Feasibility Studies for $\bar{p}p \rightarrow \phi\phi$ at PANDA Phase-1

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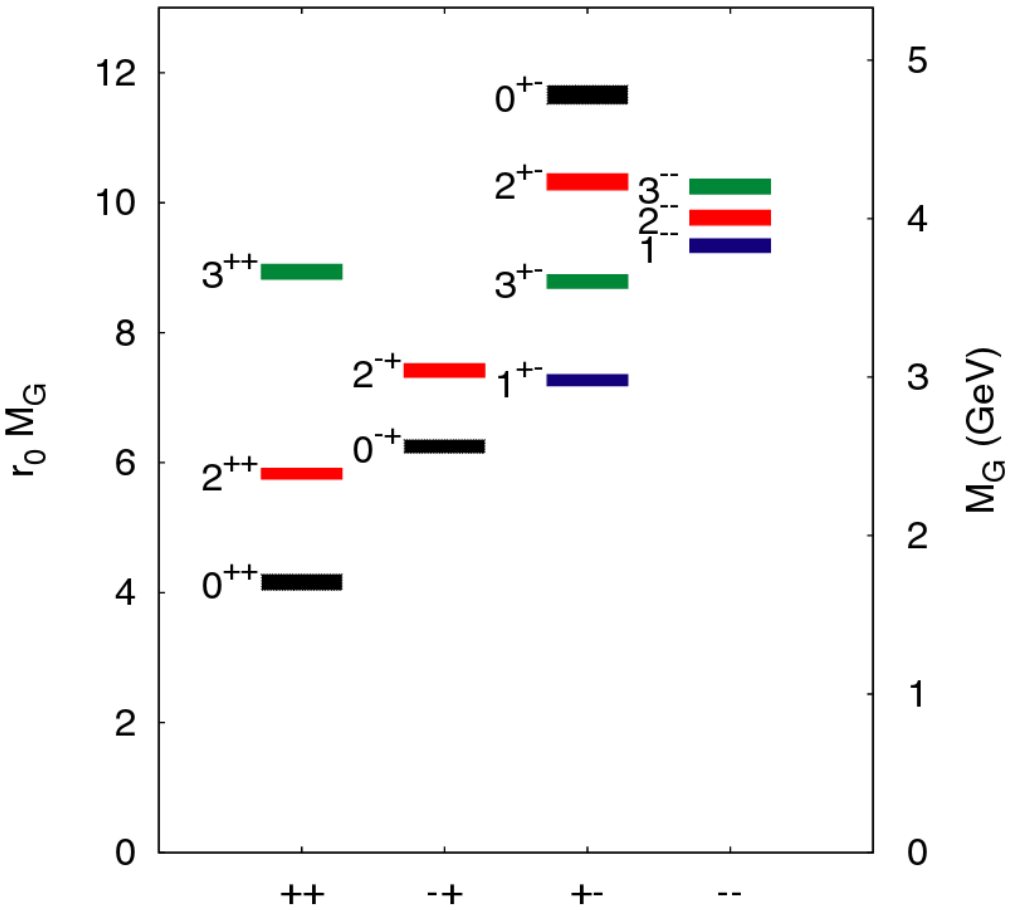
Outline

Motivation

- QCD predicts tensor glueball state at $2.4\,\mathrm{GeV}/c^2$

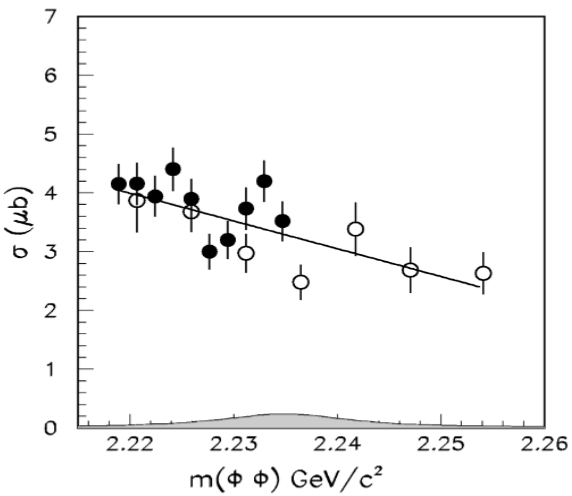


Phys.Rev. D73 (2006) 014516

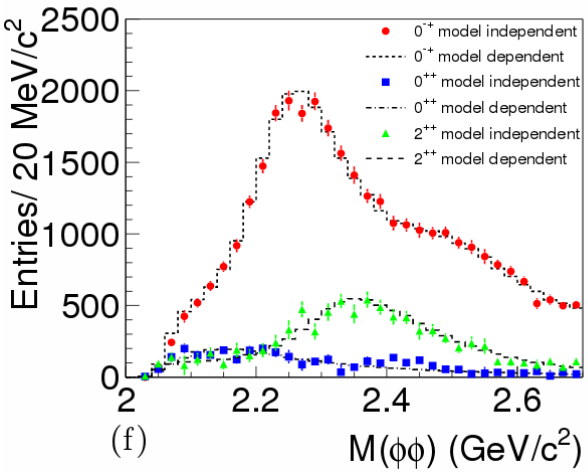
Motivation

- JETSET experiment $\rightarrow$ Magnitude of $\bar{p}p \rightarrow \phi\phi$ cross section exceeds expectations from a simple application of the OZI rule by two orders of magnitude
- Observation of resonances in $\pi^- p \rightarrow \phi\phi n \rightarrow$ PWA revealed presence of three interfering tensor resonances $f_2(2010)$, $f_2(2300)$ and $f_2(2340)$
- BESIII experiment $\rightarrow$ Tensor resonances also in $J/\psi \rightarrow \gamma\phi\phi$
- Large cross section coming from intermediate glue

