ϕ meson production in pp @ 10 GeV with SPD spectrometer

Elena Zemlyanichkina (JINR)

SPD Collaboration Meeting

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Motivation

The phi meson (ϕ-meson), also known as the $\phi(1020)$-meson, is an elementary particle belonging to the class of vector mesons composed of a strange quark (s) and its antiquark ($\bar{s}$).

Detecting ϕ mesons has significant importance for advancing our understanding of the fundamental nature of matter and its behaviour under extreme conditions.

Additionally, ϕ mesons can also be utilized in technical tasks, such as calculating the purity and contamination levels of charged hadrons following Particle Identification (PID).

ϕ meson production in pp

Citation: J. Beringer *et al.* (Particle Data Group), PR **D86**, 010001 (2012) (URL: http://pdg.lbl.gov)

$\phi(1020)$

$I^G(J^{PC}) = 0^-(1^{--})$

$\phi(1020)$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1019.455±0.020 OUR AVERAGE		Error includes scale factor of 1.1.		

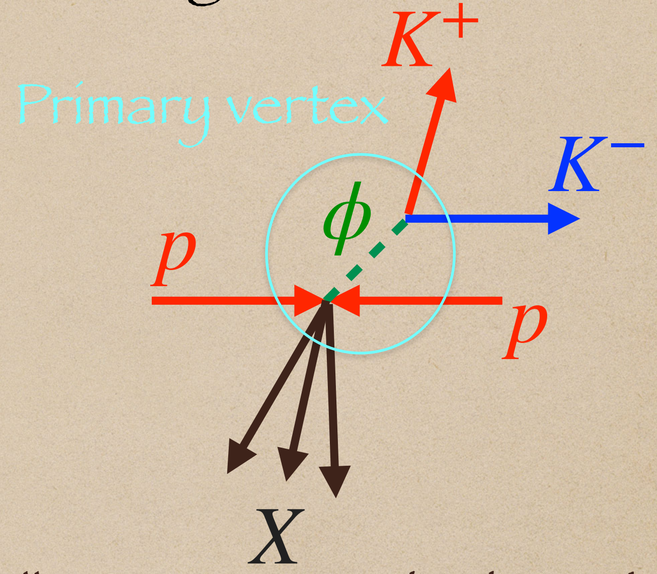
$\phi(1020)$ WIDTH

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
4.26 ±0.04 OUR AVERAGE		Error includes scale factor of 1.4. See the ideogram below.		

$\phi(1020)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	K^+K^-	(48.9 ±0.5) %	S=1.1
Γ_2	$K^0_L K^0_S$	(34.2 ±0.4) %	S=1.1
Γ_3	$\rho\pi + \pi^+\pi^-\pi^0$	(15.32 ±0.32) %	S=1.1

With the SPD, we can detect ϕ mesons through their decay into oppositely charged K mesons:



Technically, ϕ mesons are both produced and decay at the same vertex.

It is necessary to consider all pairs of oppositely charged tracks and calculate their invariant mass.

An official production status

We have datasets of unpolarized proton-proton (pp) and deuteron-deuteron (dd) Monte Carlo simulations generated using the production system provided by the MLIT JINR team.

[https://docs.google.com/spreadsheets/d/1JWob53dfwMvTlmdsGncwQmPeVbmzFKuD8DHE4rYsJFw/edit?gid=0#gid=0]

Explore

NICA / spdroot / Wiki / **Available data**

Unpolarised pp collisions

Energy	Generator	N of Events	Prod names
5 GeV	FTF	80 mln	PROD2025-007 PROD2025-008
10 GeV	FTF	40 mln	PROD2025-009
10 GeV	Pythia 8	40 mln	PROD2025-004
27 GeV	Pythia 8	200 mln	PROD2025-012 PROD2025-013 PROD2025-014 PROD2025-015 PROD2025-016

