Status of the analysis of $\gamma p \rightarrow p\eta[\eta \rightarrow \pi^+\pi^-\pi^0]$ with the CLAS g12 data set

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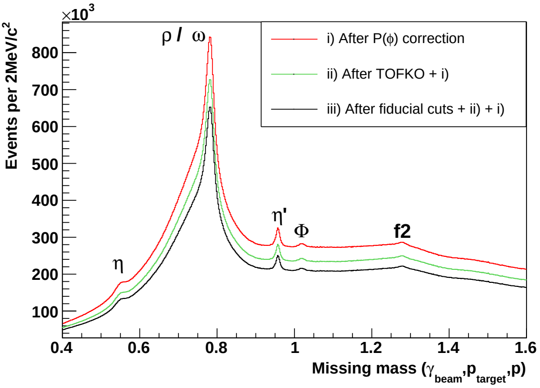
Overview

- Goal/Plan:
  - Analysis of $\gamma p \rightarrow p\eta[\eta \rightarrow \pi^+\pi^-\pi^0]$
  - Determine Q using PWA

    $\Rightarrow$ Q-value determined from WASA-at-COSY data set: $Q = 21.4 \pm 0.4$
- Task(s):
  - ☑ Prepare g12 data set for analysis (done by Michael C. Kunkel)
  - ☐ Reconstruction of $\eta \rightarrow \pi^+\pi^-\pi^0$ within the g12 data set (extract four vectors)
  - ☐ Setup MC simulations (needed for acceptance correction)
  - ☐ Determine Q

Current status of the analysis

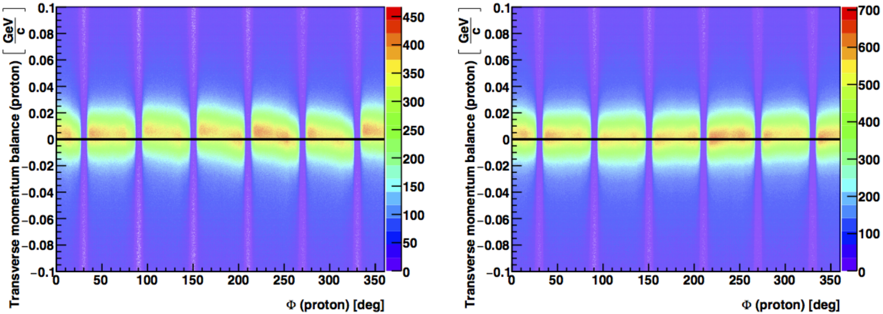


- Missing mass: $|P_{\mathbf{beam}} + P_{\mathbf{target}} - P_p| \rightarrow$ used to monitor analysis steps
- Analysis steps done/going on so far (for details see backup slides):
  - ☑ Apply detector corrections and fiducial cuts
  - ☐ Fine-tuning of kinematic fit (essential for background rejection / signal extraction)

Summary and Outlook

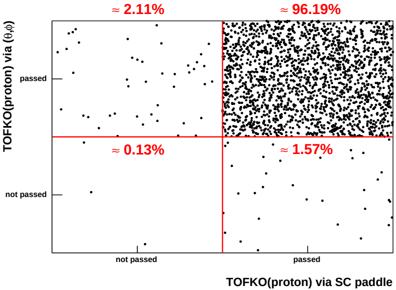
- Started analysis of $\eta \to \pi^+\pi^-\pi^0$
- Work on to-do list:
  - ☐ Reconstruction of $\eta \to \pi^+\pi^-\pi^0$ within the g12 data set (ongoing)
  - ☐ Setup MC simulations
  - ☐ Determine Q

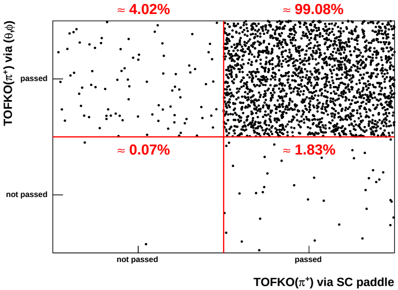
Backup: Momentum corrections: protons

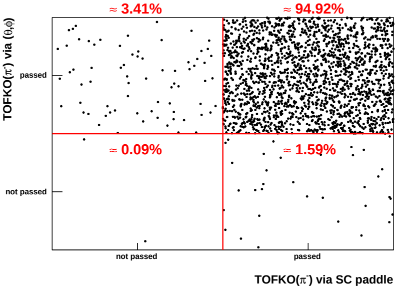


- Transverse momentum balance (proton): $[(\vec{\pi^+} + \vec{\pi^-}) - \vec{p}]_\perp$
- Investigated as function of Φ(proton)
- Left: before Φ-dependent momentum correction / Right: after Φ-dependent momentum correction
- Similar plots for positive/negative pions (see backup)

