Why we must have Low-pT Barrel TOF for exclusive VM production?

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Motivation

346 *8.4. EXCLUSIVE MEASUREMENTS*

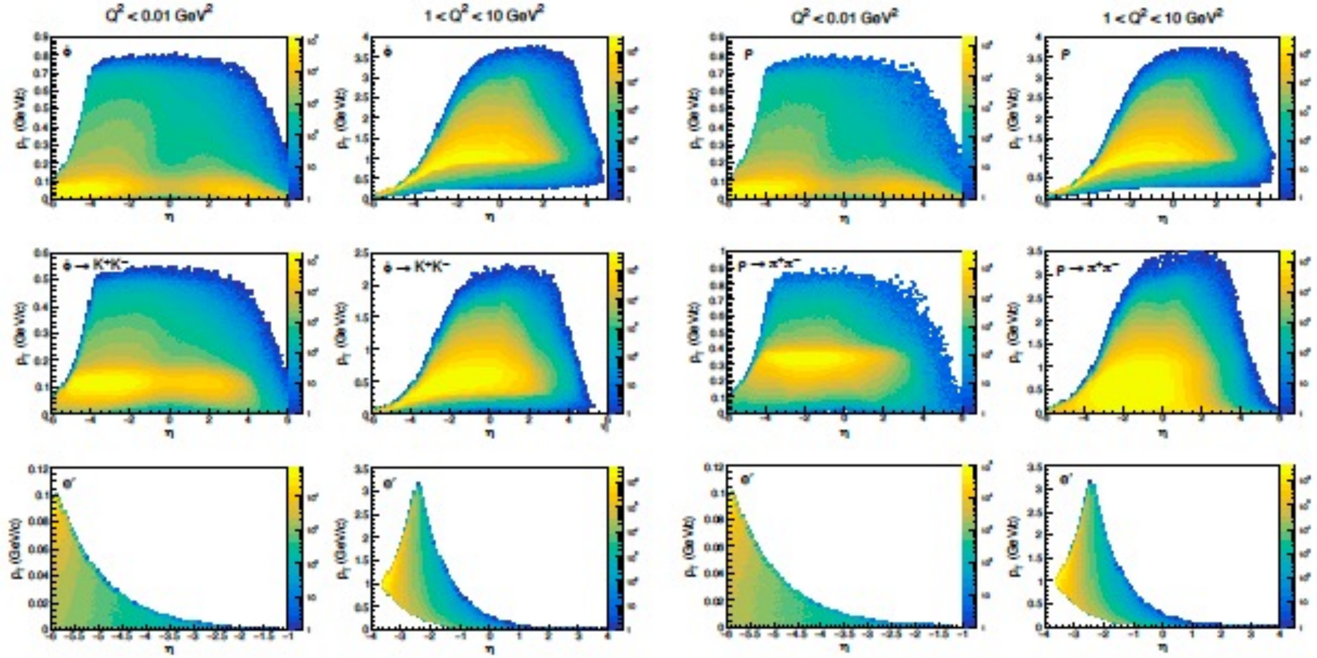


Figure 8.84: Left: Kinematics for diffractive $e + \mathrm{Au} \to e' + \mathrm{Au}' + \phi$ with ϕ decaying into K^+K^-. The left column is for photoproduction and the right for $1 < Q^2 < 10$ GeV^2. Shown, from top to bottom are p_T versus pseudorapidity (η) for ϕ, kaons from the ϕ decay, and the scattered electron. **Right:** Same for $e + \mathrm{Au} \to e' + \mathrm{Au}' + \rho$ with ρ decaying into $\pi^+\pi^-$. Note the different scale on the vertical axis for photoproduction and electroproduction.

Yellow Report

a) Incoherent DVCS on deuteron+ pi^0 + BH (central gamma or gamma gamma + p + n)
b) Timelike Compton Scattering (central e^+e^-)
c) Phi production in eA (central K^+K^- + intact/dissociated ion)
d) Upsilon in ep (e^+e^- or mu^+mu^- + proton)
e) Backward/u-channel photoproduction of omega -> pi^0 gamma.
f) Z_c^+ -> J/psi pi^+ (or other spectroscopy channel)

Exclusive and Tagging Group

Why do we need PID for exclusive?