Unpolarised dd collisions

Energy	Generator	N of Events	Prod names
4 GeV	FTF	5 mln	PROD2025-010

Simulation+Reconstruction

- An official production name: PROD2025-004
[https://docs.google.com/spreadsheets/d/1JWob53dfwMvTlmdsGncwQmPeVbmzFKuD8DHE4rYsJFw/edit?gid=0#gid=0]
- pp@10 GeV with Pythia 8 + SPDroot-dev-4.1.7 (~40 mln events)
- The description of the first-phase detector is utilized.
- According to the Technical Design Report (TDR), the Micromegas-based Central Tracker is 90 *cm* in length $(-45\ \text{cm} < Z < 45\ \text{cm}, R = 5\ \text{cm})$
- Central part of beam pipe is made of Aluminum
- Options for track reconstruction:

- CheckMinItsHits(true, 0);
- CheckMinTsHits(true, 6);
- CheckMinHits(true, 7);
- Check MinPartPt(true, 0.1);
- CheckMinPartMomentum(true, 0.15);

Track Selection

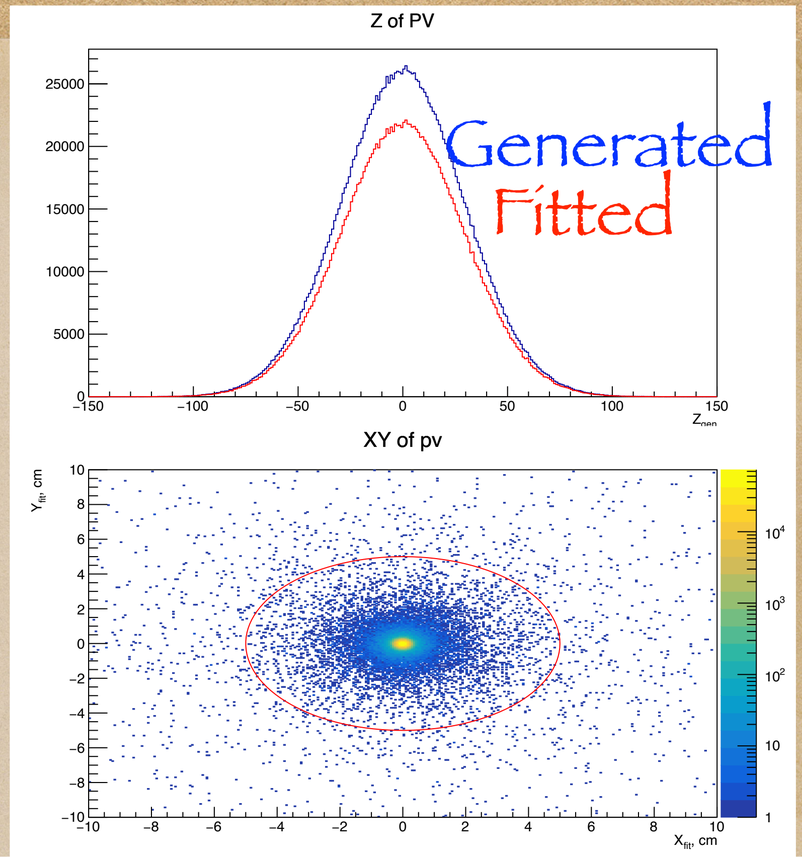
Vertex selection:

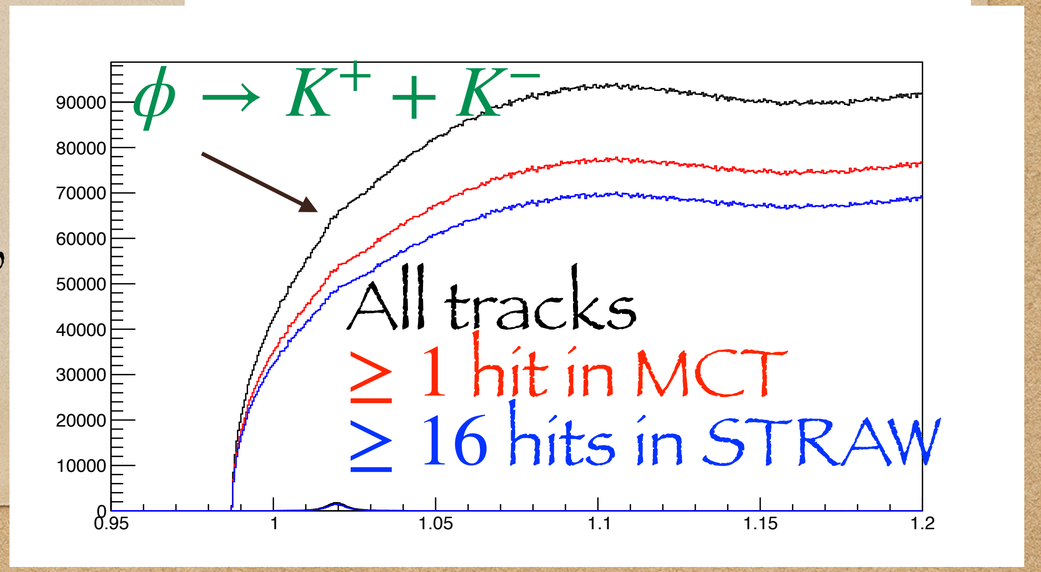
should be fitted and located inside the MCT:

