Simulated Measurements of the D_s Semileptonic Decay Form Factor with the PANDA Detector
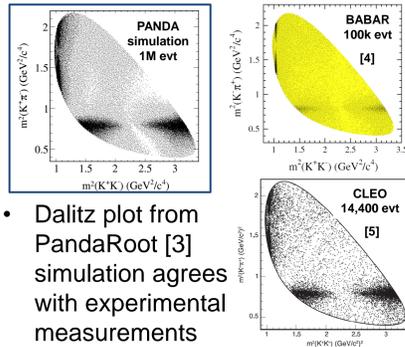
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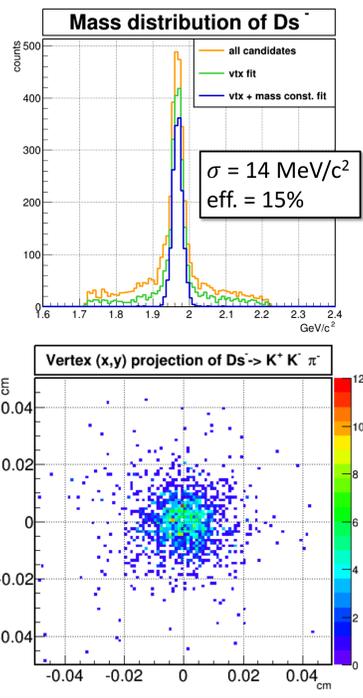
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Motivation

- Semileptonic decays $D_s^+ \rightarrow e^+ \nu_e \eta/\eta'$ allow access to form factor and V_{cs}
- Experimental validation becomes important as theoretical calculations of form factor offer increasing precision [1]
- Relative branching ratio can help to investigate $\eta - \eta'$ mixing [2]

PANDA Detector

- Experiment at FAIR, Darmstadt, Germany
- Study interactions of antiproton beam $p = 1.5\sim15$ GeV/c

~13 m

Reconstruction of Decay Channels: 1. $D_s^- \rightarrow K^+ K^- \pi^-$

- $D_s^+ D_s^-$ pairs generated from $p\bar{p}$ system by EvtGen at $\sqrt{s} = 4.108$ GeV
- New decay model in PandaRoot for $D_s \rightarrow KK\pi$

- 10,000 events simulated
- Mass window: 1.968 ± 0.25 GeV/c²

Resolution	M [MeV/c²]	V_x [μm]	V_y [μm]	V_z [μm]	P_t [%]	P_z [%]
	14	75	73	160	3.0	1.4

- Dalitz plot from PandaRoot [3] simulation agrees with experimental measurements

$\sigma = 14$ MeV/c²
eff. = 15%

2. $\pi^0 \rightarrow \gamma\gamma$

- Invariant mass of two-photon:
$$m_{\gamma\gamma} = \sqrt{2E_{\gamma1}E_{\gamma2}(1 - \cos\theta_{\gamma\gamma})}$$

- Photon energy scaling [6] (angle fixed):
$$E_{\gamma i}^{rec} = \frac{m_\pi}{m_{\gamma\gamma}} E_{\gamma i}$$

- 4-momentum of reconstructed π^0:
$$p_\pi = p_{\gamma1}^{rec} + p_{\gamma2}^{rec}$$

$m_{PDG}^{\pi^0} = 0.135$ GeV/c²

Kinematics of $e^+ \nu_e$ and Form Factor

Invariant mass squared of $e^+ \nu_e$:
$$M^2(e^+\nu_e) = (E_{p\bar{p}} - E_\eta - E_{D_s^-})^2 - (\vec{p}_{p\bar{p}} - \vec{p}_\eta - \vec{p}_{D_s^-})^2$$

Mass window: $|M^2(\nu_e)| < 0.1$ GeV²/c²
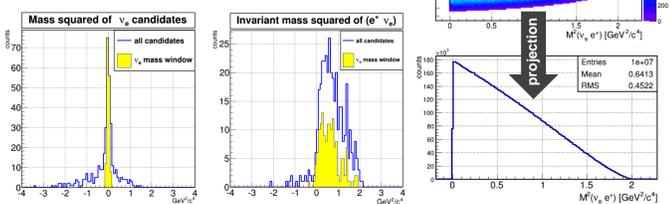
- Form factor $f_+(q^2)$; kinematically accessible q^2 is $M^2(e^+\nu_e)$; reco. efficiency is 3.7%
- Preliminary estimation of ~150 evt/mon with luminosity $L = 2 \times 10^{32}$ cm⁻²s⁻¹, assuming cross section is 20 nb [7]

$$\frac{d\Gamma(Ds \rightarrow \nu_e e^+ \eta)}{dq^2} = \frac{G_F^2}{24\pi^3}|V_{cs}|^2 p_x^3 |f_+(q^2)|^2$$