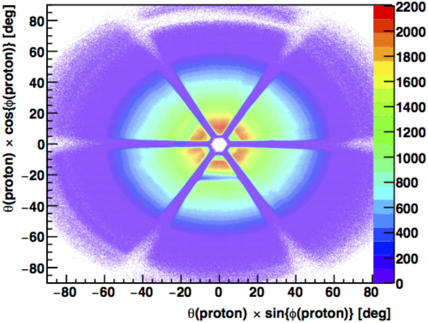
Backup: ToF-Knockouts: Statistics

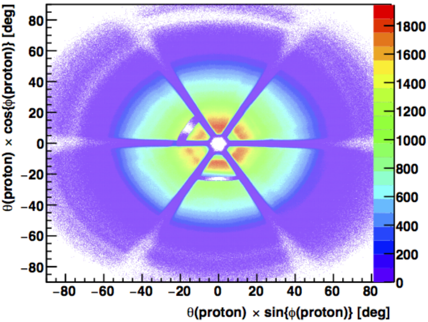






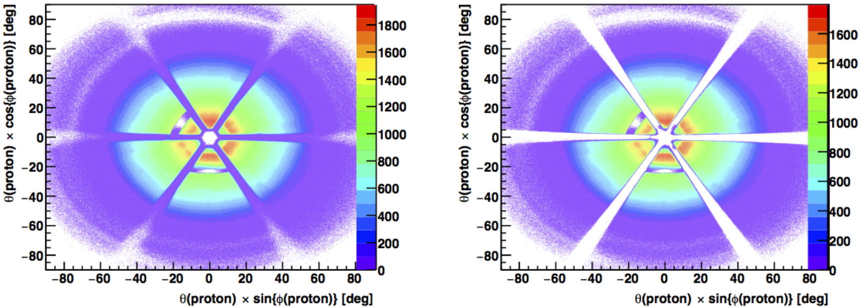
Backup: ToF-Knockouts: protons





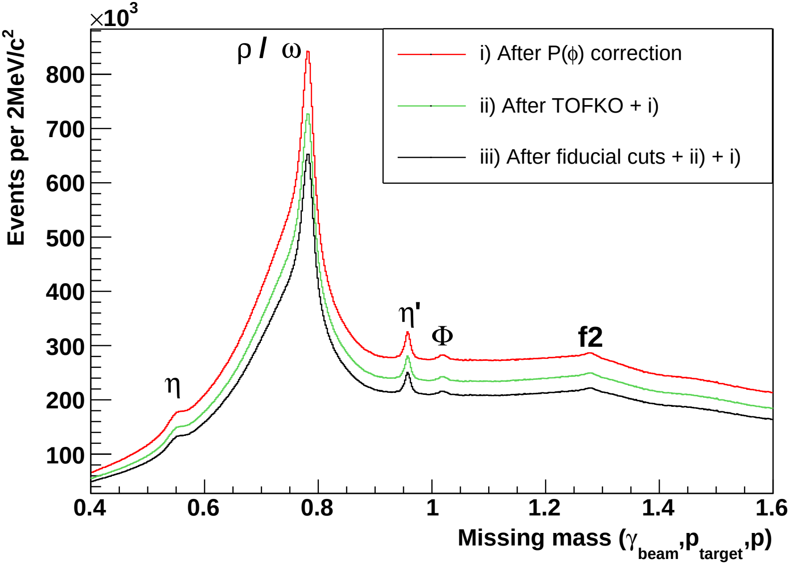
- Left: without knockout / Right: with knockout
- ToF-Knockout via:
  - i) θ and ϕ
  - ii) SC paddle number
- Similar results for positive/negative pions (see backup)

Backup: Fiducial cuts: protons



- Cut strength set to: nominal
- Left: Before fiducial cuts / Right: after fiducial cuts
- Also done for positive/negative pions (see backup)