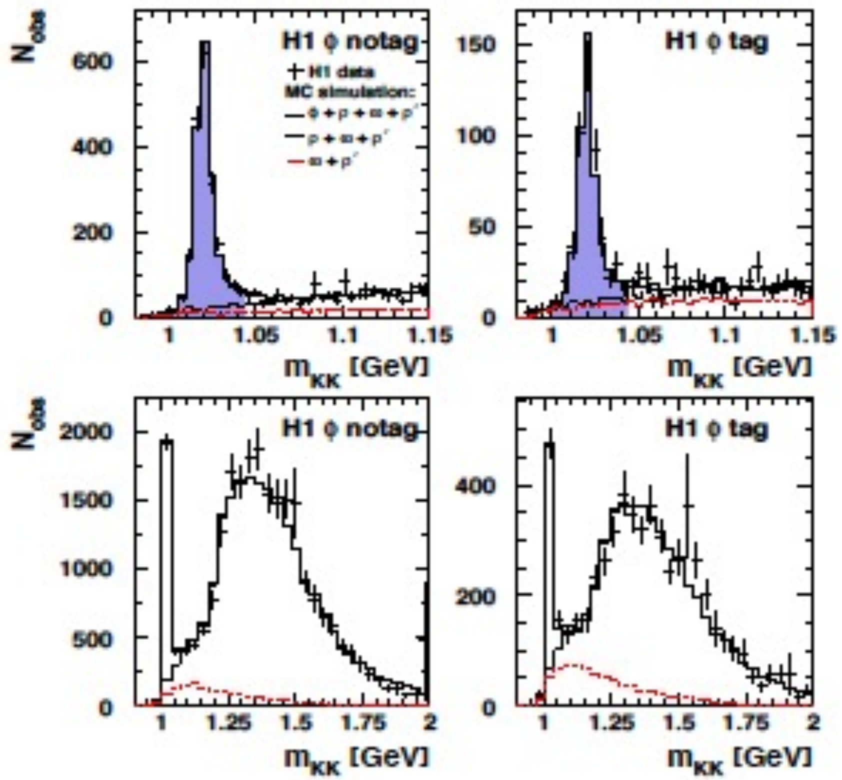


Figure 6: Distributions of the invariant mass m_{KK}: (upper plots) in the ϕ mass region, for the notag and tag samples separately; (lower plots) over an extended mass range, showing the ϕ signal and the reflection of ρ production and the backgrounds. The dashed histograms show the sum of the ρ', ω and $\phi \to 3\pi$ backgrounds, the dotted histograms show in addition the ρ and non-resonant $\pi\pi$ backgrounds, and the full histograms the $\phi \to KK$ signal and the sum of all backgrounds. In (a) and (b), the mass domain where the cross section measurements are performed is shaded.

H1, 0910.5831

If different VMs are all at different single fixed mass value, we do not have PID issue.