3. $\eta \rightarrow \pi^+ \pi^- \pi^0$

- Vertex fit for charged $\pi^+\pi^-$
- Mass constraint fit for combination of $\pi^+\pi^-\pi^0$

Resolution	M [MeV/c²]	V_x [μm]	V_y [μm]	V_z [μm]	P_t [%]	P_z [%]
	7.5	363	319	943	2.1	1.8

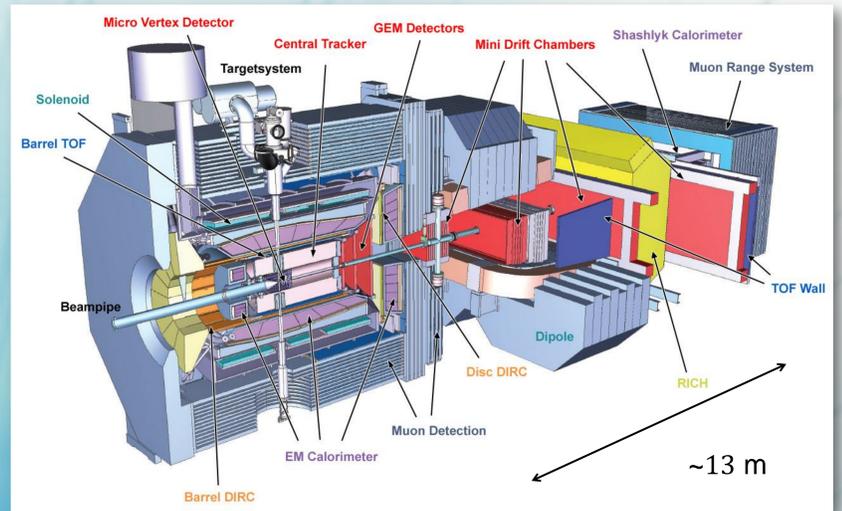$\sigma = 7.5$ MeV
eff. = 20%

Summary

- New decay model DS_DALITZ implemented in PandaRoot
- Preliminary reconstruction efficiency and production rate obtained
- Mass resolution improved comparing previous analysis [8]
- Expand kinematic fit for unmeasured neutrino

Outlook

- Include $D_s \rightarrow \eta' l\nu$ in simulation chain for study of $\eta - \eta'$ mixing
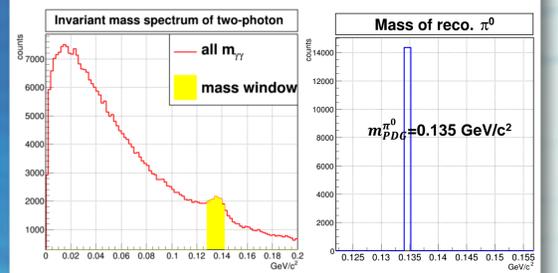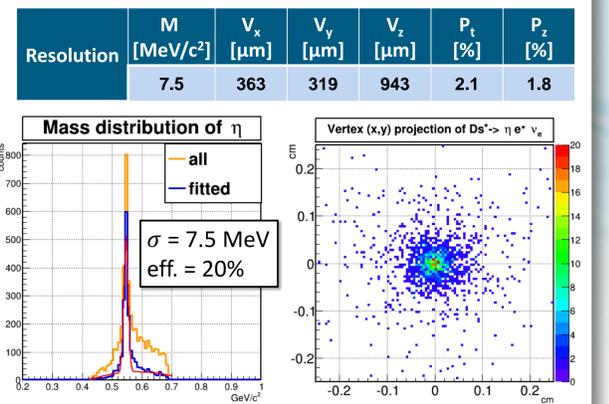- Investigate background channels

References

[1] N. Offen *et al.* Phys. Rev. D 88: 034023 (2013).
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[3] S. Spataro J. Phys.: Conf. Ser. 396: 022048 (2012).
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[6] K. Korzecka *et al.* Nucl. Instr. and Meth. A 453: 606 (2000).
[7] J. Haidenbauer *et al.* arXiv: 1404.4174 [hep-ph] (2014).
[8] L. Cao and J. Ritman J. Phys.: Conf. Ser. 503: 012024 (2014).

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