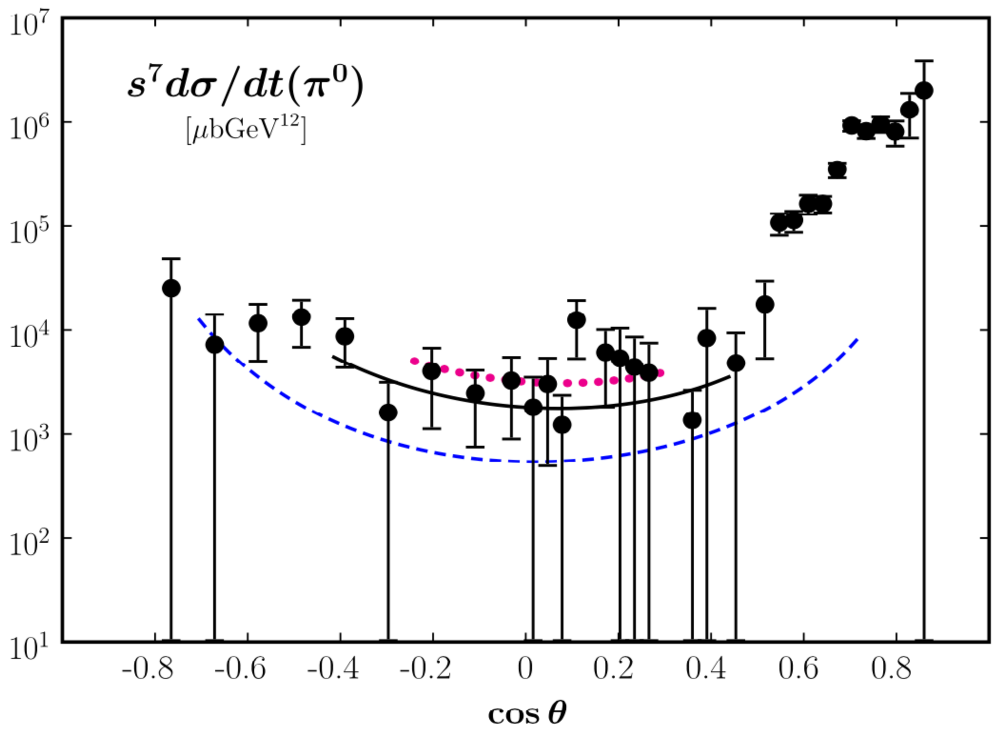

FIG. 3. Results for the cross section of π^0 photoproduction versus the cosine of the c.m.s. scattering angle, θ. The solid (dashed, dotted) curves represent our results at $s = 11.06(20, 9)$ GeV^2. The data at $s = 11.06$ GeV^2 are taken from CLAS [34]. The cross sections are multiplied by s^7, and the theoretical results are only shown for $-t$ and $-u$ larger than 2.5 GeV^2.

Twist-3 contributions to wide-angle photoproduction of pion

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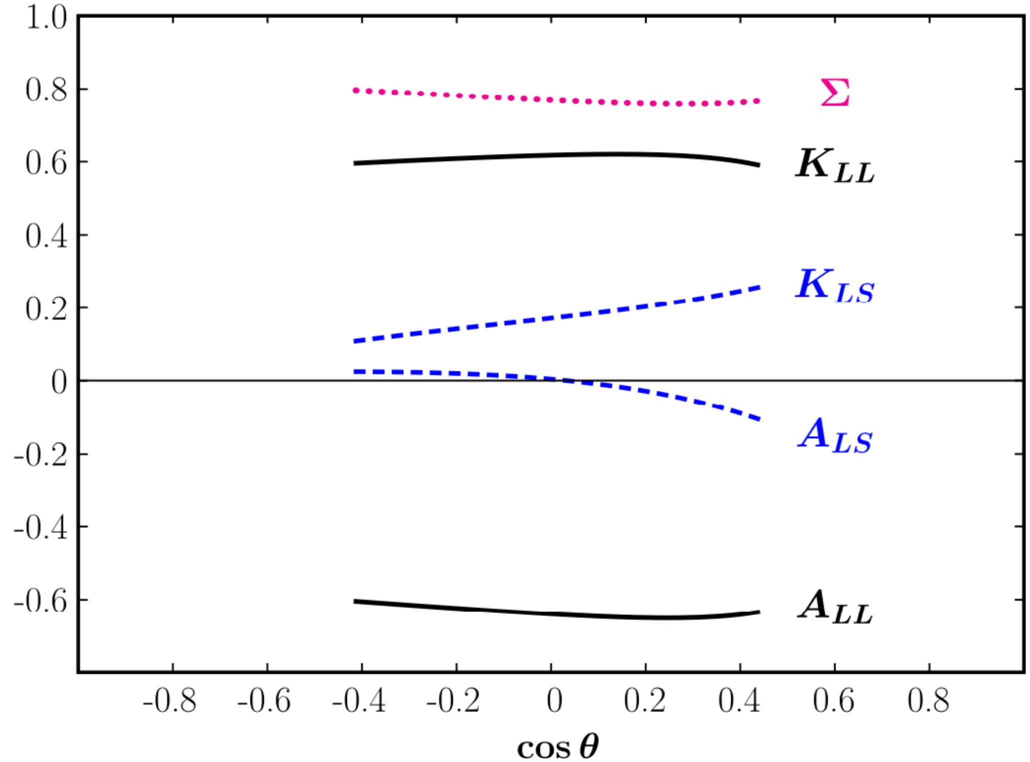


FIG. 4. Predictions for spin observables of π^0 photoproduction at $s = 11.06$ GeV^2. The parametric uncertainty is $\simeq$15% near 90 deg.

In Fig. 4 we show predictions on the spin-dependent observables for π^0 photoproduction. One sees that A_{LL} and K_{LL} are large in absolute value and almost mirror symmetrical. The observables A_{LS} and K_{LS} are small in

How to do experimental study?