Phi mass window +-20MeV

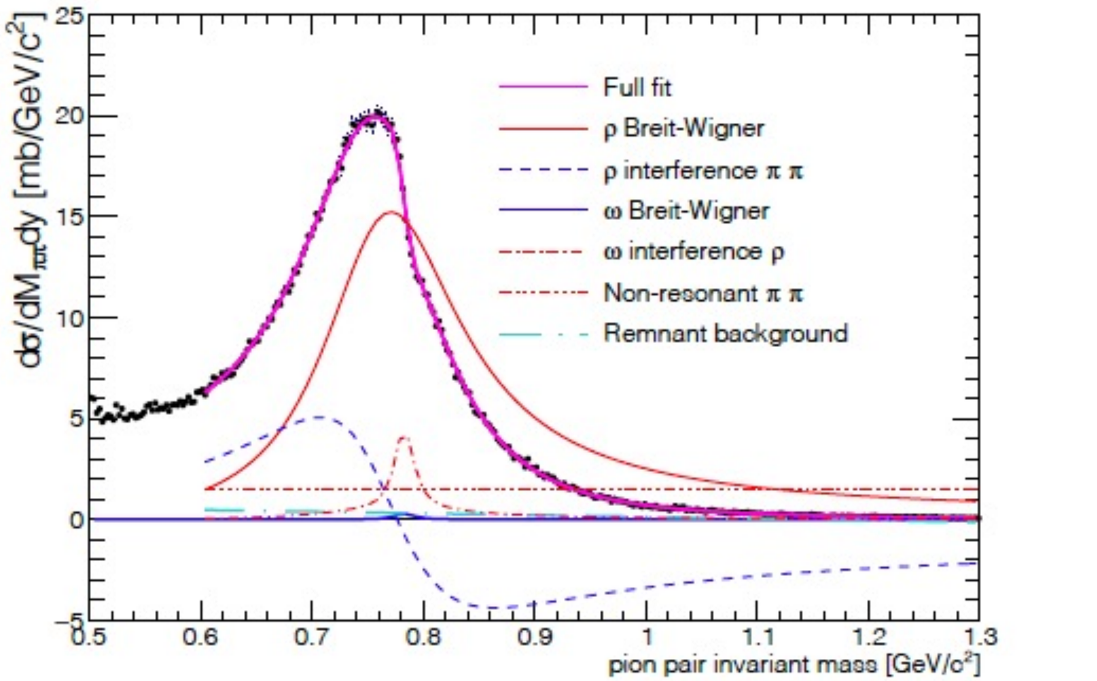
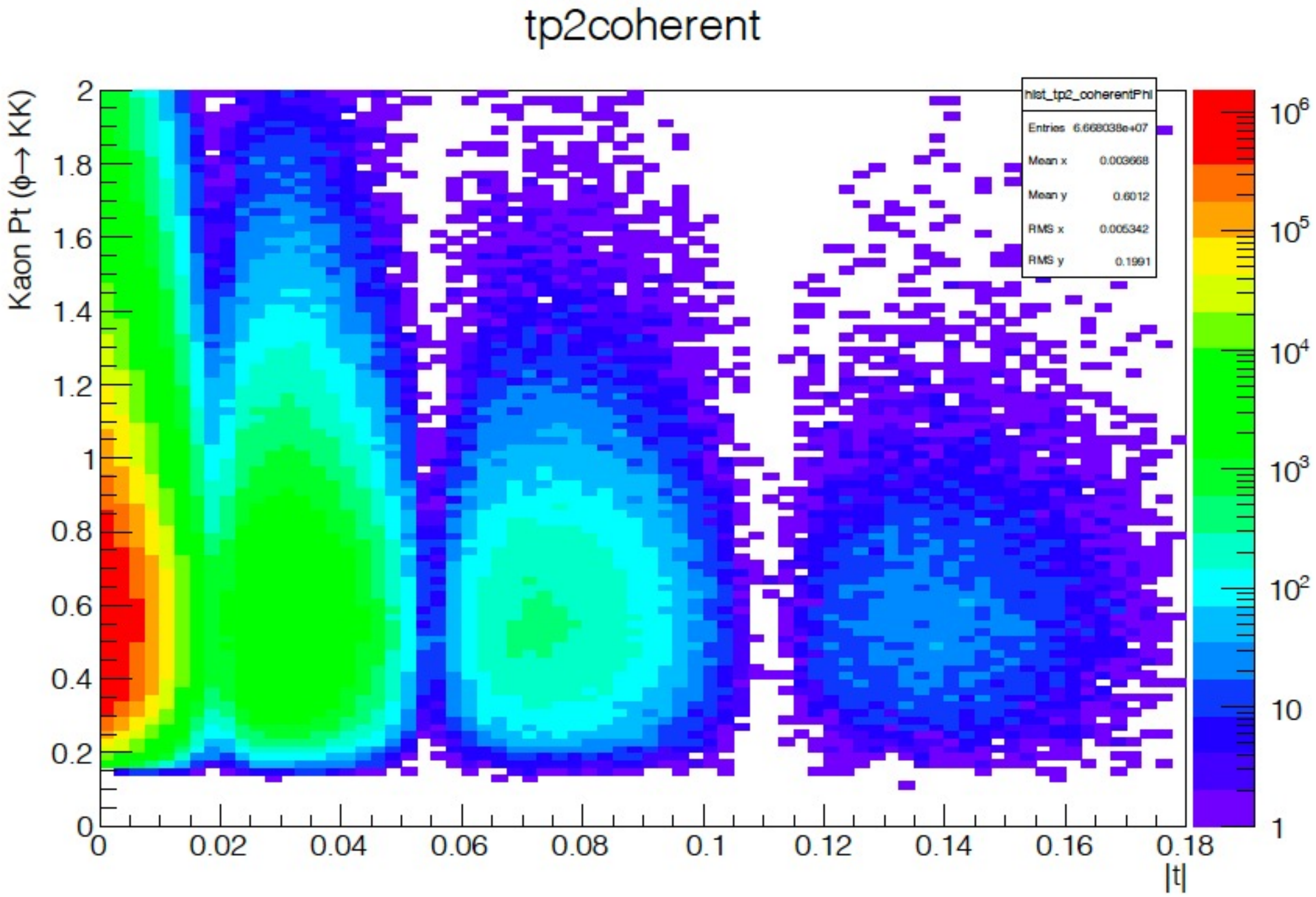