JETSET, Phys.Rev.D57,5370



BESIII, Phys.Rev.D93,112011



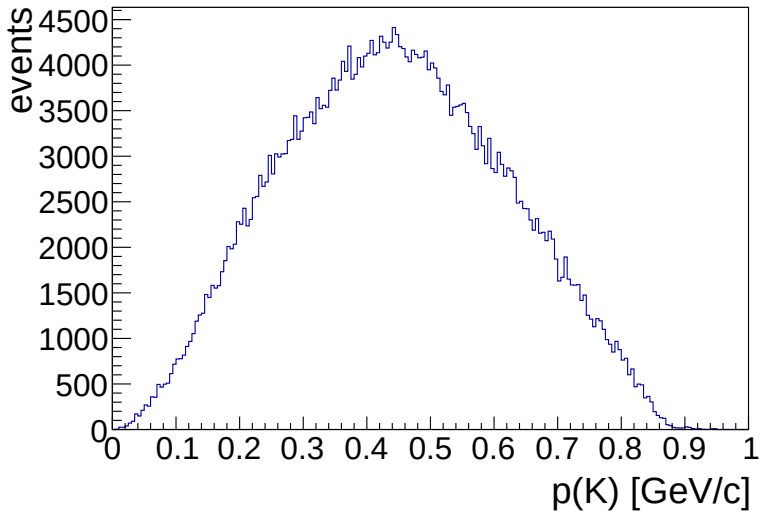
Motivation

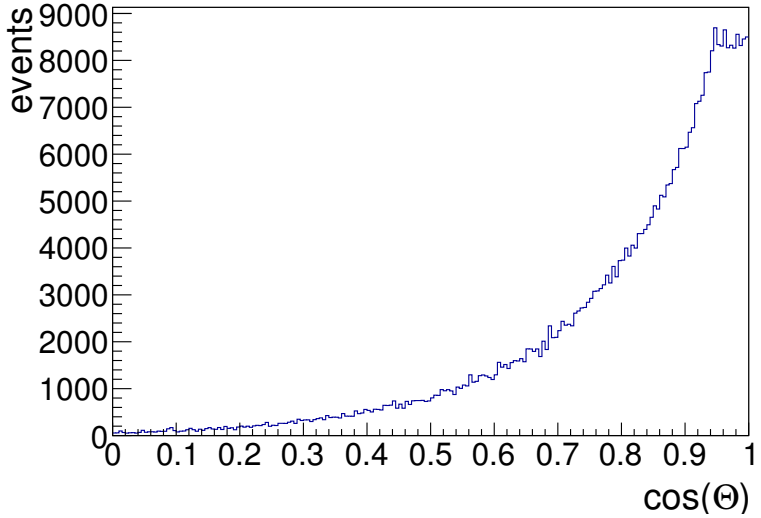
- Feasibility study of the reconstruction of the decay $\bar{p}p \to X \to \phi\phi \to K^+K^-K^+K^-$
- Scan the cross section in the mass region of the tensor glueball candidate ($\sqrt{s} = (2.25 - 2.7)\text{GeV}/c^2$)
- Extract 2^{++} contributions by performing Partial Wave Analysis

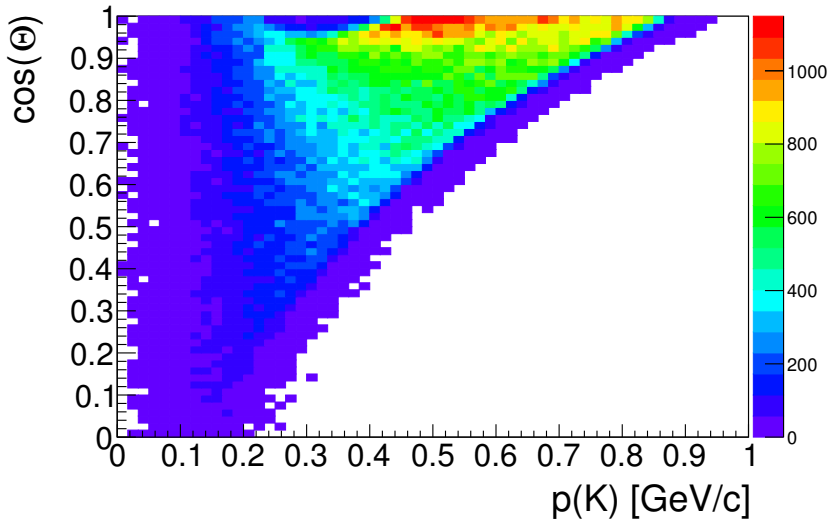
Technical Aspects

- Phase 1 detector setup $\rightarrow$ day1 macros
- PandaRoot release dec17
- Ideal tracking
- Track reconstruction with kaon hypothesis
- 100k $\bar{p}p \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$ events at $p_{\bar{p}} = 1.5$ GeV/c

Generated Monte Carlo Truth



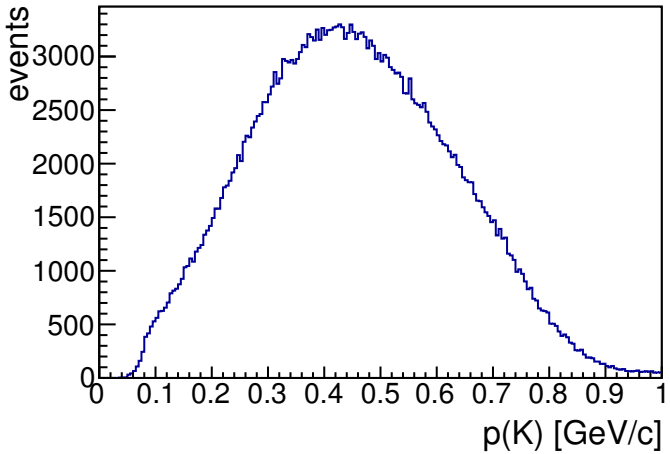


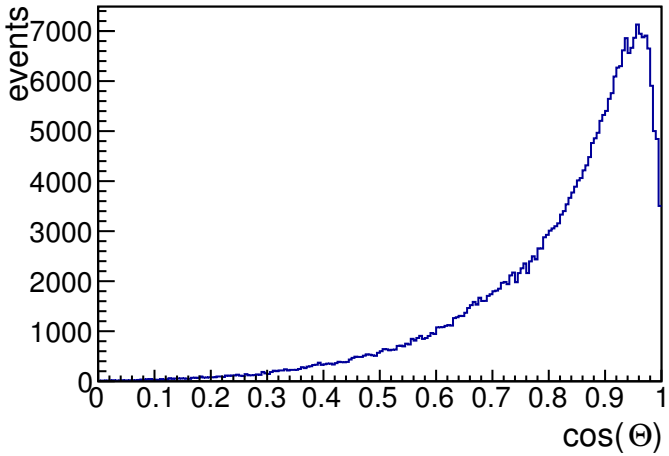


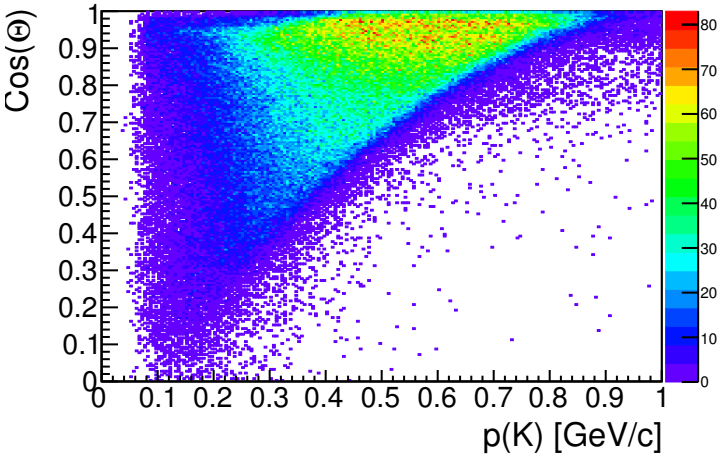
- $\sim$ 25% of tracks $\cos(\Theta) > 0.9$ $(0^\circ < \Theta(K) < 20^\circ)$
- $\sim$ 7% of tracks $p(K) < 0.2$

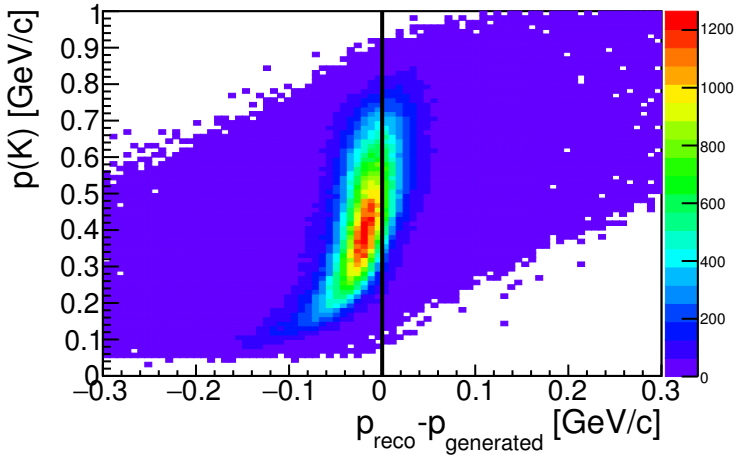
Reconstruction of Kaons with default (muon) Hypothesis