Backup: Missing mass

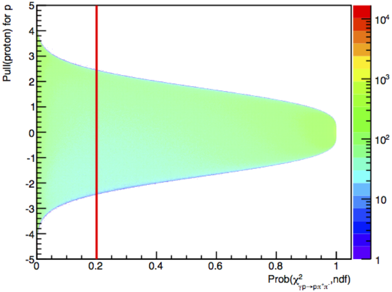


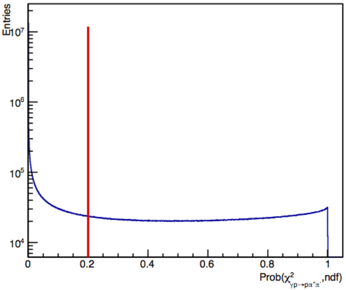
Backup: Kinematic Fit

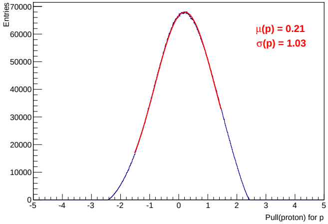
- Check existing error parameterisation (i.e. elements of covariance matrix)
- Do kinematic fit with reaction hypothesis: $\gamma p \rightarrow p\pi^+\pi^-(x)$ (4C-fit)
- Previous shown analysis steps have been applied
- Compare fit results with / without including multiple scattering effects for charged particles
- Look at pull distributions

Backup: Kinematic Fit: Pull distributions

Without including multiple scattering

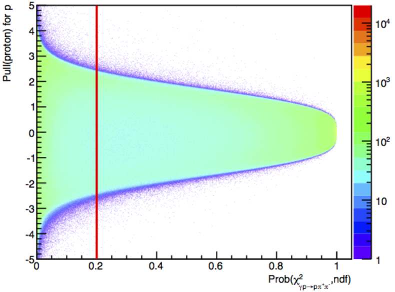


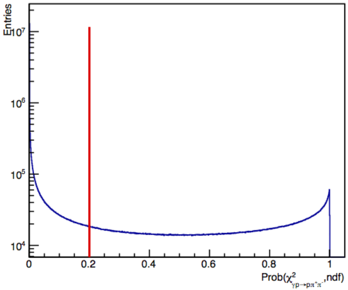


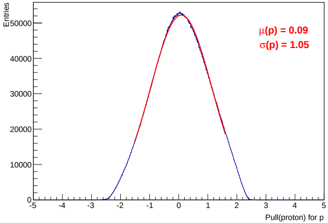


Backup: Kinematic Fit: Pull distributions

Including multiple scattering

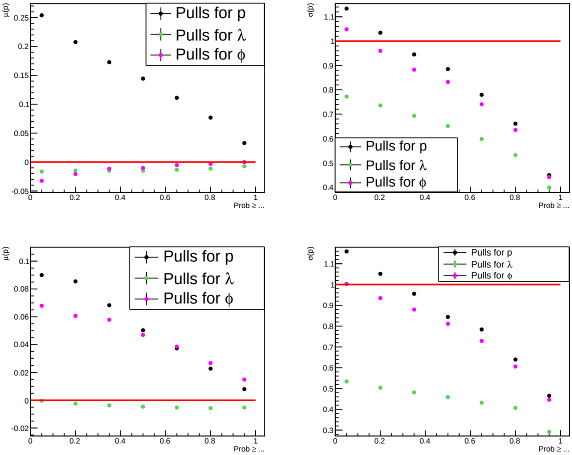






Backup: Kinematic Fit: Pull distributions for different probability cuts

For protons

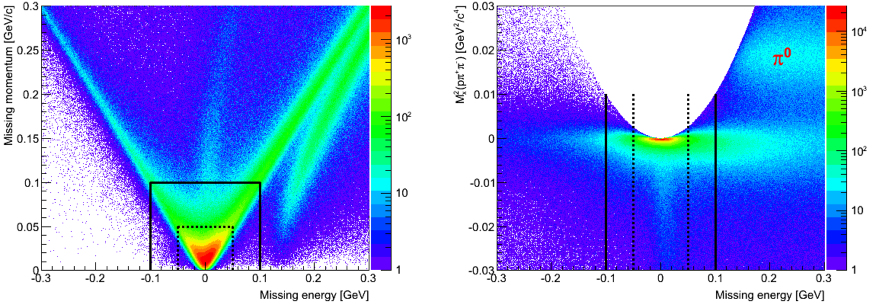


- Top: without including multiple scattering / Bottom: including multiple scattering