Figure 4: The $\pi^+\pi^-$ invariant mass distribution for all selected $\pi\pi$ candidates with $p_T < 100$ MeV/c. The black markers show the data (in 2.5 MeV/c^2 bins). The magenta curve is the modified Söding fit to the data in the range $0.6 < M_{\pi\pi} < 1.3$ GeV/c^2. Also shown are the ρ^0 Breit-Wigner component of the fit (brown curve), constant non-resonant pion pair component (brown-dashed curve), interference between non-resonant pion pairs and the ρ^0 (blue-dashed curve), Breit-Wigner distribution for the ω mesons (blue solid curve), interference between ρ^0 and ω (red-dashed curve), and a small contribution from the remnant background, fit by a linear polynomial (cyan-dashed curve).

STAR, 1702.07705

SARTRE simulation of phi→KK kinematics



Exclusive ϕ→KK
In e+Au at 18+110 in SARTRE
with |eta|<4

Provided by Thomas
in standard generator

Fixed mass value for all VM in SARTRE,
Possible choices of implementing spectral functions:

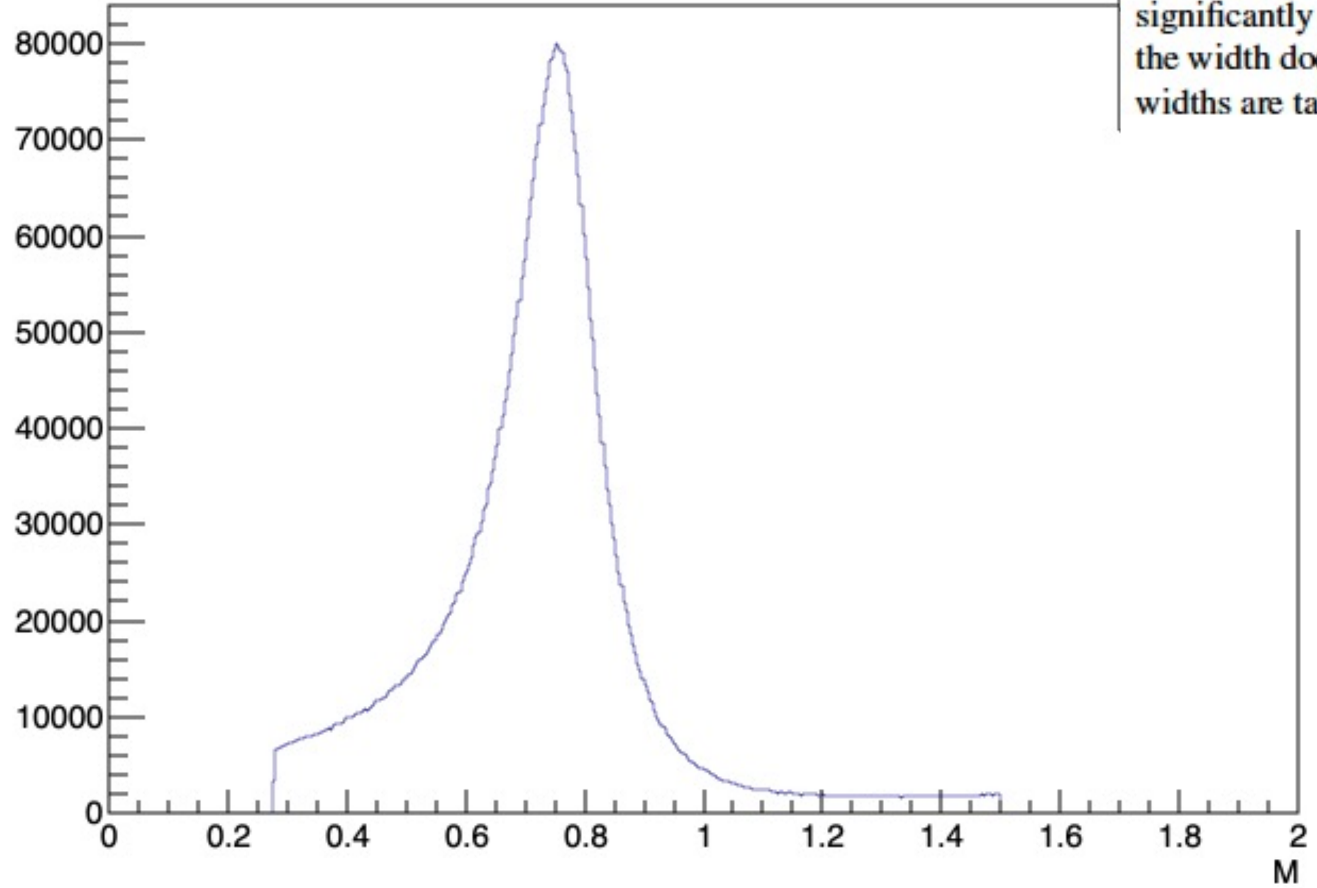
1. Keep 3Vector p, change mass
2. Keep energy, change mass and 3Vector
3. Figure out how to implement energy and momentum conservation globally