- Shift in $p_{\mathrm{reco}} - p_{\mathrm{generated}}$
- Low efficiency for tracks with $\cos(\Theta) > 0.9$



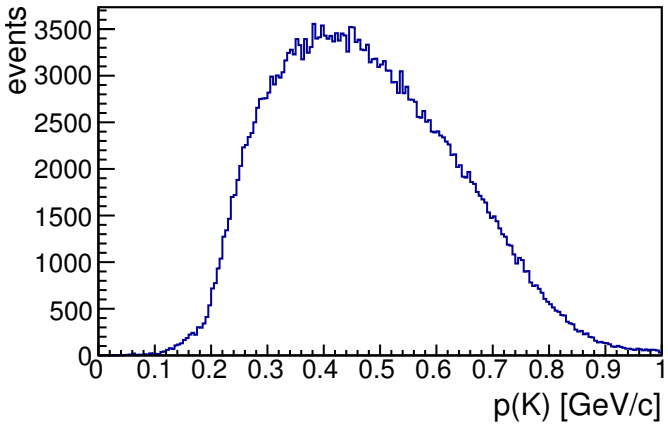


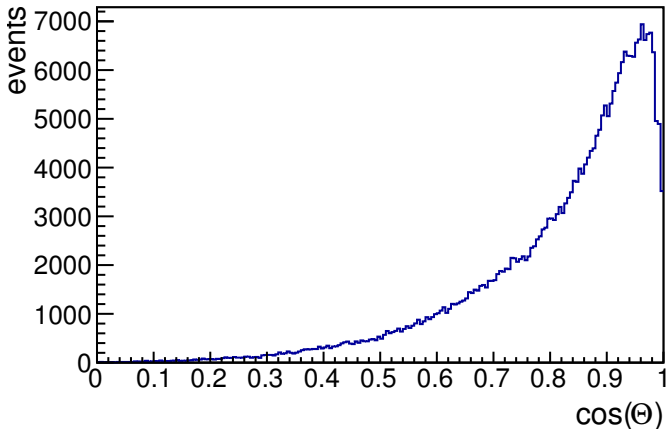


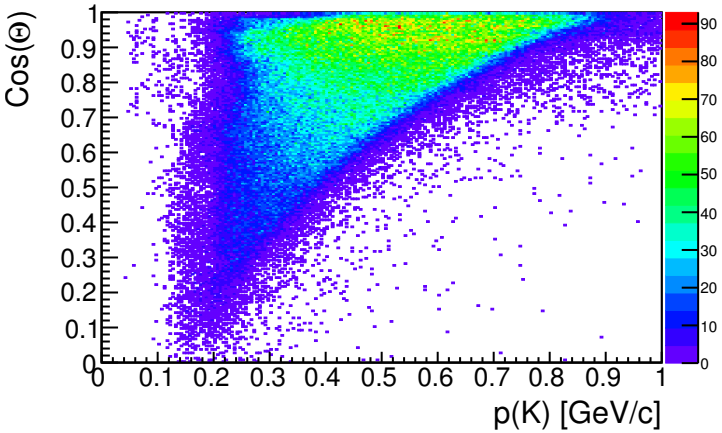


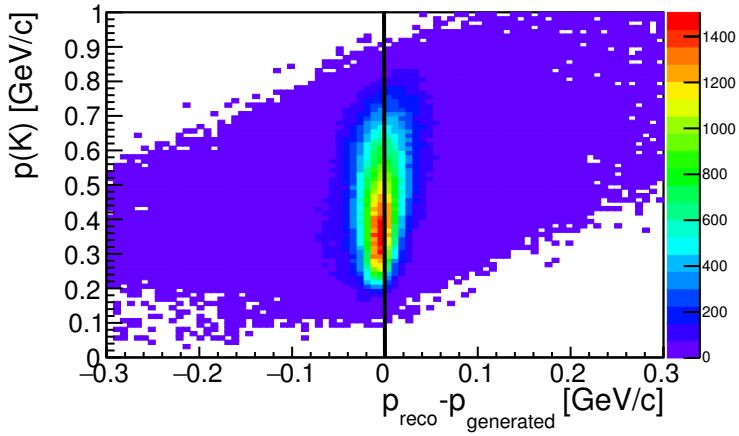
Reconstruction of Kaons with kaon Hypothesis

- Shift in $p_{\mathrm{reco}} - p_{\mathrm{generated}}$ gets reduced
- Low efficiency for tracks with cos(Θ) $>$ 0.96 and p(K)$<$ 0.2







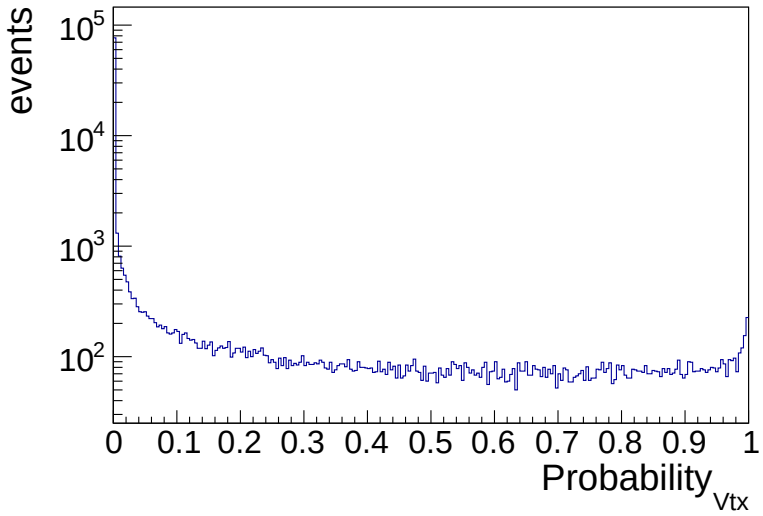


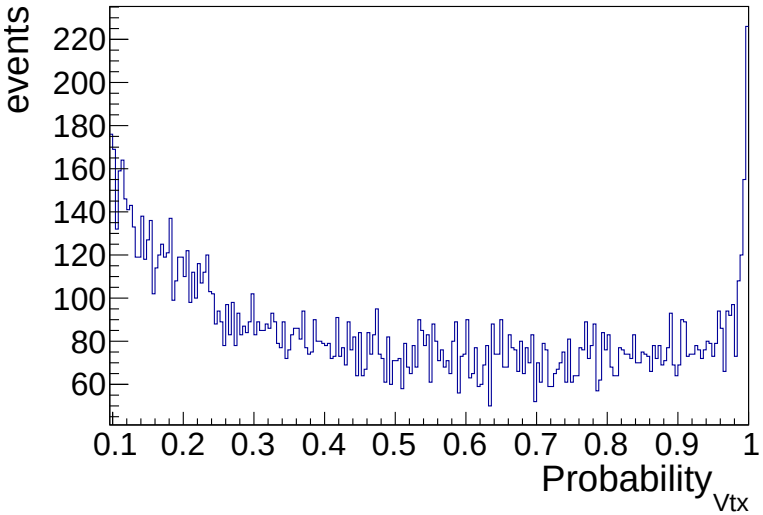
Selection Criteria

1. List of $\bar{p}p$ candidates by forming all combinations of 2 K^+ and 2 K^-
2. Vertex Fit (RhoKinVtxFitter) $P_{\bar{p}p} > 0.001$
3. 4C Fit (Rho4CFitter) $P_{\bar{p}p} > 0.001$
4. Select combination with minimal $r = \sqrt{(m(K_1K_2) - m_\phi)^2 + (m(K_3K_4) - m_\phi)^2}$
5. Mass window r < 10 MeV$/c^2$