Backup: Intermediate summary

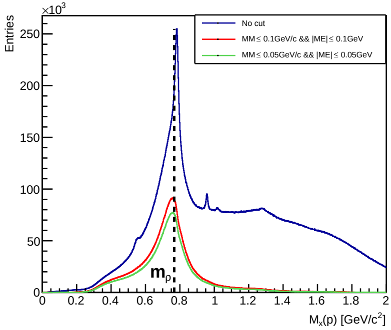
- Applied g12-Corrections
- First look at performance of kinematic fit
- Next steps:
  - i) Reconstruct $\gamma p \to pX[X \to \pi^+\pi^-]$ exclusively
  - ii) Do again a 4C kinematic fit and recheck pull-distributions

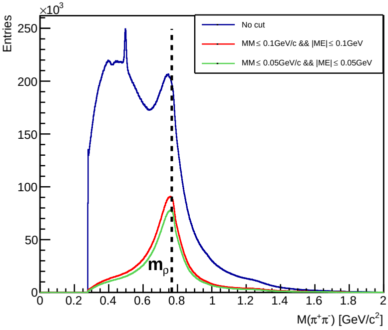
Backup: Check energy and momentum balance



- Missing energy and missing momentum:
  - Missing momentum: $P_{miss} = |\vec{P}_{in} - \vec{P}_{out}|$
  - Missing energy: $E_{miss} = E_{in} - E_{out}$
- Shape might be parameterised by: $P_{miss} = \sqrt{(E_{miss} + \delta)^2 + M}$
- Use box cut to select events only with charged particles in the final state
- Remark: This cut should used with caution in a "regular" analysis

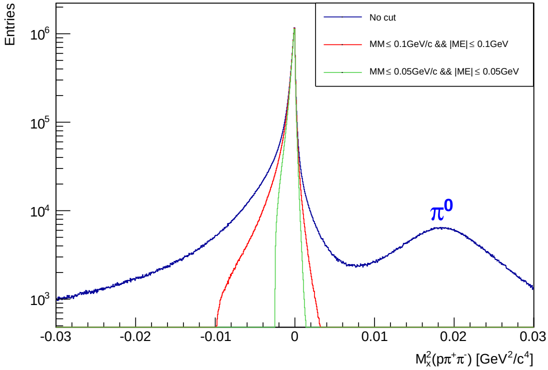
Backup: Effects of the box cut: missing mass and invariant mass





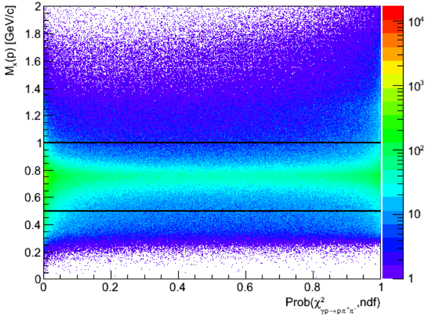
- Invariant mass of final state pions and proton missing mass have same shape ⇒ Indication of proper event selection
- Also look at proton-pion missing mass

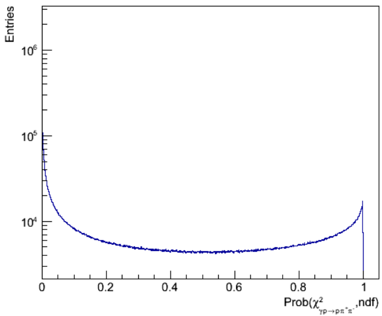
Backup: Effects of the box cut: missing mass (proton and pions)



- Clear rejection of events with a π^0
- Next: Do kinematic fit and check probability distribution
- A results shown in the following are obtained by using the tight box cut

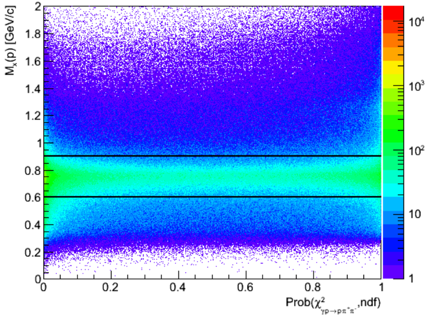
Backup: Effetcs of the box cut: The kinematic fit probability

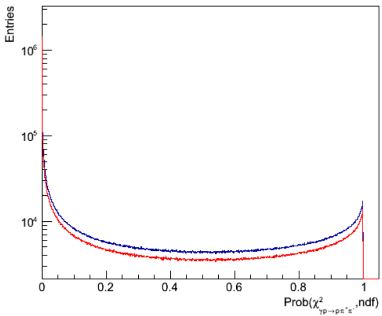




- Look at $M_x(p)$ vs. the kinematic fit probability
- Do a projection onto the X-axis for different missing mass windows:
  - Inspect shape of probability distribution
  - Recheck event selection $\rightarrow$ Is there a contamination from other reaction channels?