VM spectral function

$$\frac{d\sigma}{dM_{\pi^+\pi^-}} \propto \left| A_\rho \frac{\sqrt{M_{\pi\pi} M_\rho \Gamma_\rho}}{M_{\pi\pi}^2 - M_\rho^2 + iM_\rho\Gamma_\rho} + B_{\pi\pi} + C_\omega e^{i\phi_\omega} \frac{\sqrt{M_{\pi\pi} M_\omega \Gamma_{\omega\to\pi\pi}}}{M_{\pi\pi}^2 - M_\omega^2 + iM_\omega\Gamma_\omega} \right|^2 + f_p \qquad (2)$$

where A_ρ is the ρ amplitude, $B_{\pi\pi}$ is the amplitude for the direct pions, C_ω is the amplitude for the ω, and f_p is a linear polynomial that accounts for the remaining background. The momentum-dependent widths in Eqs. (3) and (4) below are motivated by the forms proposed in Ref. [29], where Γ_0 is the pole width for each meson. Several variations of the dipion mass dependence for the ω width were tried, but none were significantly different from a constant, reflecting the fact that the ω width is small, and the width does not change significantly in that mass range. The momentum-dependent widths are taken to be

$$\Gamma_\rho = \Gamma_0 \frac{M_\rho}{M_{\pi\pi}} \left(\frac{M_{\pi\pi}^2 - 4m_\pi^2}{M_\rho^2 - 4m_\pi^2} \right)^{3/2} \qquad (3)$$