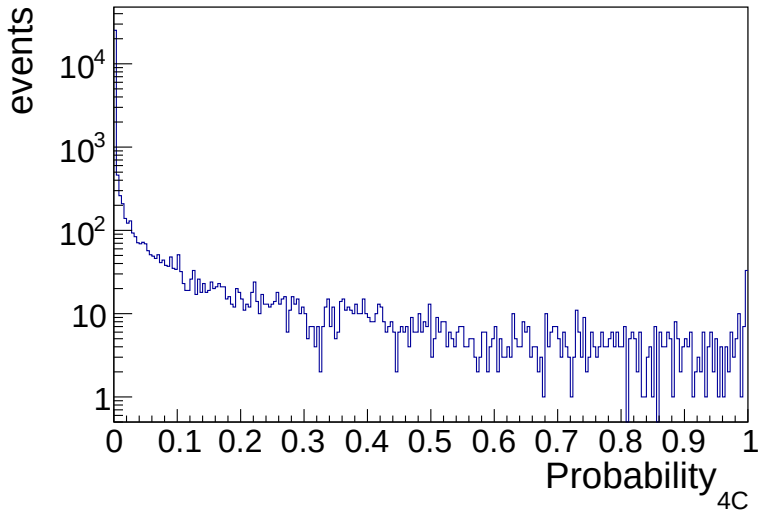
Probabilities

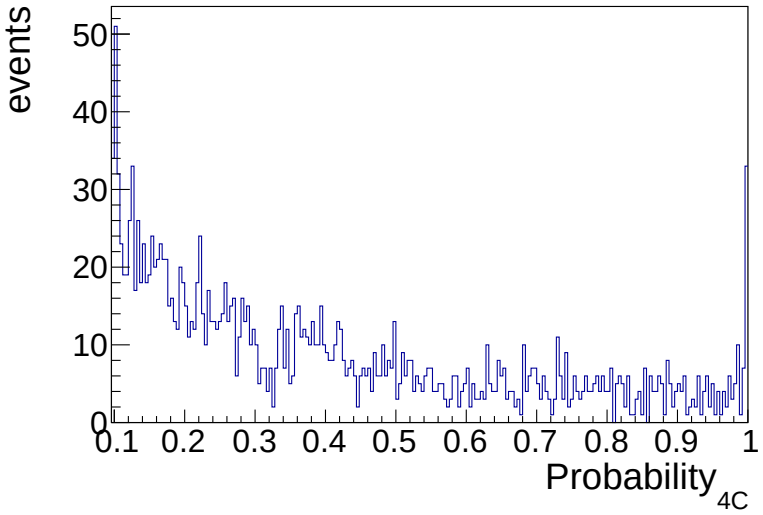
Probability Vertex Fit



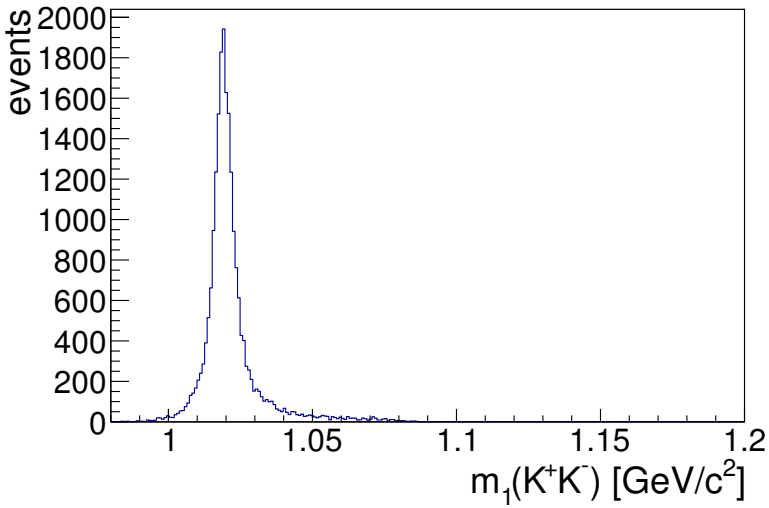


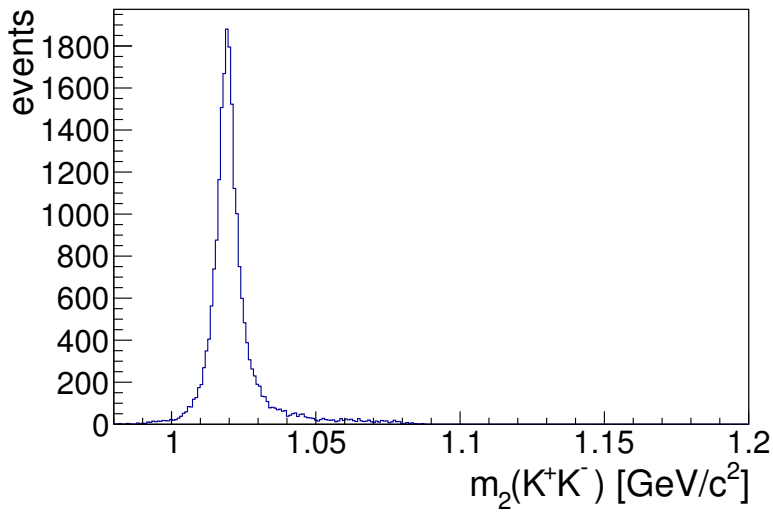
Probability 4C Fit

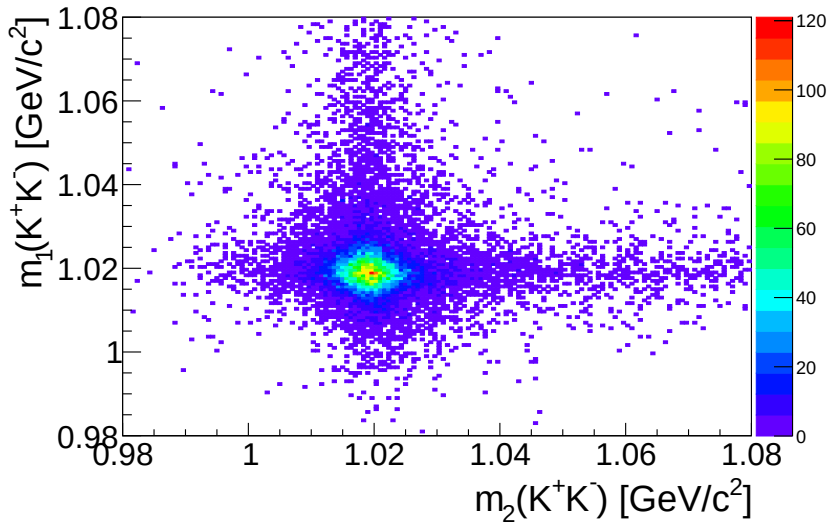




Reconstructed K^+K^- mass after Vertex and 4C Fit



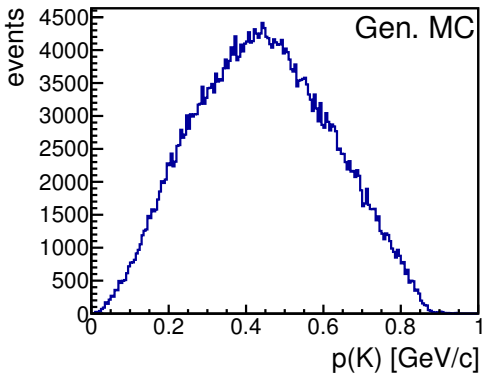


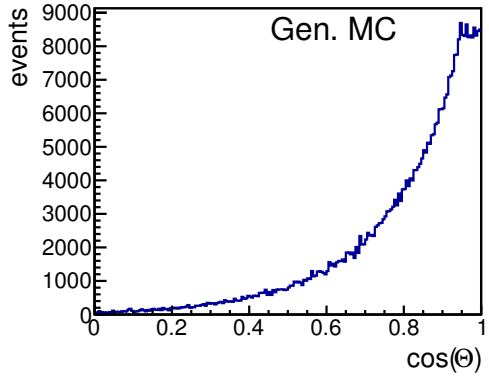


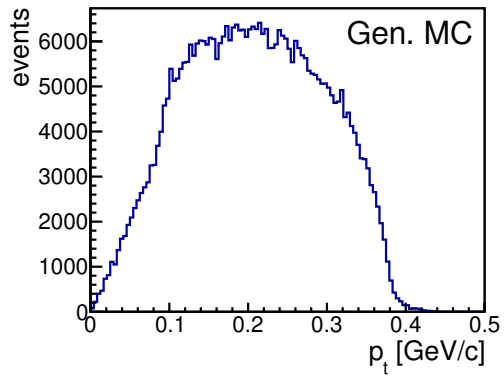