The case for π⁻ from a neutron (see also talk in SBS-2019)

ALL from $^3\vec{He}(\vec{e},\pi^-\, p)epp$

KLL from $D(\vec{e},\pi^-\vec{p})ep$

SBS and BB are as in the GEn-II experiment
(thanks to the two-arm detector system)

SBS physics program

- GMn
- GEn (He-3)
- GEp (p -> p polarimeter)
- GEn-RP (n -> p & n -> n polarimeters)
- SIDIS
- TDIS
- Wide Angle Pion Production $\vec{\gamma}n, \pi^-\vec{p}$ => KLL
- L/T cross section for neutron - nTPE
- WAPP from polarized He-3: $\vec{\gamma}\vec{n}, \pi^-p$ => ALL
- Strange FF at 2.5 GeV^2
- J/Psi with proton polarimeter: e+ e- p
- g1, g2 for DIS with 12 GeV and BB/SBS
- DVCS on transversely polarized target and BB/SBS
- ϕ as Deeply Virtual Vector Meson production

GEn group of experiments

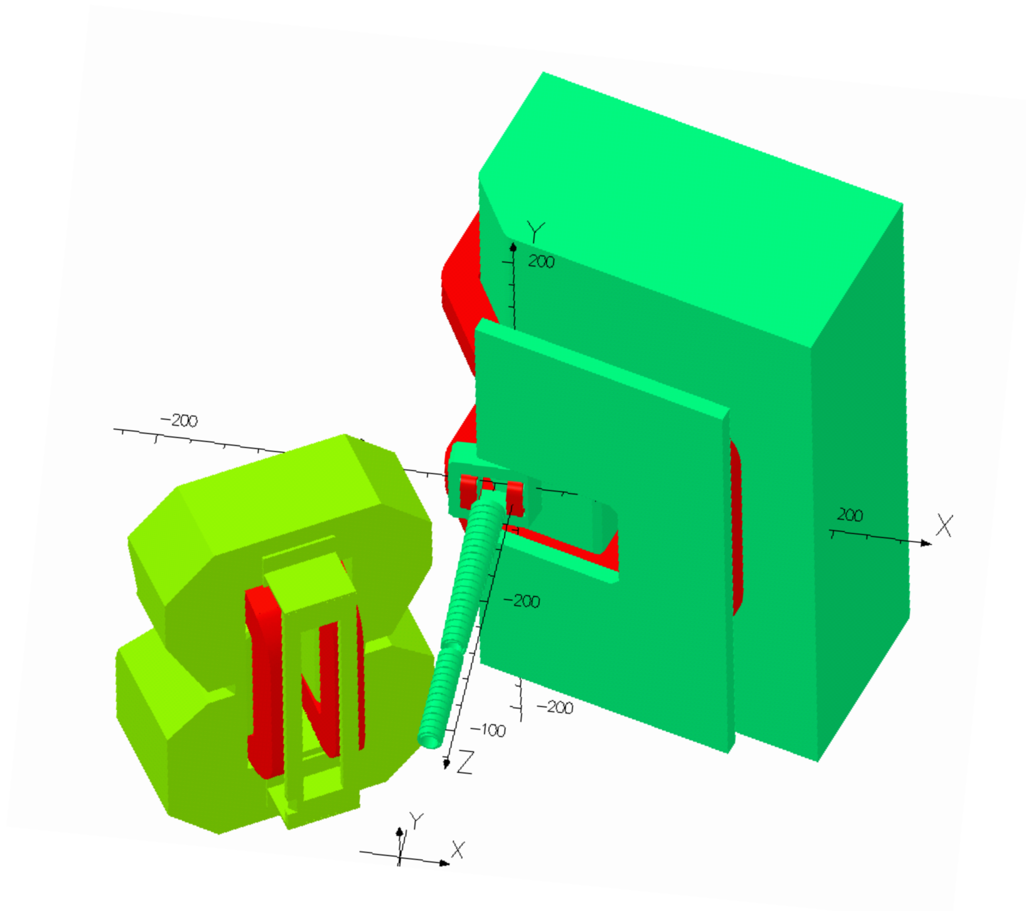
- GEn