- $-45\ \text{cm} < Z < 45\ \text{cm}$ and $\sqrt{X^2 + Y^2} < 5\ \text{cm}$

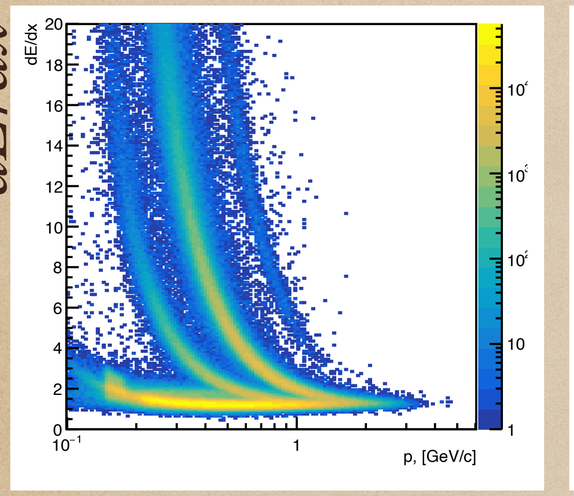
Track selection:

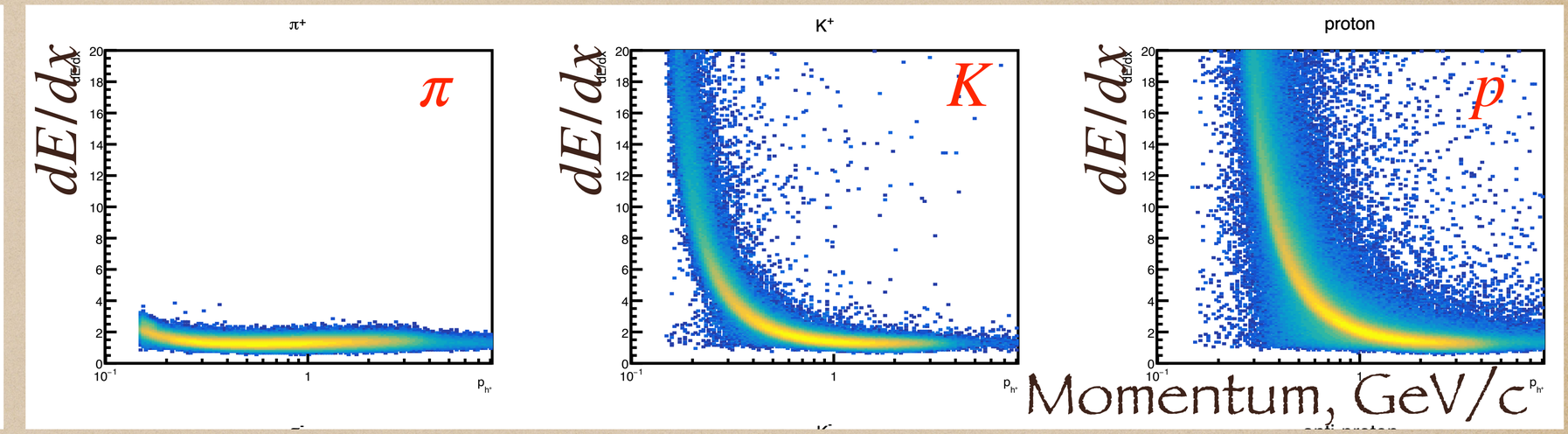
- All tracks produced in PV (fitted, converged)
- Number of hits: $N_{MCT\ hits} >= 1$ and $N_{STRAW\ hits} >= 16$
- Hadron momentum $p > 150\ MeV/c$
- Since charged hadrons are predominantly pions, particle identification (PID) is necessary!