- Selection of events with $r < 10\ \mathrm{MeV}/c^2$

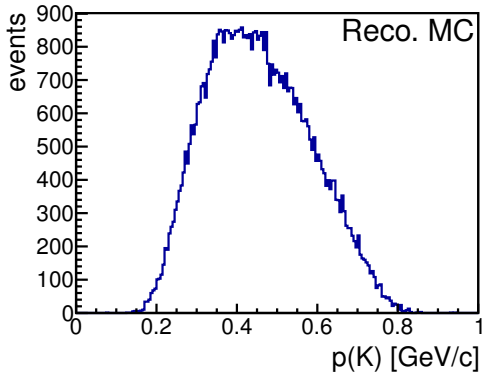
Mom and cos(Θ) after all selection criteria

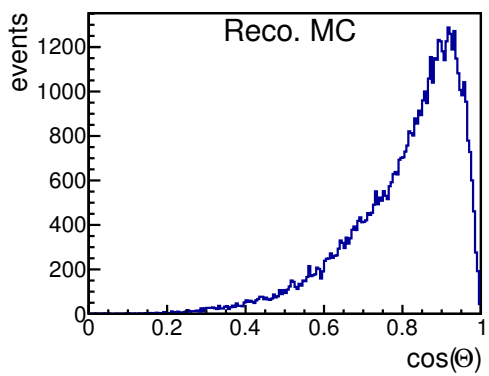
- Low efficiency for tracks with cos(Θ) $>$ 0.9 and p(K)$<$ 0.2

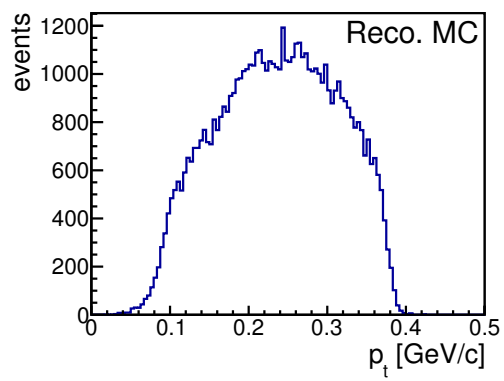




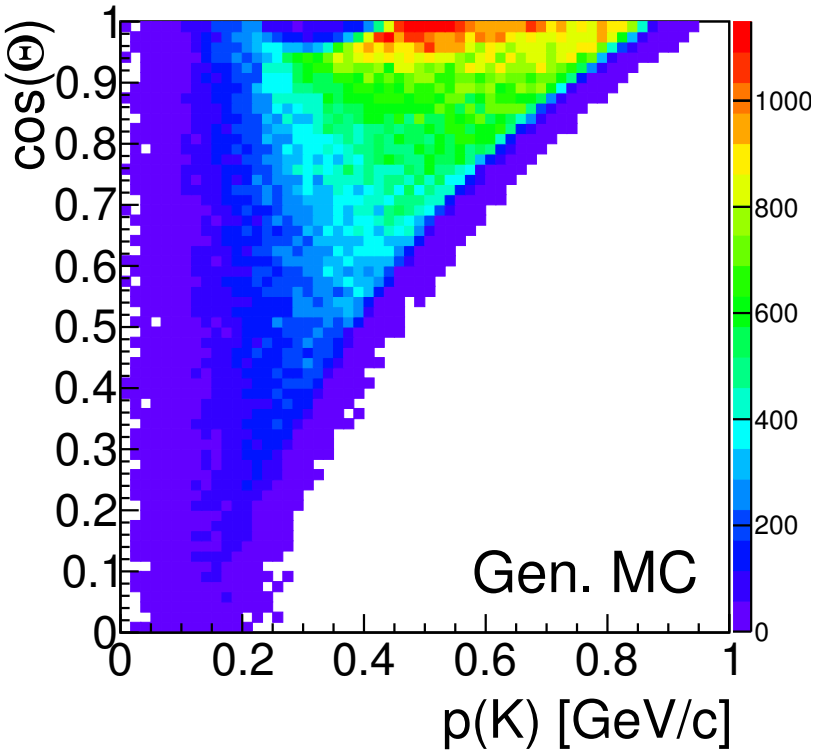


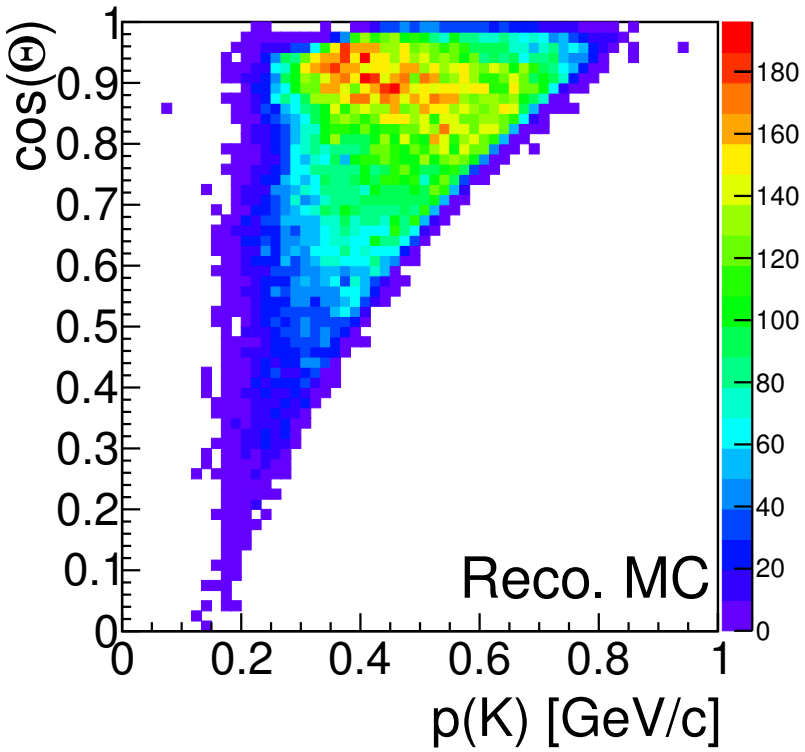






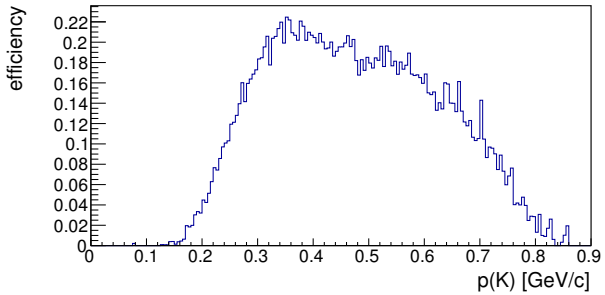
Momentum Vs. cos(Θ)