PI team: T.Averett, G.Cates, S.Riordan (left), B.Wojtsekhowski*

- WAPP-ALL

PI team: G.Cates, R.Montgomery, A.Tadepalli, B.Wojtsekhowski*

Two-arm setup



$\sigma_p/p = 0.08 + 0.004 \times p[\mathrm{GeV}]$

$\sigma_\theta = 1 - 2 \;\; \mathrm{mrad}$

$\Omega = 70 - 90$ msr, for $\theta \geq 30^\circ$

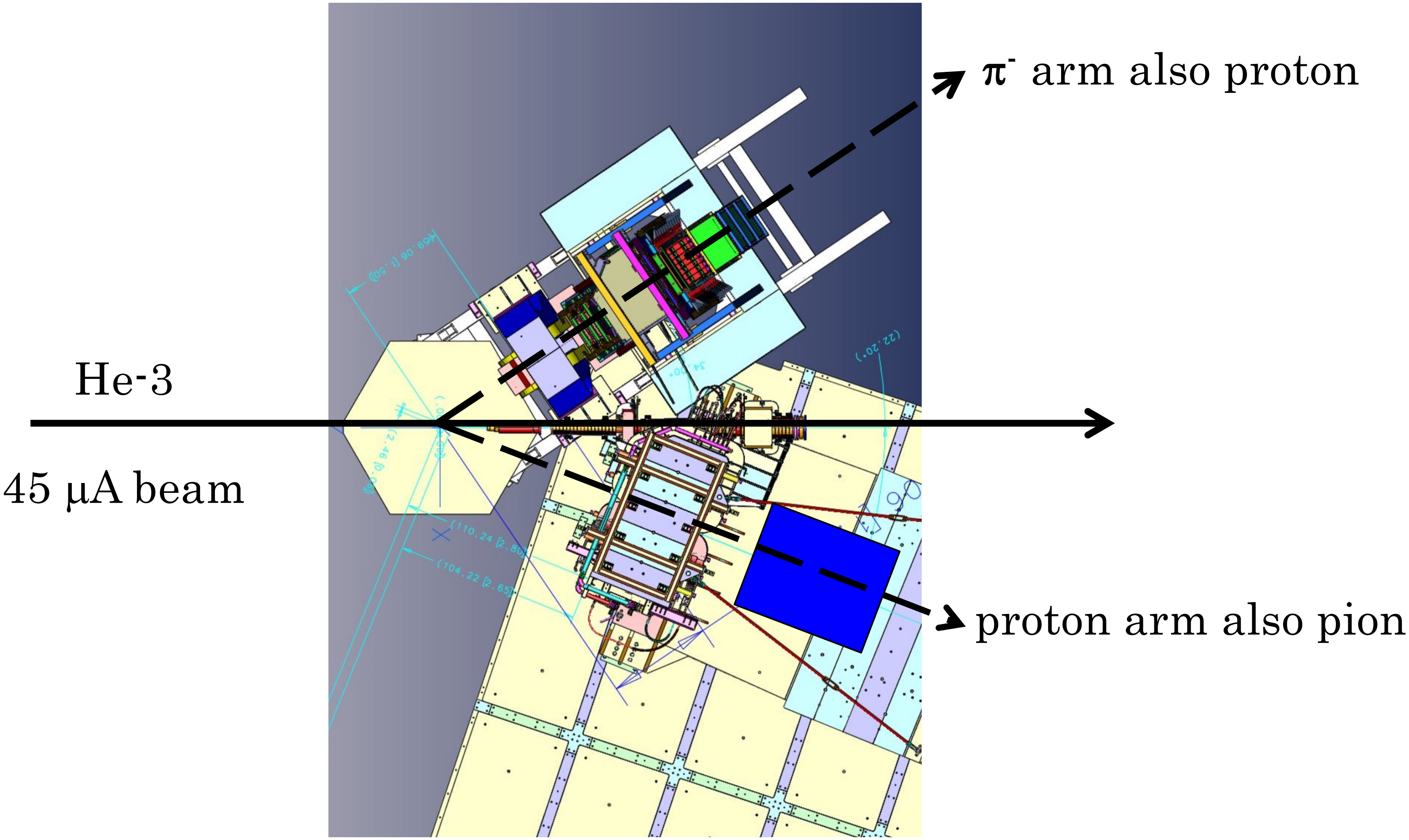
$\sigma_p/p = 0.0029 + 0.0003 \times p[\mathrm{GeV}]$

$\sigma_\theta = 0.14 + 1.3/p[\mathrm{GeV}], \; \mathrm{mrad}$

$\Omega = 72$ msr, for $\theta \geq 15^\circ$

$\Omega = 30$ msr, for $\theta = 7.5^\circ$

Layout for the pionALL experiment



Polarized He-3 target performance

BW, High-t reactions (2002)

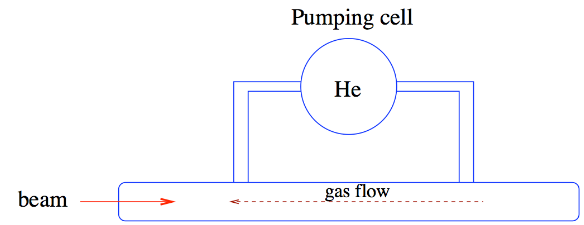
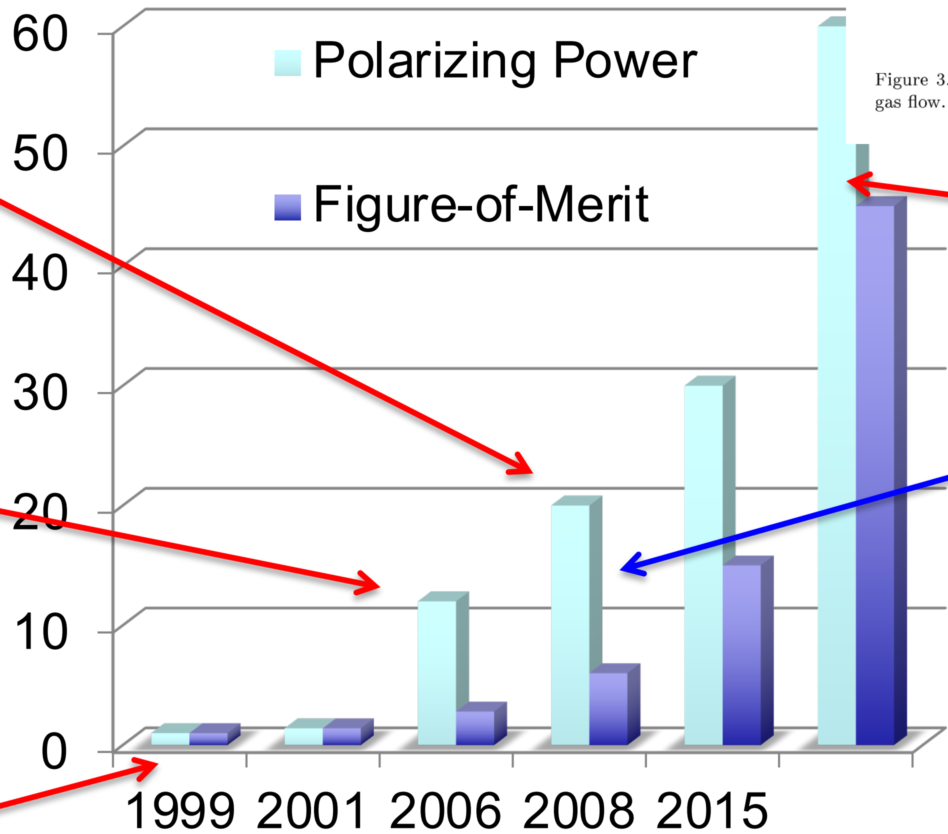


Figure 3. The target cell with two attachments to the pumping cell which allow the gas flow.