Backup: Effetcs of the box cut: The kinematic fit probability





- Look at $M_x(p)$ vs. the kinematic fit probability
- Do a projection onto the X-axis for different missing mass windows:
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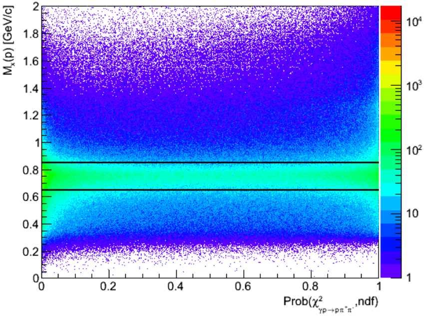
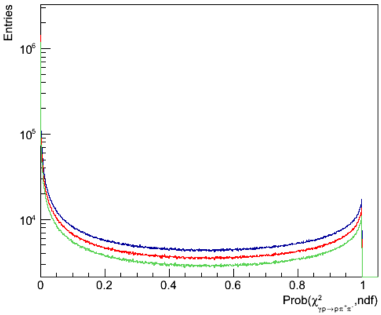
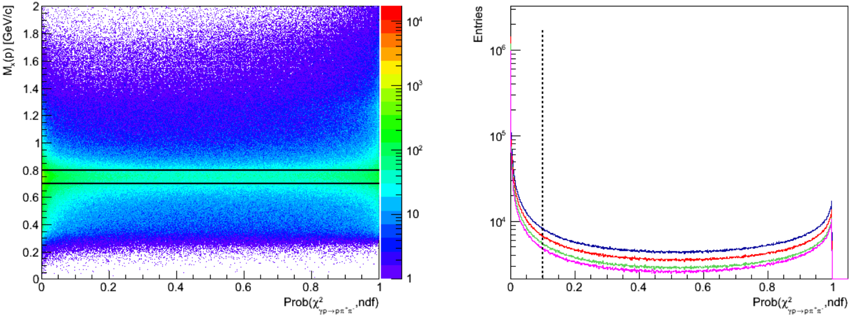
Backup: Effetcs of the box cut: The kinematic fit probability





- Look at $M_x(p)$ vs. the kinematic fit probability
- Do a projection onto the X-axis for different missing mass windows:
  - Inspect shape of probability distribution
  - Recheck event selection $\rightarrow$ Is there a contamination from other reaction channels?

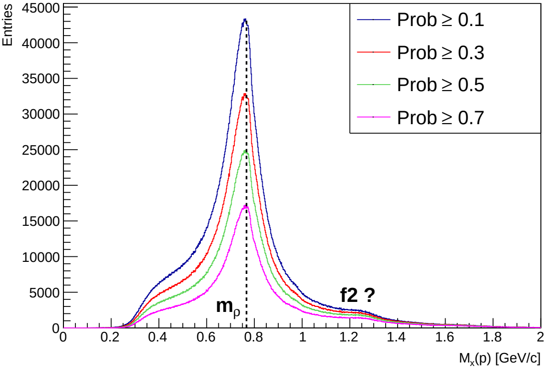
Backup: Effetcs of the box cut: The kinematic fit probability



- Look at $M_x(p)$ vs. the kinematic fit probability
- Do a projection onto the X-axis for different missing mass windows:
  - Inspect shape of probability distribution
  - Recheck event selection $\rightarrow$ Is there a contamination from other reaction channels?