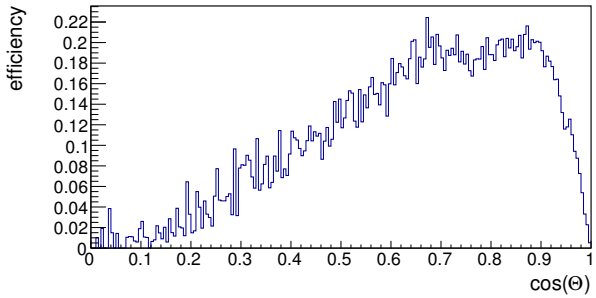


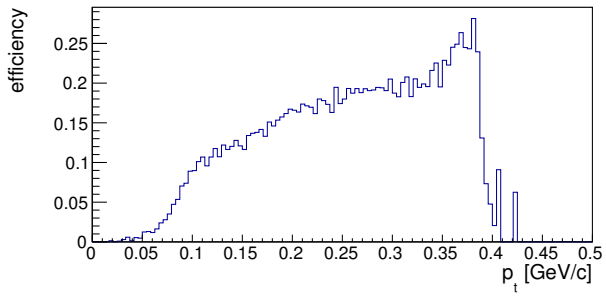


Efficiencies

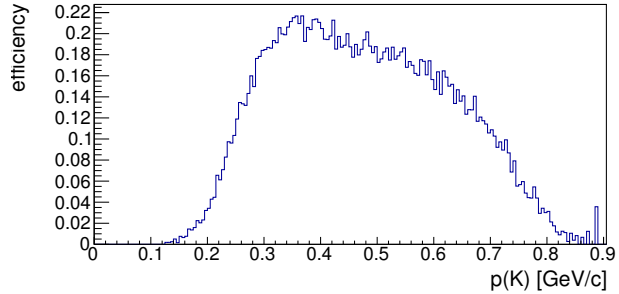
Phase 1 detector setup

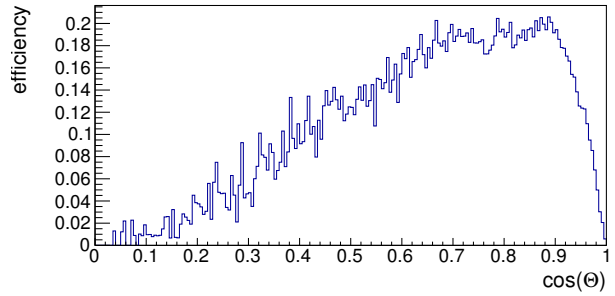


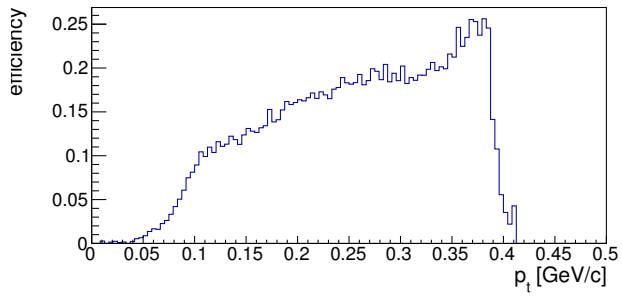




Full detector setup







- → Loss of tracks not due to phase 1 detector setup

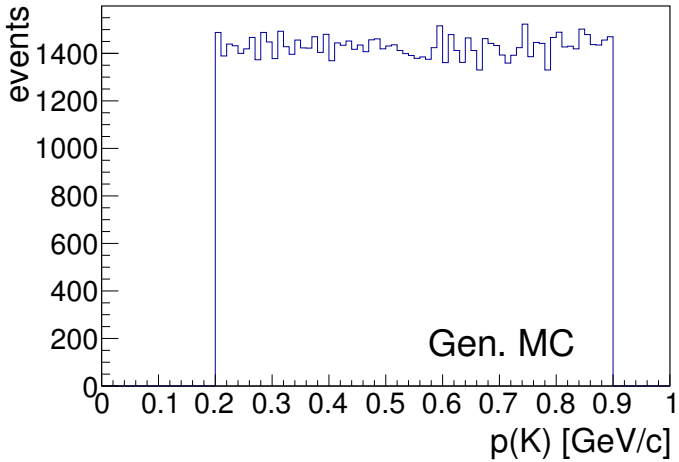
Efficiency

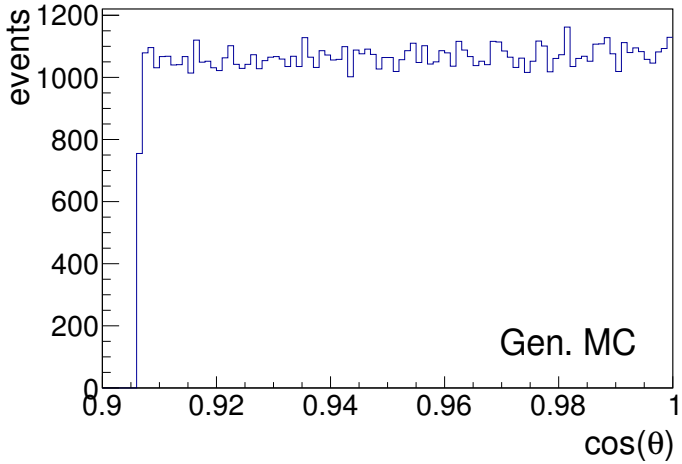
PandaRoot Option	Efficiency
Day1 + Default (muon) hypothesis	6.9%
Day1 + Kaon hypothesis	14.9%
Efficiency PANDA Physics Book 2009	25%