G. Cates, Optimized lasers width

G. Cates, Hybrid alkali Rb-K

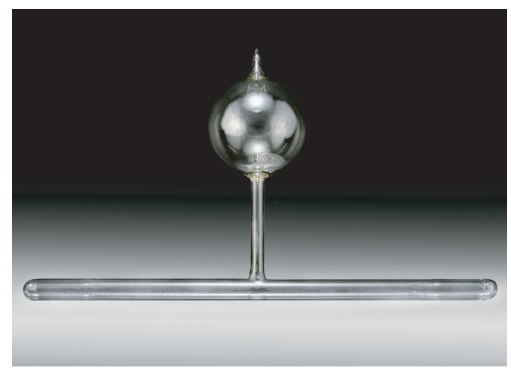
G. Cates, SLAC type



GDH A1n GEn(1) Tranv. A1n GEn-II

Convection gas flow cell

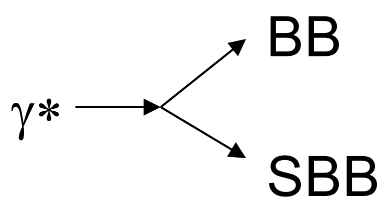
Slow diffusion exchange



ALL experiment challenges and solutions

- The goal is to measure ALL asymmetry, so the target polarization should be oriented along the beam direction.
  However, the design of the mirror mounts does not allow it.
- The natural way to study photo-production requires a radiator
  However, the radiator was not designed and which holded ERR

- Solution is to measure ALL and ALS with two symmetrical arms.
  Design group confirmed space availability of such geometry.



Call event L
if Pion in BB
Proton in SBS

Call event R
if Pion in SBS
Proton in BB

$A_L = ALL*P_n*\cos\theta + ALS*P_n*\sin\theta$

$A_R = ALL*P_n*\cos\theta - ALS*P_n*\sin\theta$

- High performance polarized target allows us to use intensive electron beam, so quasi real photons will be used.

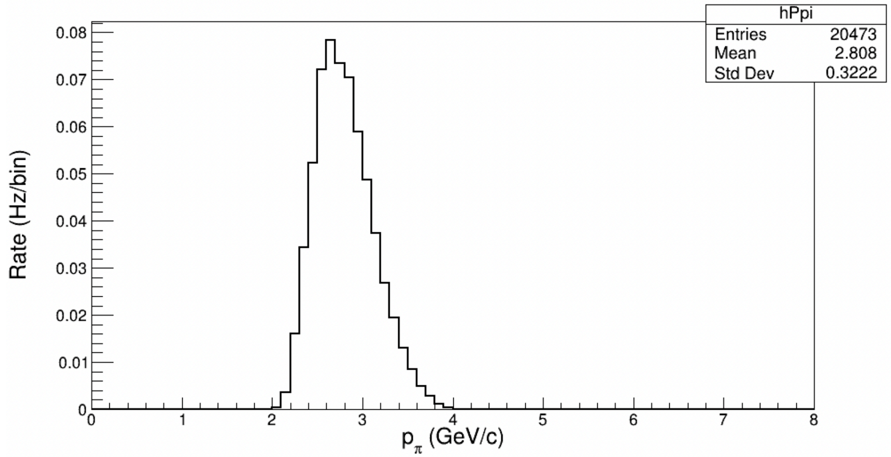
Three halls with polarized beam

9/9/23	Saturday	2.1	Physics	Installation		Installation		NPS Group
9/10/23	Sunday	2.1	Physics	Installation		Installation		NPS Group
9/11/23	Monday	2.1	Physics	E12-09-016	8.4/45/p/500	Installation		NPS Group
9/12/23	Tuesday	2.1	Physics	E12-09-016	8.4/45/p/500	Installation		NPS Group
9/13/23	Wednesday	2.1	Physics	E12-09-016	8.4/45/p/500	Installation		NPS Group
9/14/23	Thursday	2.1	Physics	E12-09-016	8.4/45/p/500	Installation		NPS Group
9/15/23	Friday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/16/23	Saturday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/17/23	Sunday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/18/23	Monday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/19/23	Tuesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/20/23	Wednesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/21/23	Thursday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/22/23	Friday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/23/23	Saturday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/24/23	Sunday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/25/23	Monday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/26/23	Tuesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/27/23	Wednesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/28/23	Thursday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/29/23	Friday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
9/30/23	Saturday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/1/23	Sunday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/2/23	Monday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/3/23	Tuesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/4/23	Wednesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/5/23	Thursday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/6/23	Friday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/7/23	Saturday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/8/23	Sunday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/9/23	Monday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/10/23	Tuesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/11/23	Wednesday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/12/23	Thursday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/13/23	Friday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/14/23	Saturday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/15/23	Sunday	2.1	Physics	E12-09-016	8.4/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/16/23	Monday	2.1	Physics	E12-09-017	8.4/45/p/501	Run Group D	10.5/200/p/500	NPS Group
10/17/23	Tuesday	2.1	Physics	Reconfigure		Run Group D	10.5/200/p/500	NPS Group
10/18/23	Wednesday	2.1	Physics	Reconfigure		Run Group D	10.5/200/p/500	NPS Group
10/19/23	Thursday	2.1	Physics	Reconfigure		Run Group D	10.5/200/p/500	NPS Group
10/20/23	Friday	2.1	Physics	Pass Change		Run Group D	10.5/200/p/500	NPS Group
10/21/23	Saturday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/22/23	Sunday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/23/23	Monday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/24/23	Tuesday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/25/23	Wednesday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/26/23	Thursday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/27/23	Friday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/28/23	Saturday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/29/23	Sunday	2.1	Physics	E12-15-006	6.6/45/p/500	Run Group D	10.5/200/p/500	NPS Group
10/30/23	Monday	2.1	Physics	Installation		Run Group D	10.5/200/p/500	Pass change