$\Rightarrow$ Probability distributions have same shape for values > 0.1

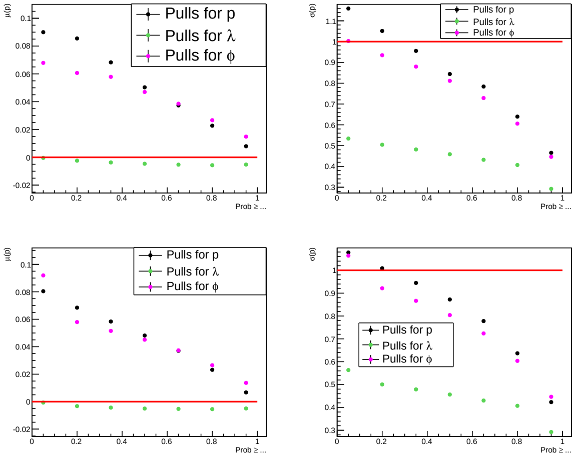
Backup: Kinematic fit: Recheck missing mass



- X-check: Look at proton missing mass for different probability cuts → Do I see, what I want/should see?
- Contribution from f2?
- Next step: Check pull-distributions

Backup: Kinematic fit: Recheck pull-distributions

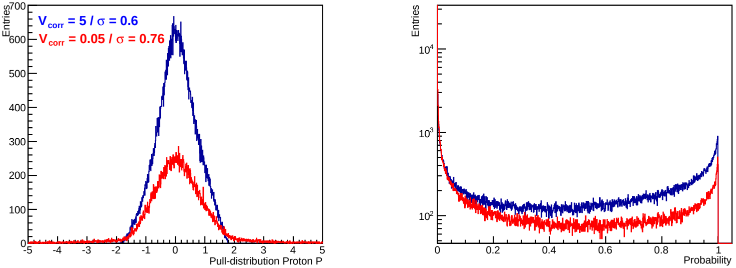
For protons



- Top: without requesting energy and momentum balance
- Bottom: requesting energy and momentum balance

Backup: Kinematic fit: Scale matrix elements

- Look at the elements of the covariance matrix $\rightarrow$ i.e. change one element and investigate influence on probability-/pull- distributions
- Change matrix element (i,j) according to:
  $V(i,j) \mapsto V(i,j) \times V_{corr}(i,j)$
- Example shown below: $V^{pp}_{\text{proton}} \mapsto V^{pp}_{\text{proton}} \times V_{corr}$ and a cut: Probability $>= 0.5$



Scaling matrix elements

Scaled: $V^{pp}_{\text{proton}} \mapsto V^{pp}_{\text{proton}} \times V_{corr}$

V_{corr}	$\sigma_E(\gamma)$	$\sigma_p(\pi^+)$	$\sigma_p(p)$	$\sigma_\lambda(\pi^-)$
5	0.94	0.73	0.6	0.44
2.5	0.94	0.79	0.75	0.45
1.5	0.99	0.76	0.84	0.46
1.0	1.05	0.80	0.79	0.49
0.5	1.08	0.82	0.82	0.52
0.25	1.04	0.85	0.75	0.52
0.05	1.01	0.86	0.76	0.56

Scaling matrix elements

Scaled: $V_{\pi^-}^{\lambda\phi} \mapsto V_{\pi^-}^{\lambda\phi} \times V_{corr}$

V_{corr}	$\sigma_E(\gamma)$	$\sigma_p(\pi^+)$	$\sigma_p(p)$	$\sigma_\lambda(\pi^-)$
5	1.06	0.87	0.85	0.54
2.5	1.05	0.80	0.85	0.51
1.5	1.00	0.78	0.85	0.51
1.0	1.05	0.80	0.79	0.49
0.5	1.01	0.78	0.80	0.49
0.25	1.08	0.79	0.84	0.49
0.05	1.01	0.77	0.84	0.48

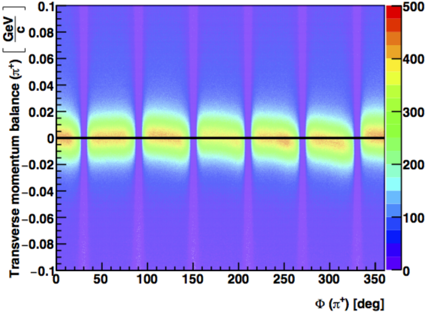
Scaling matrix elements

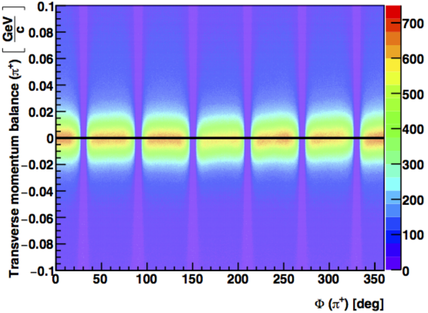
Scaled: $V_\gamma^E \mapsto V_\gamma^E \times V_{corr}$