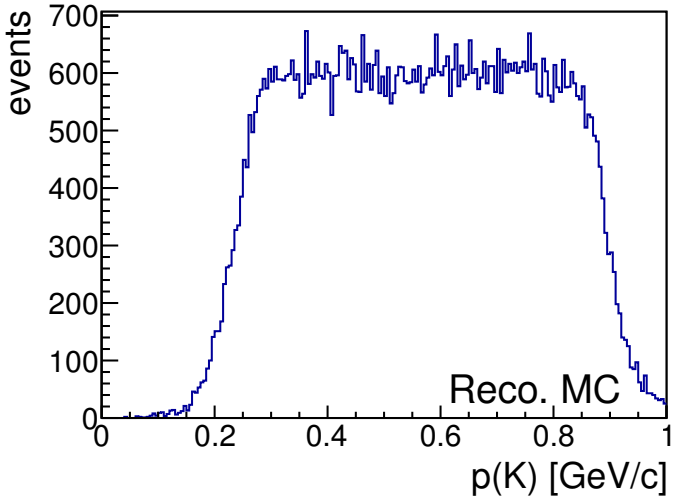
Kinematics with Box Generator

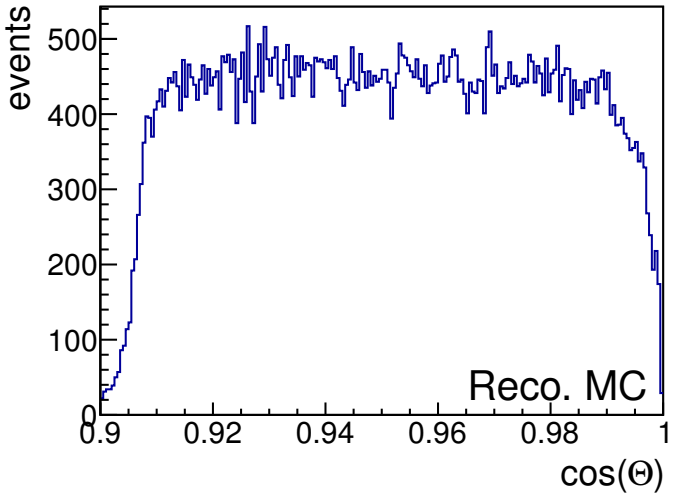
- Flat distribution in $0.2\,\mathrm{GeV}/c <$ p(K)$< 0.9\,\mathrm{GeV}/c$ and $0.9<\cos(\Theta)< 1$
  $\rightarrow$ What happens to kaons with $0^\circ<\Theta<20^\circ$?
- Flat distribution in $0.1\,\mathrm{GeV}/c <$ p(K)$< 0.2\,\mathrm{GeV}/c$ and $0.2<\cos(\Theta)< 0.86$ $(30^\circ<\Theta<80^\circ)$
  $\rightarrow$ What happens to kaons with p(K)$< 0.2\,\mathrm{GeV}/c$?

Flat Distribution in 0.2 GeV/c < p(K)< 0.9 GeV/c and 0.9<cos(Θ)< 1



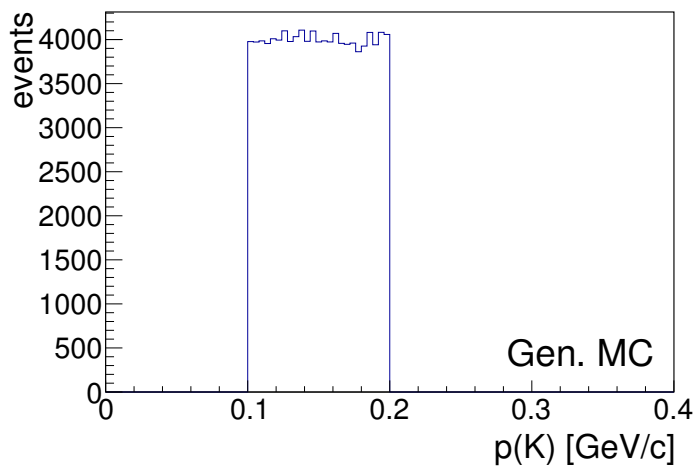


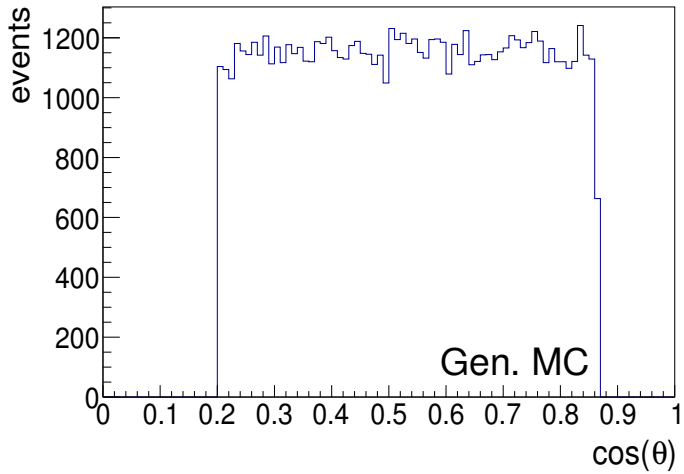


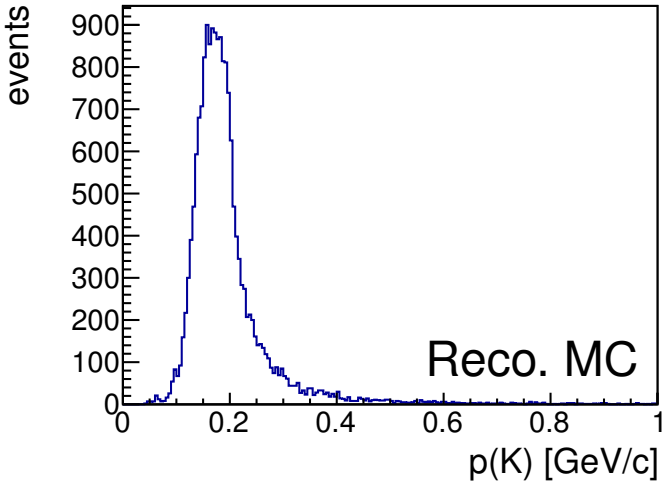


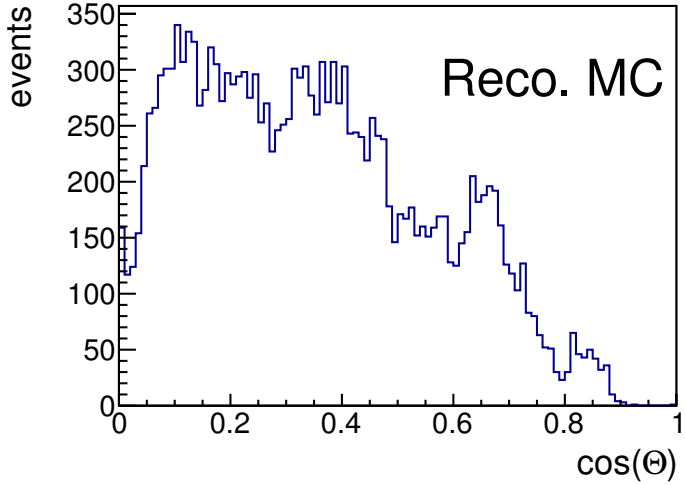
- → No reconstruction of kaons with small Θ angles