MC results using **g4sbs**

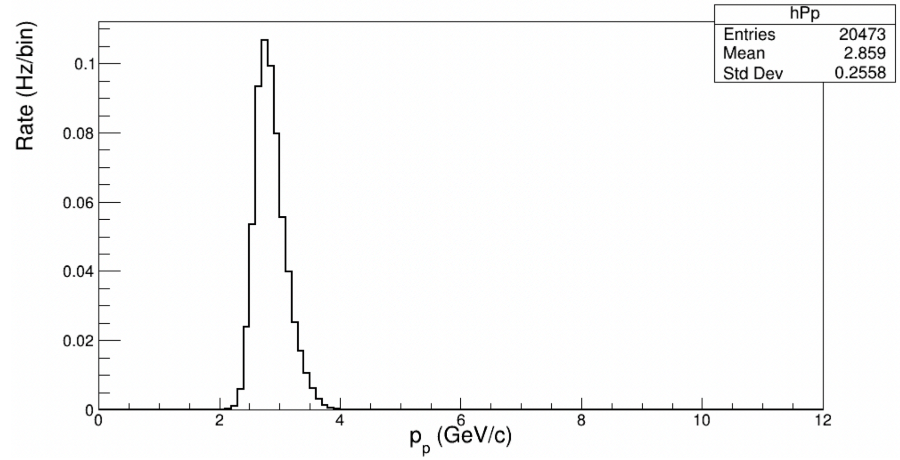
BB

Pion momentum

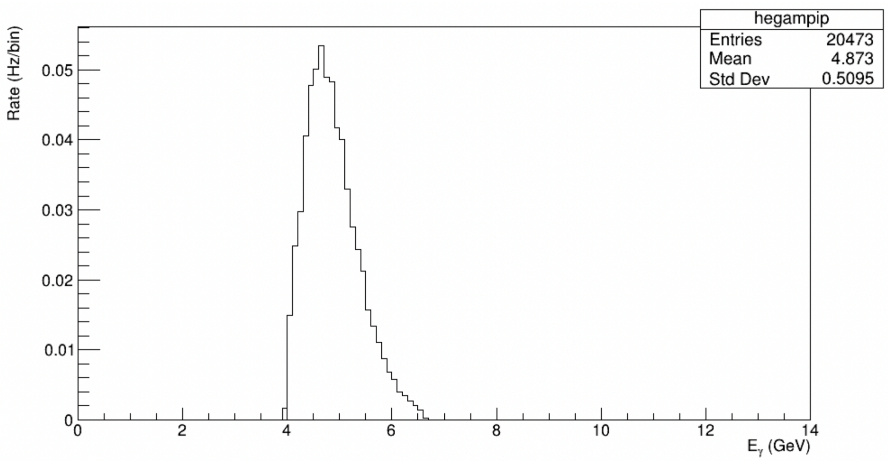


SBS

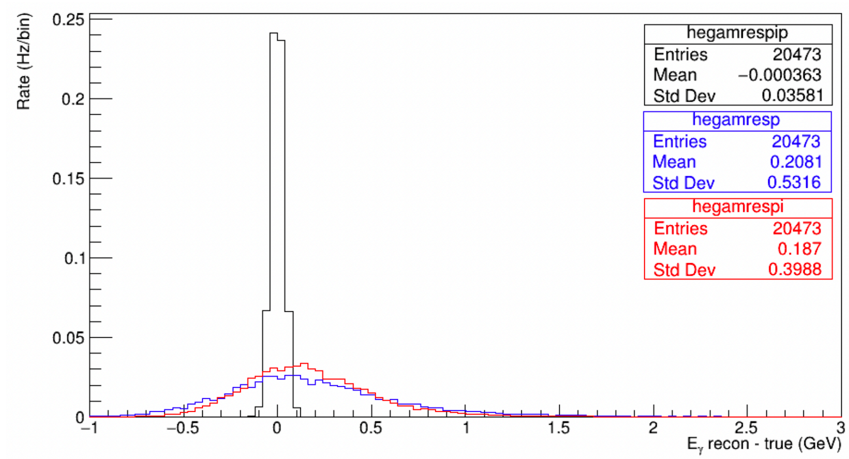
Proton momentum



E_gamma from pi and p reconstruction method



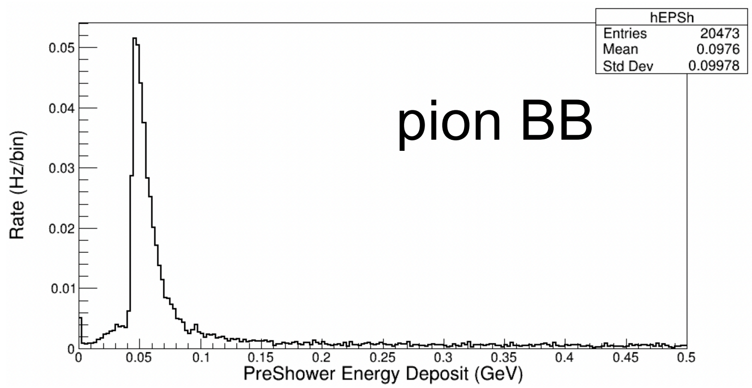
Black = using pi and p; blue = using p; red = using pi

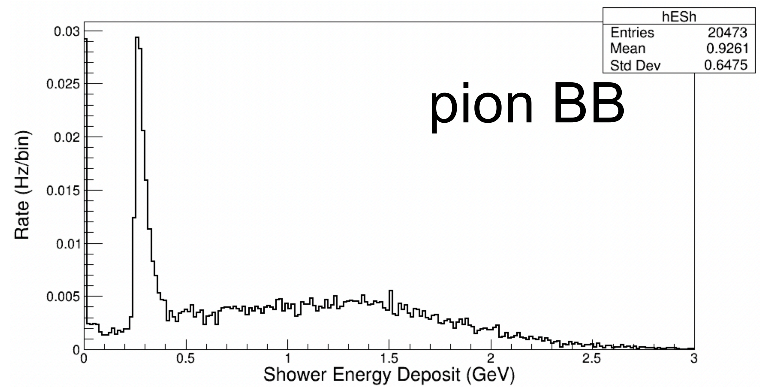


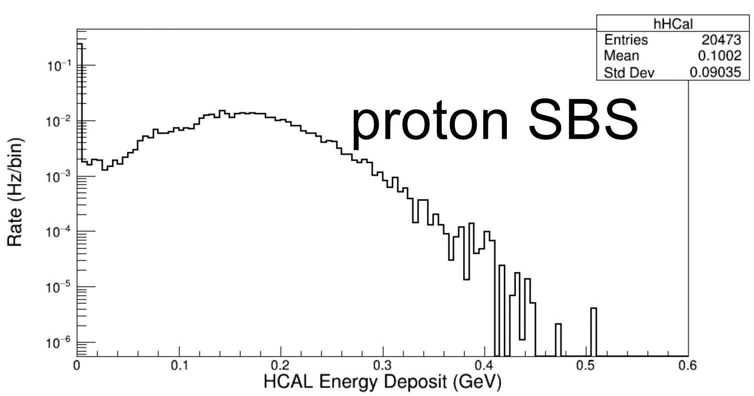
Integrated rate = 0.62 Hz across all Gamma energies (but nb no calorimeter cuts)