V_{corr}	$\sigma_E(\gamma)$	$\sigma_p(\pi^+)$	$\sigma_p(p)$	$\sigma_\lambda(\pi^-)$
5	1.05	0.80	–	–
2.5	1.05	0.80	–	–
1.5	1.05	0.80	–	–
1.0	1.05	0.80	–	–
0.5	1.05	0.80	–	–
0.25	1.05	0.80	–	–
0.05	1.05	0.80	–	–

- Open questions:
  - Global scaling factor or individual scaling factor?
  - How large has V_{corr} to be for V_γ^E, in order to see an influence?
- Investigations are ongoing

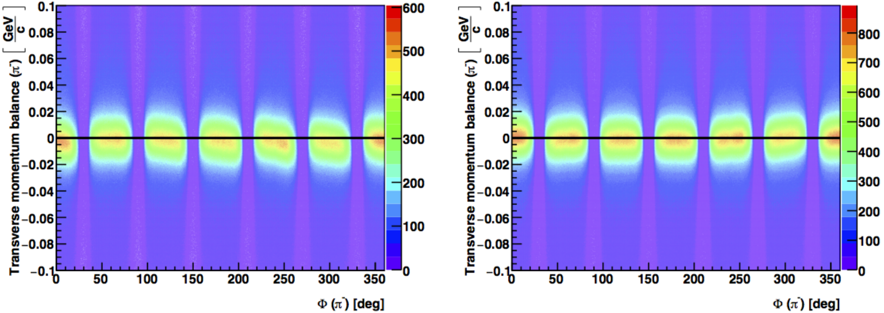
Backup: Momentum corrections: positive pions





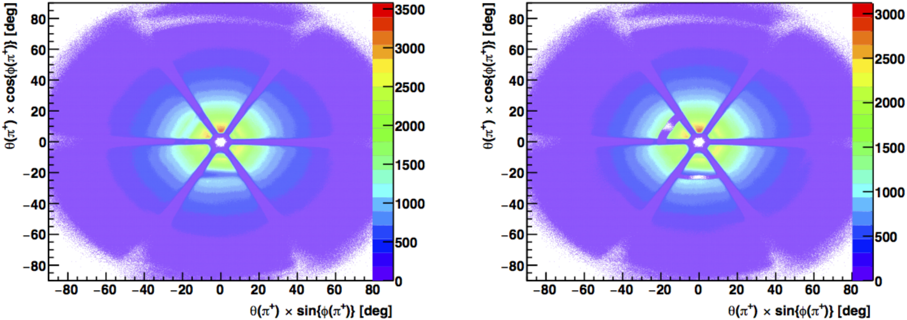
- Transverse momentum balance (pi^+): $[(\vec{p} + \vec{\pi^-}) - \vec{\pi^+}]_\perp$
- Investigated as function of $\Phi(\pi^+)$
- Left: before Φ-dependent momentum correction / Right: after Φ-dependent momentum correction

Backup: Momentum corrections: negative pions



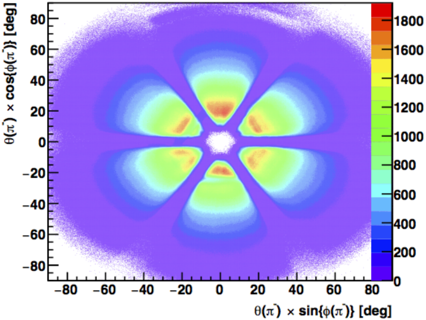
- Transverse momentum balance (pi^-): $[(\vec{p} + \vec{\pi^+}) - \vec{\pi^-}]_\perp$
- Investigated as function of $\Phi(\pi^-)$
- Left: before Φ-dependent momentum correction / Right: after Φ-dependent momentum correction

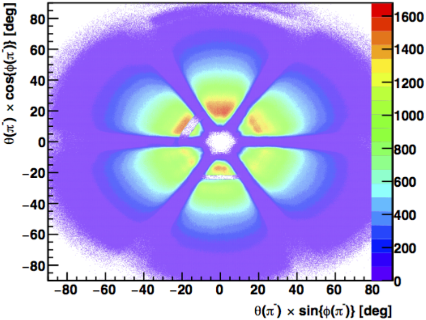
Backup: ToF-Knockouts: positive pions



- Left: without knockout / Right: with knockout
- ToF-Knockout via:
  - i) θ and ϕ
  - ii) SC paddle number