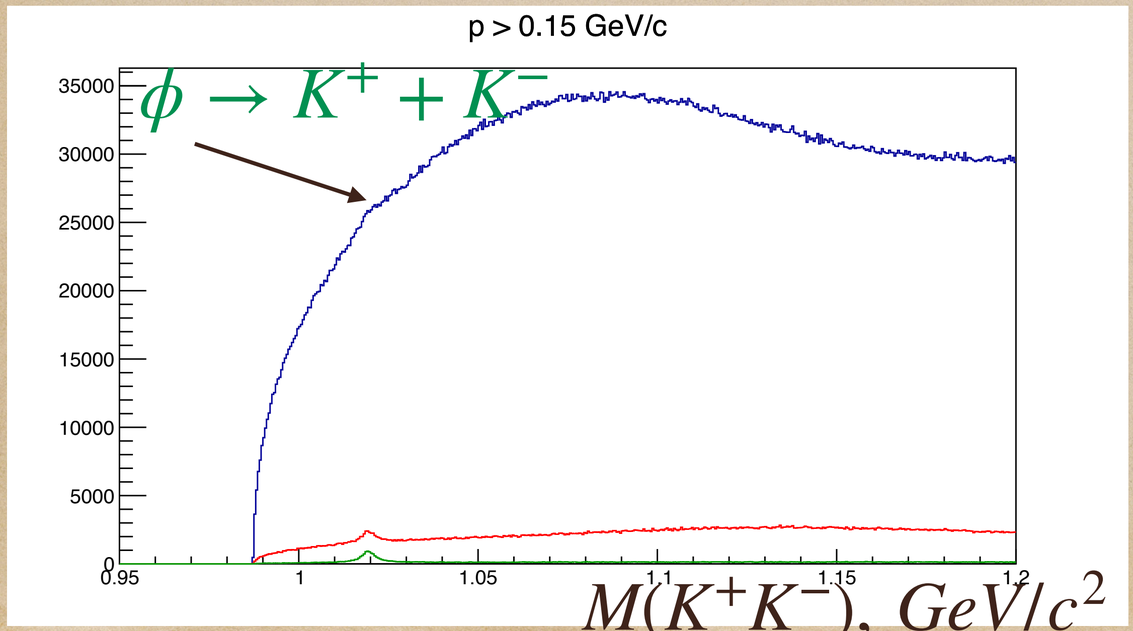




PID with STRAW







No PID

One hadron is identified as kaon

Both hadrons are identified as kaons

With the STRAW detector, it is possible to identify hadrons with momenta of up to a maximum of 1 *GeV/c*.

Geometry acceptance (40.5 % /36.7 %)