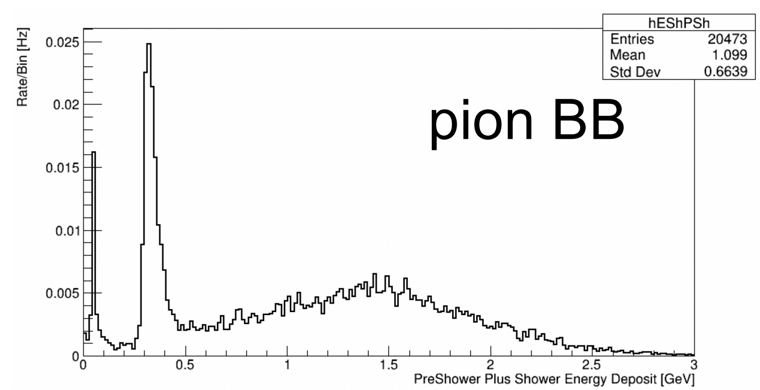
MC results using **g4sbs**

Full field in both magnets



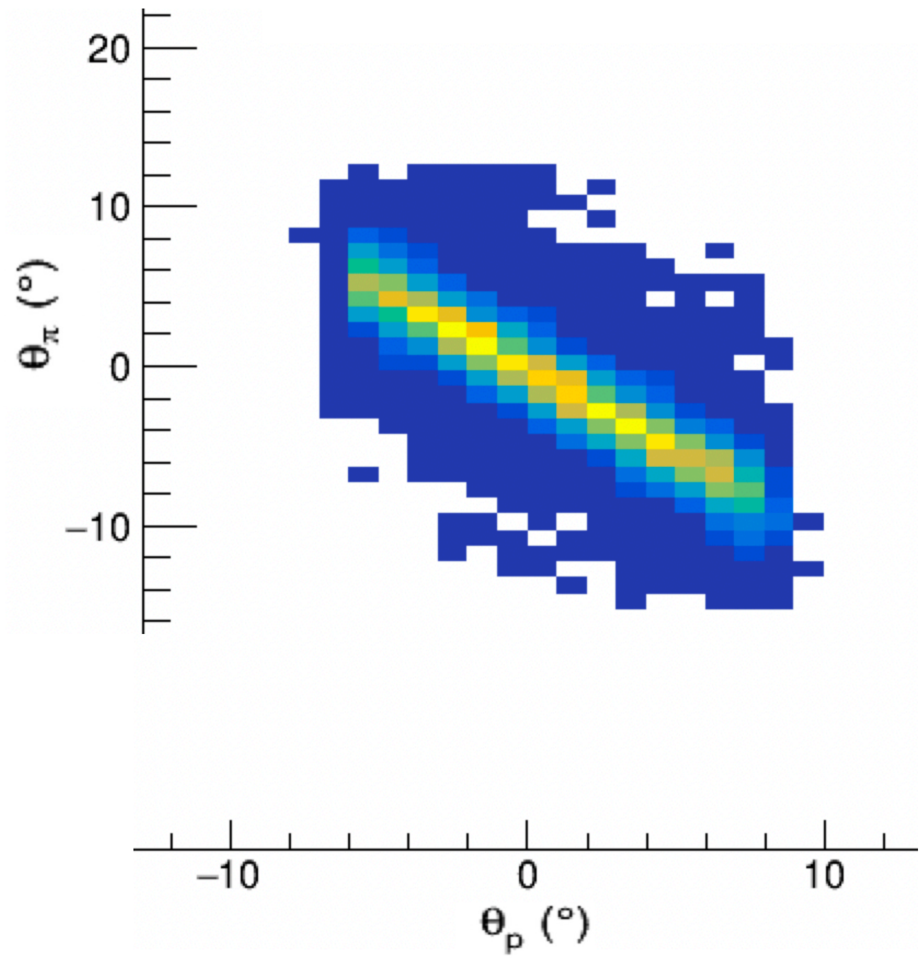






MC results using **g4sbs**

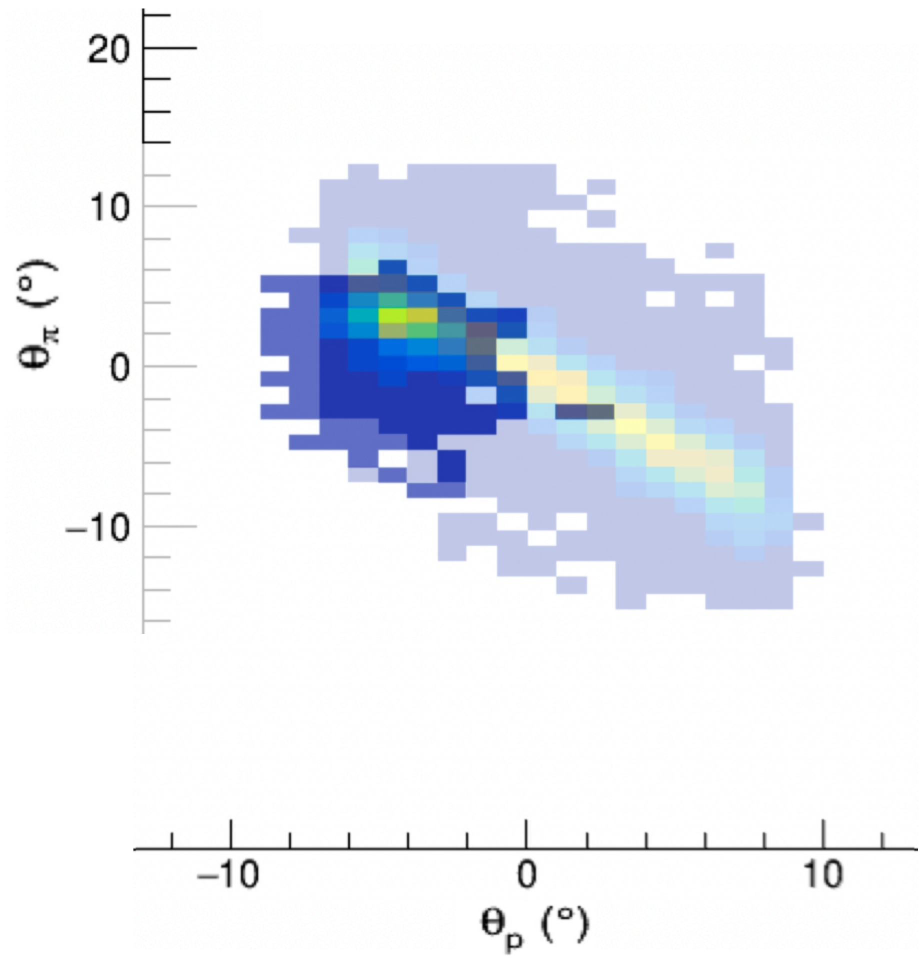
Full field in both magnets



No cuts on calorimeters: full acceptance for pion in BB

MC results using **g4sbs**

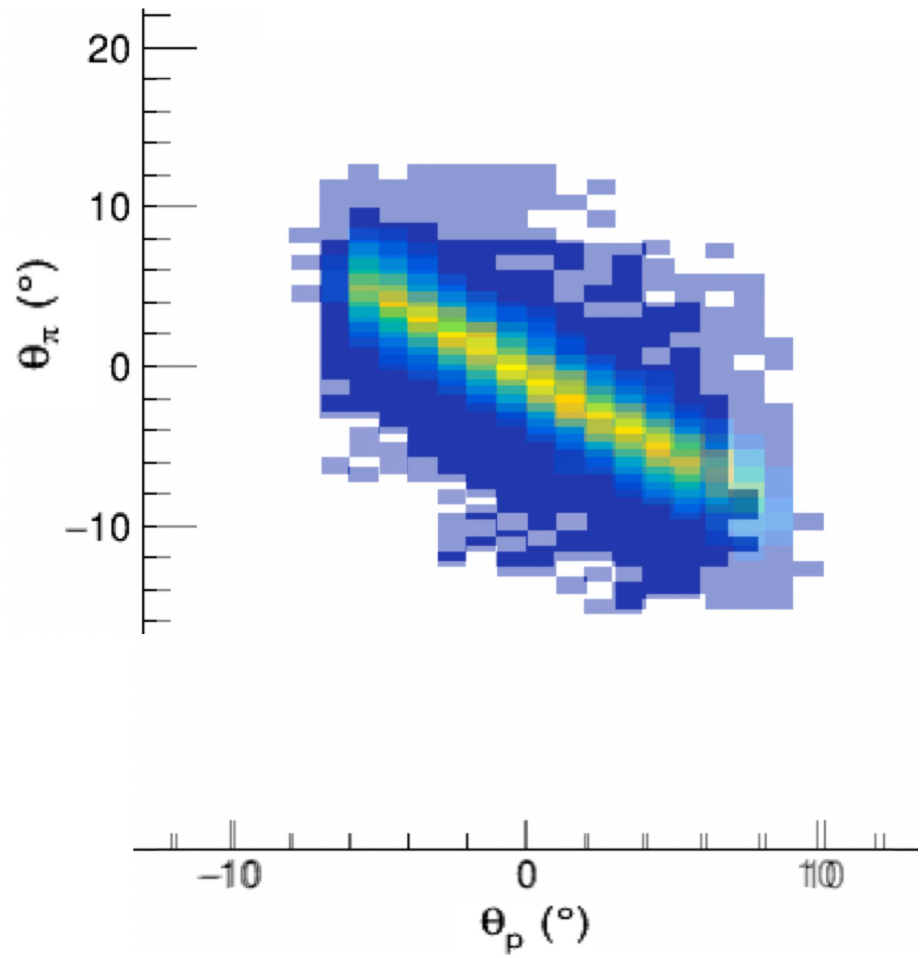
Full field in both magnets



BBCal>200 MeV, HCAL>100 MeV : very small acceptance for pion in SBS

MC results using **g4sbs**

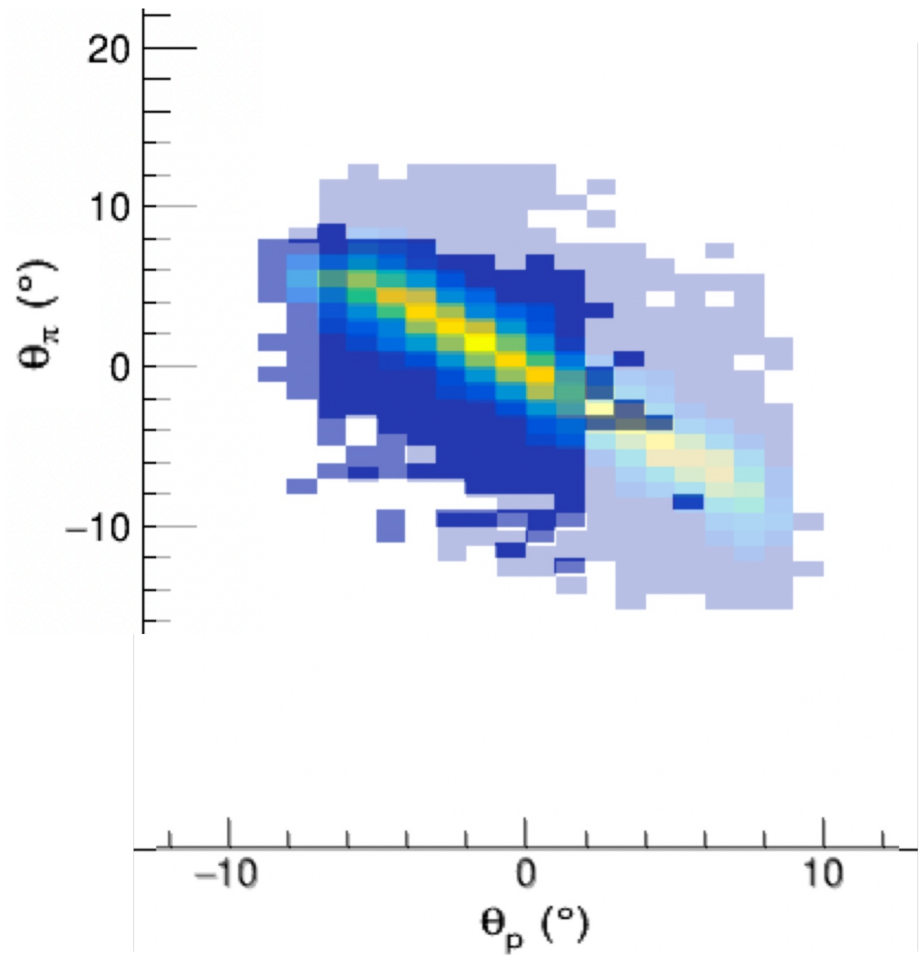
30% field in both magnets



BBCal>200 MeV, HCAL>100 MeV: ~ full acceptance for pion in BB

MC results using **g4sbs**

30% field in both magnets



BBCal>200 MeV, HCAL>100 MeV: 50% acceptance for pion in SBS