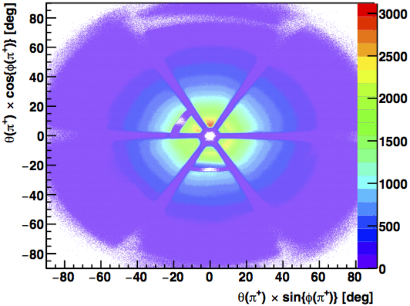
Backup: ToF-Knockouts: negative pions

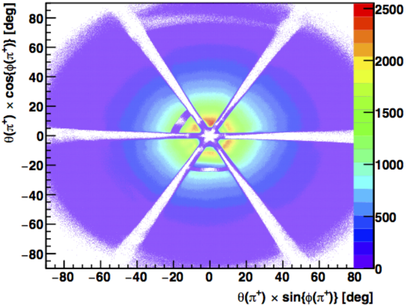




- Left: without knockout / Right: with knockout
- ToF-Knockout via:
  - i) θ and ϕ
  - ii) SC paddle number

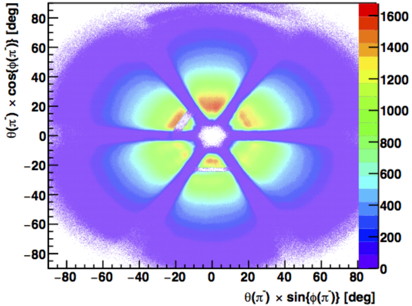
Backup: Fiducial cuts: positive pions

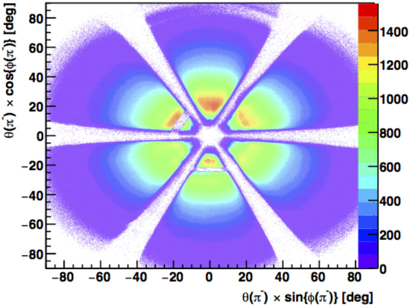




- Cut strength set to: nominal
- Left: Before fiducial cuts / Right: after fiducial cuts

Backup: Fiducial cuts: negative pions

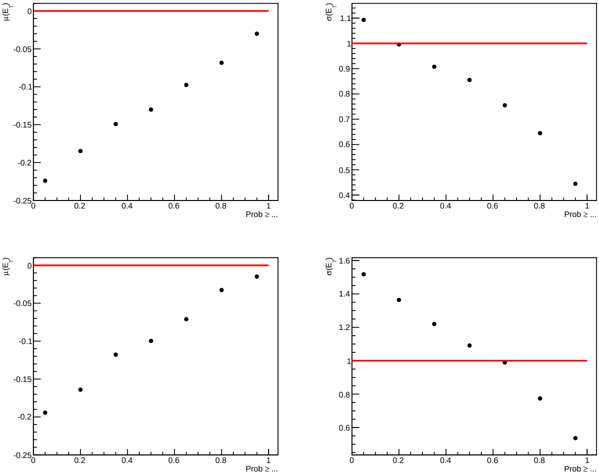




- Cut strength set to: nominal
- Left: Before fiducial cuts / Right: after fiducial cuts

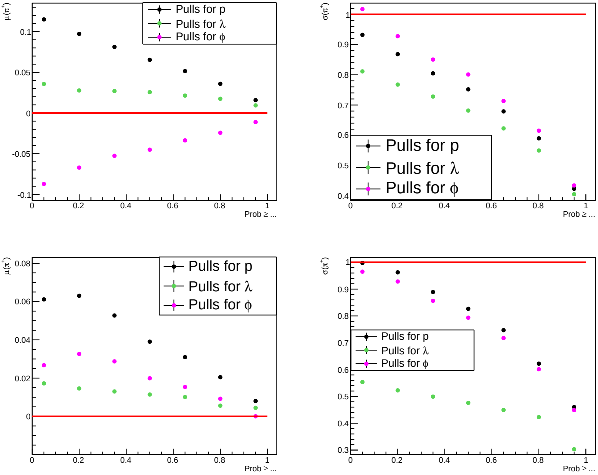
Backup: Kinematic Fit: Pull distributions for different probability cuts

For the beam photon



Backup: Kinematic Fit: Pull distributions for different probability cuts

For π^+



Backup: Kinematic Fit: Pull distributions for different probability cuts

For π^-