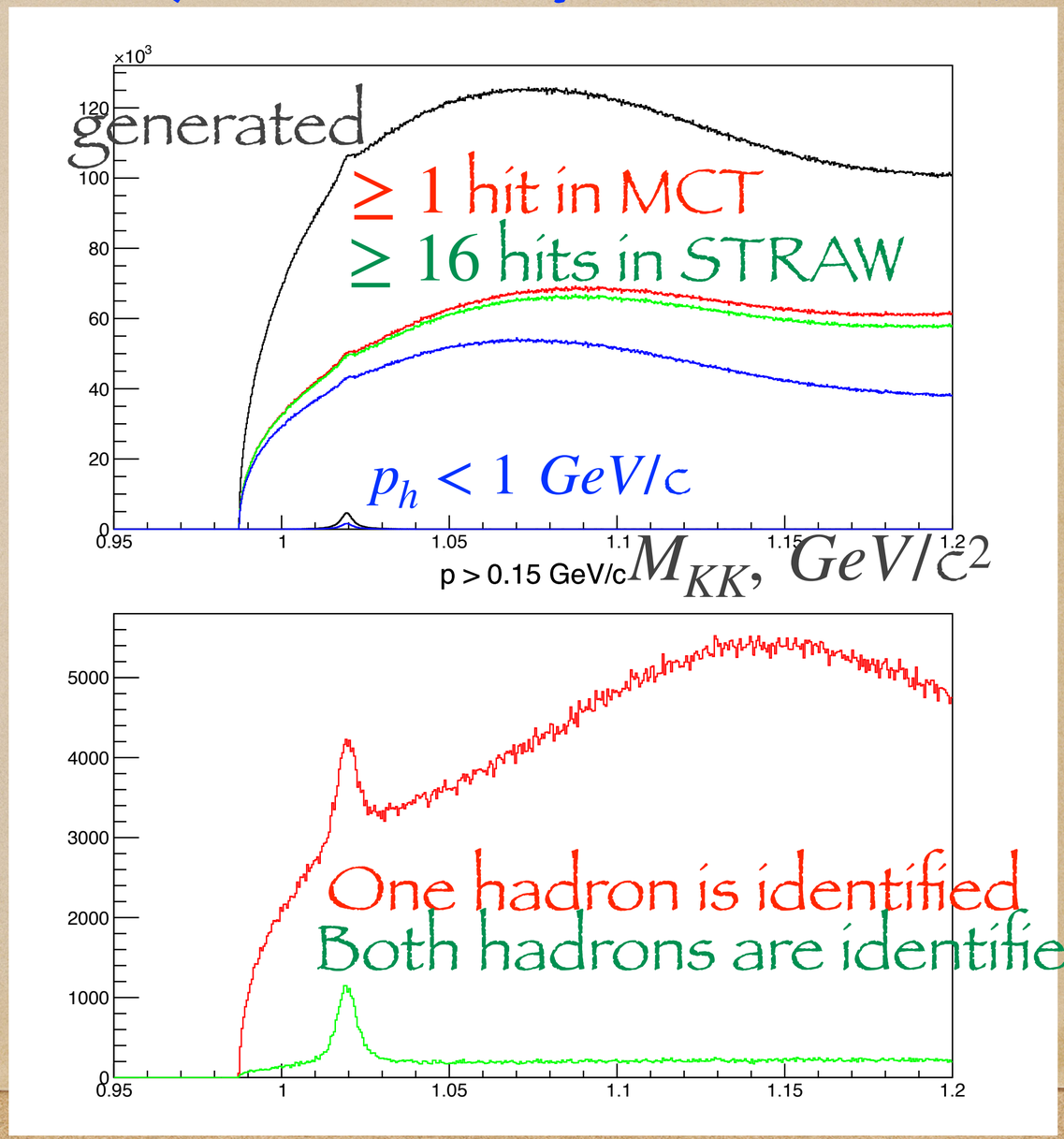
Selection of generated $\phi \to K^+ + K^-$:

- SpdMCParticle::GetGeneration() == 1
- Momentum of charged tracks > 150 MeV/c

Selection of accepted $\phi \to K^+ + K^-$:

- Number of ITS hits ≥ 1
- Number of STRAW hits ≥ 16
- Momentum of charged tracks < 1 GeV/c (PID with STRAW only)

$$Geometry\ acceptance = \frac{Number\ of\ accepted\ \phi}{Number\ of\ generated\ \phi}$$