MC results using **g4sbs**

Statistics from 72 hours is 50k in combined pi-p + p-pi

With 6.6 GeV electron and P_e =0.85 the 5 GeV photon has P_γ ~ 0.77

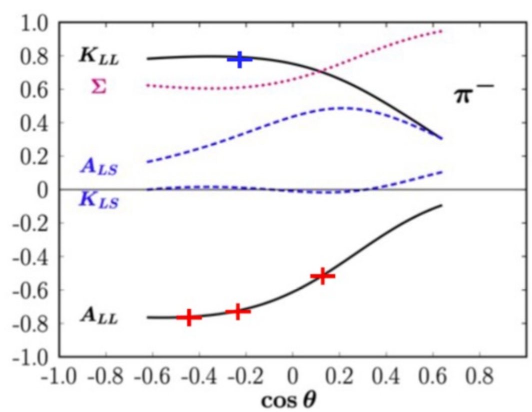
With P_n = 0.86 x P_{He} = 0.35, so the polarization product is 0.27

Resulting accuracy for asymmetry 0.017; or 0.033 for ALL and ALS

Projected results are ALL = 0.70 +/- 0.033; ALS = 0.40 +/- 0.033

In the proposal:

We propose an experiment to measure the helicity correlation parameter, A_{LL} for meson photo-production in the wide angle regime for five different kinematic settings. This proposed experiment will be performed in Hall A of Jefferson Lab using the SBS apparatus, a 60 cm long polarized ^{3}He target, a 6% copper radiator and three different CEBAF beam energies at 20 μA beam current.