Flat Distribution in 0.1 GeV/c < p(K)< 0.2 GeV/c and 0.2<cos(Θ)< 0.86



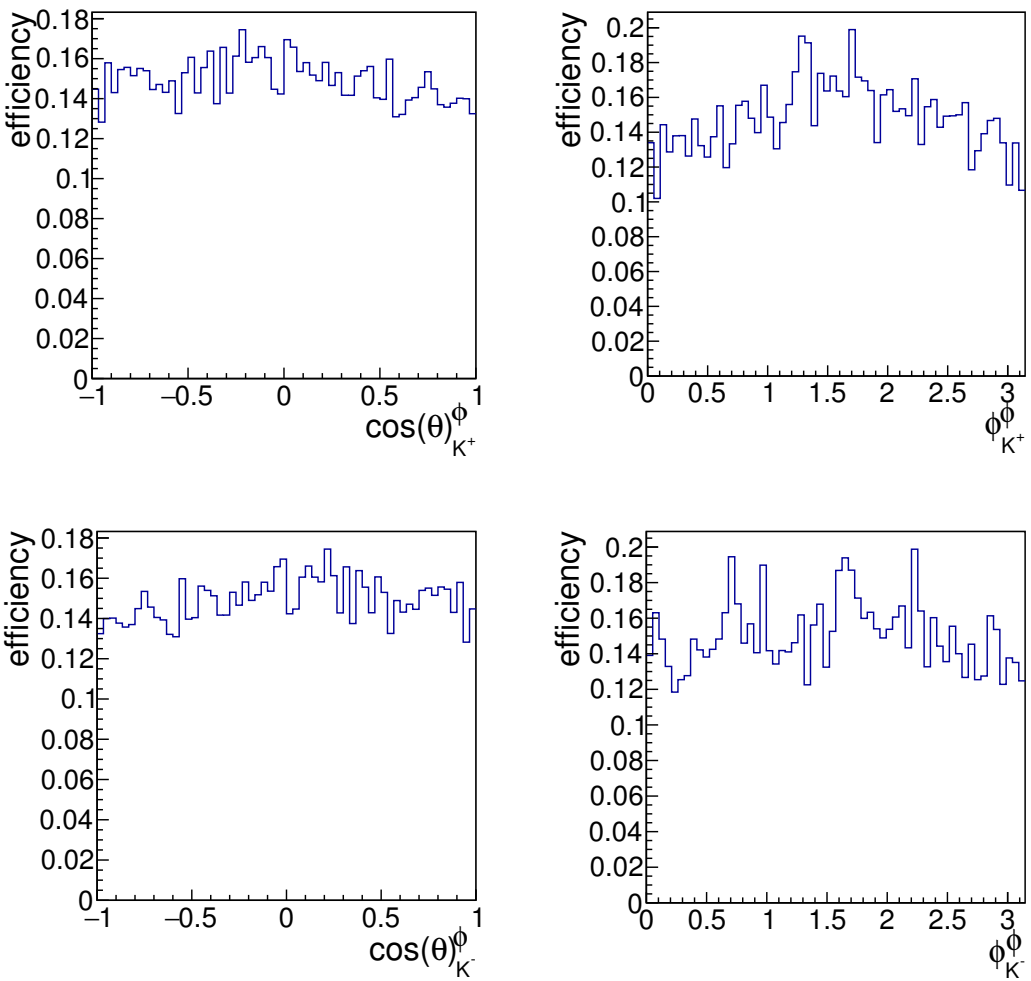






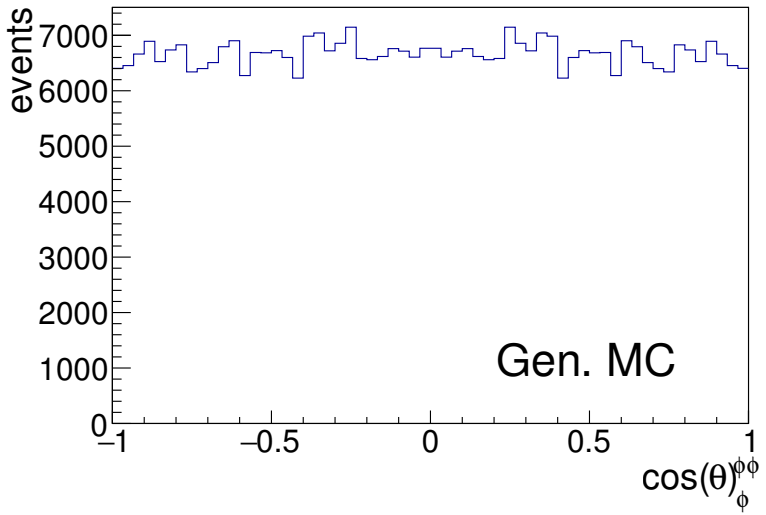
- → Reconstruction of tracks with p(K) < 0.2 GeV/c possible with box generator

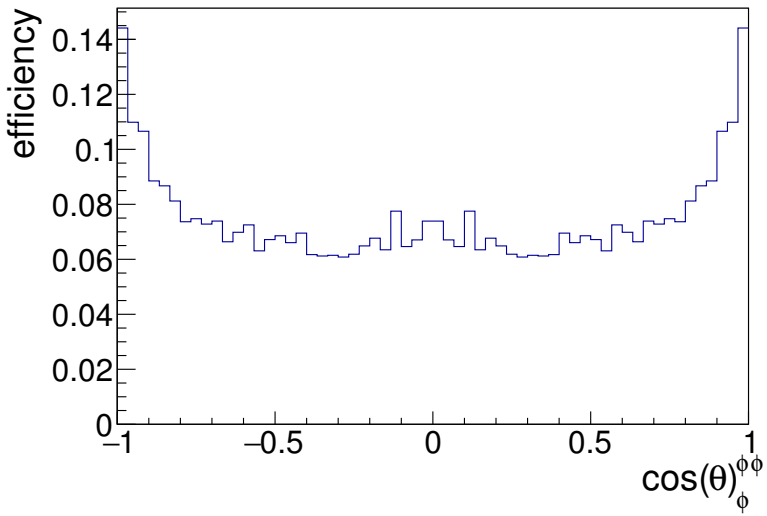
Decay angle distributions



- Flat cos(Θ) distribution for kaons in system of ϕ meson
- Almost flat ϕ angle distribution for kaons in system of ϕ meson

Decay angle distributions





- Decay angle distributions depend on efficiency distributions
- Higher efficiency for smaller decay angles

Summary and Outlook

- Better results when reconstructing with kaon hypothesis
- No proper reconstruction of tracks with $0^\circ < \Theta(K) < 20^\circ$
- No proper reconstruction of tracks with $p(K) < 0.2$ GeV
  $\rightarrow$ Lower limit for kaon reconstruction with PANDA?
- Efficiency: 14.9%
- Decay angle distributions reasonably flat

- Background studies with generic DPM events
- Possible decay channels:
  $\bar{p}p \rightarrow \pi^+\pi^-\pi^+\pi^- (\sigma = 2.5 \text{ mb})$
  $\bar{p}p \rightarrow 3\pi^+3\pi^-\pi^0 (\sigma = 2.3 \text{ mb})$
  $\bar{p}p \rightarrow K^+K^-\pi^+\pi^- \ (\sigma = 0.4 \text{ mb})$
  ...
- Performance of Partial Wave Analysis

Summary and Outlook

- $\mathcal{L}_{p=1.5\mathrm{GeV/c}} = 788/(\mathrm{nb}\cdot\mathrm{day})$
- $\sigma_{\bar{p}p\to\phi\phi} \approx 4\mu b$
- $\epsilon = 14.9\%$

$\rightarrow$ For $1\cdot 10^6$ reconstructed $\bar{p}p \to \phi\phi \to K^+K^-K^+K^-$ events run time of < 8 days needed

$\rightarrow$ For background analysis: $\sim 15\cdot 10^9$ $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$
$\sim 15\cdot 10^9$ $\bar{p}p \to 3\pi^+3\pi^-\pi^0$
$\sim 2.5\cdot 10^9$ $\bar{p}p \to K^+K^-\pi^+\pi^-$
generic DPM events needed

- Huge amount of background events
  $\rightarrow$FairFilteredPrimaryGenerator will be used!