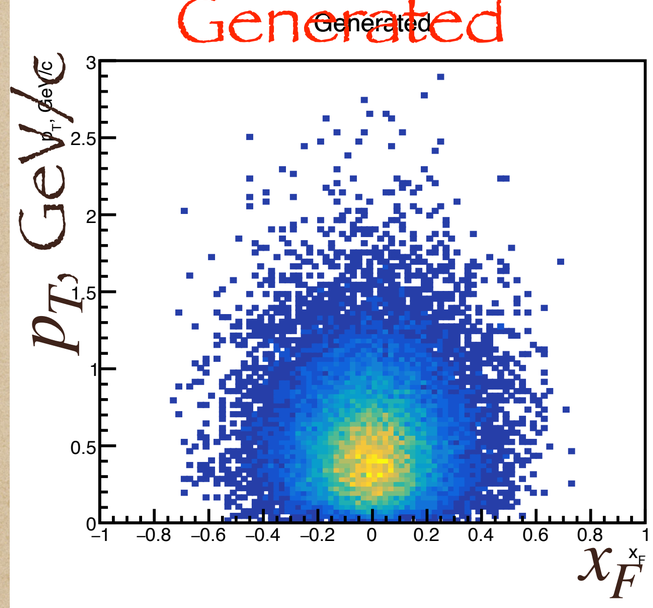


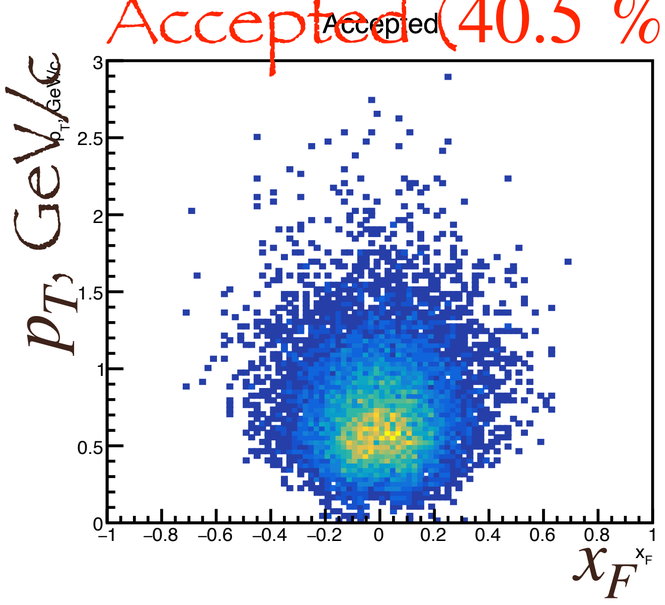
$\phi \rightarrow K^+ + K^-$

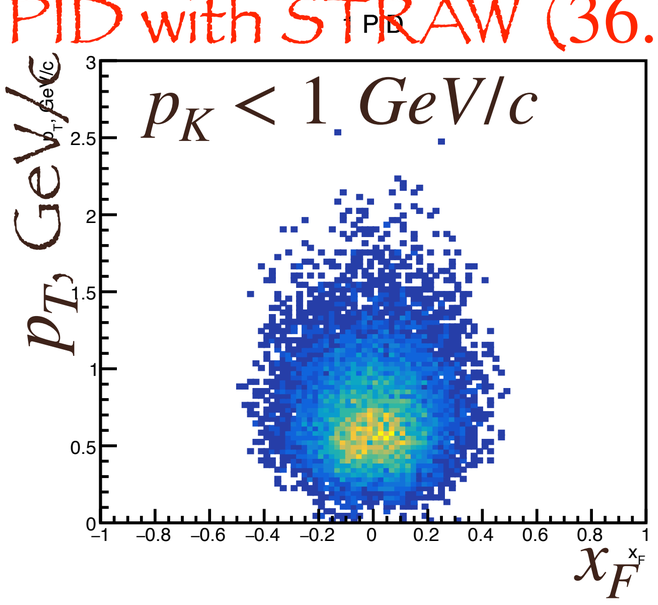
Generated

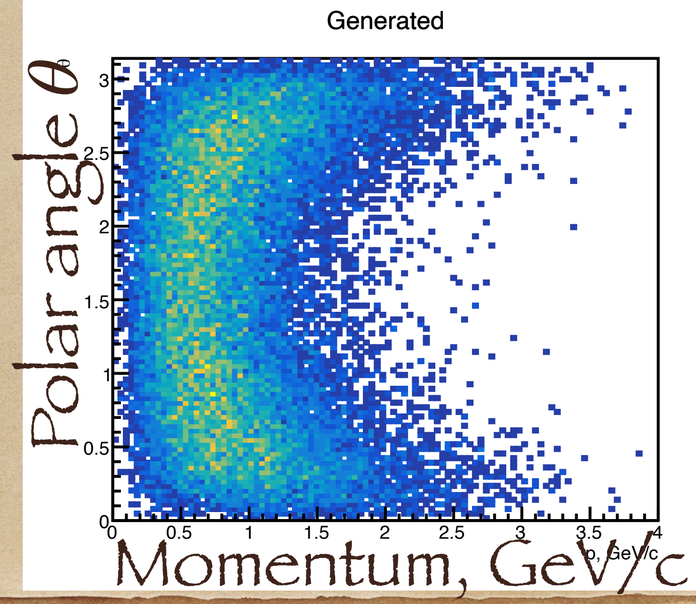
Accepted (40.5 %)

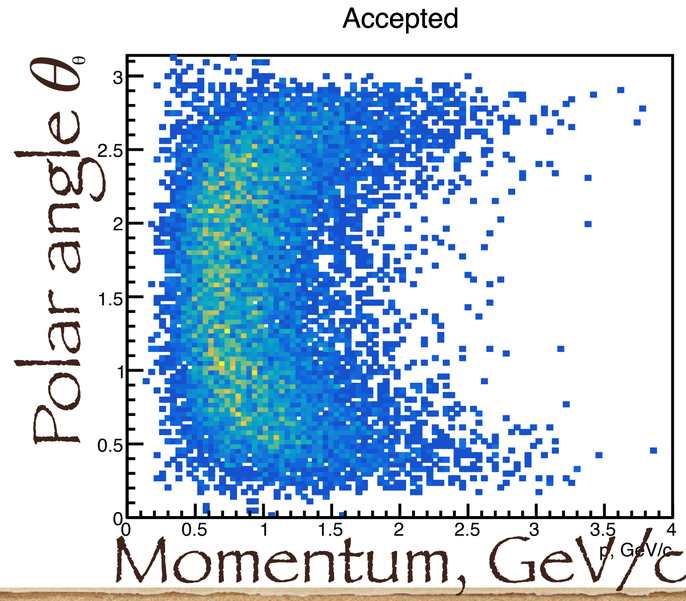
PID with STRAW (36.7 %)

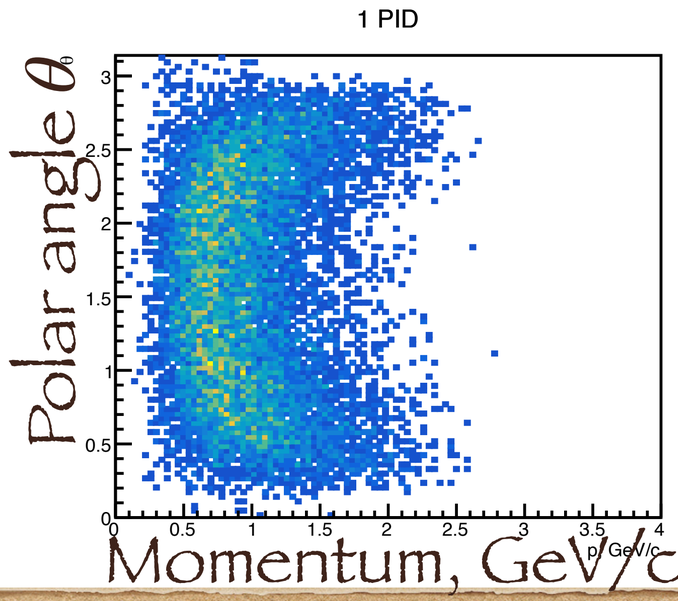












Summary

- 40.5 % of $\phi \to K^+ + K^-$ are accepted by the SPD spectrometer
- Since charged hadrons are predominantly pions, to reduce the large background under the ϕ meson peak in invariant mass, particle identification (PID) is essential!
- The STRAW detector can independently identify kaons with momenta of up to a maximum of 1 GeV/c.
- Geometry acceptance: 36.7 % of $\phi \to K^+ + K^-$ mesons can be selected
- Available kinematical range is $-0.4 < x_F < 0.4$, $p_T < 2.0\ GeV/c$

Thanks for your attention!