MC results using **g4sbs**

Expected detector and DAQ rates

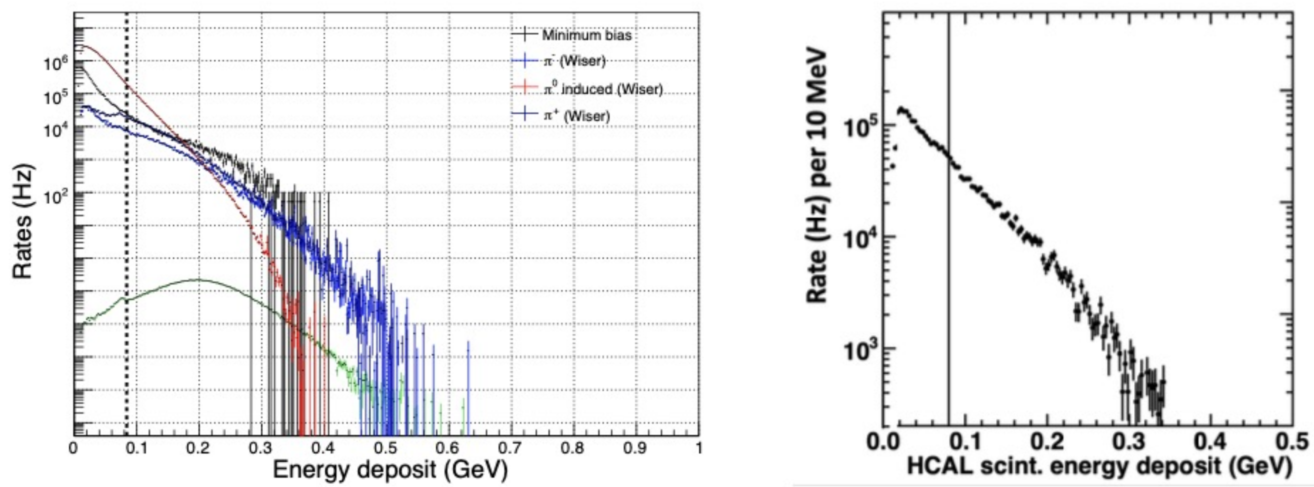
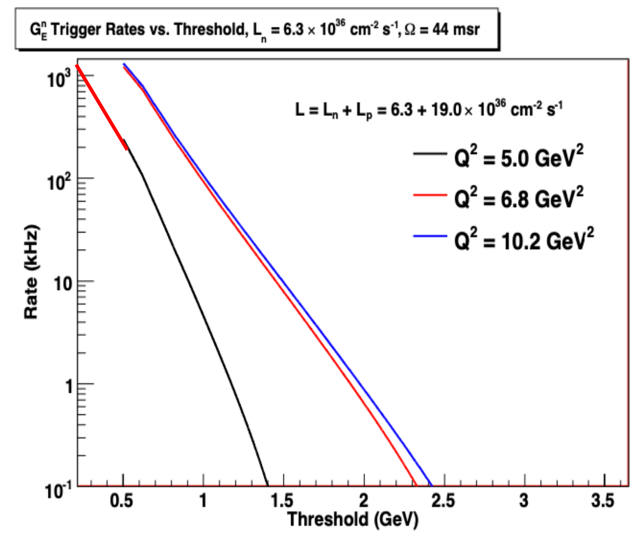


Figure 15: HCAL rate vs. energy deposition. Left: Rate above the given threshold (figures is taken from E12-20-010). Right: Rate per 10 MeV (figure is taken from E12-20-008). Figures are corrected to the luminosity of this proposal.



BBCal in GEn-II proposal

In HCAL expected ~ 200 kHz for 100 MeV threshold due to reduced photon flux

To get data at 30% BB field will take one hour of beam time – low energy can contribute

Need to prepare for a 30 ns coincidence time