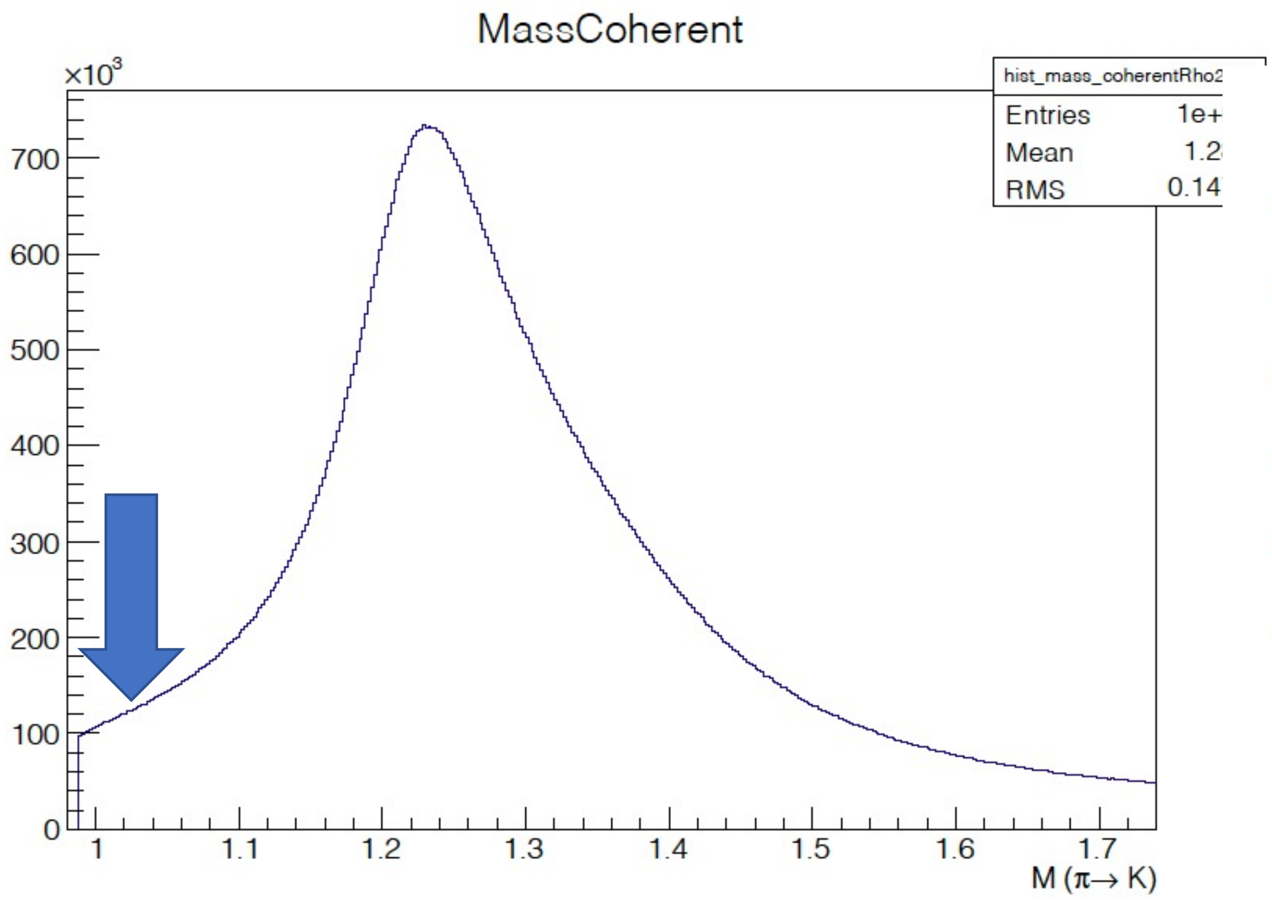


Fit Parameter	value	units
M_ρ	0.7762 ± 0.0006	GeV/c^2
Γ_ρ	0.156 ± 0.001	GeV/c^2
A_ρ	1.538 ± 0.005	
$B_{\pi\pi}$	-1.21 ± 0.01	$(\text{GeV}/c^2)^{-1/2}$
C_ω	0.55 ± 0.04	
M_ω	0.7824 ± 0.0008	GeV/c^2
Γ_ω	0.017 ± 0.002	GeV/c^2
ϕ_ω	1.46 ± 0.11	radians
f_p p_0	0.99 ± 0.07	$(\text{GeV}/c^2)^{-1}$
f_p p_1	-0.86 ± 0.06	$(\text{GeV}/c^2)^{-2}$

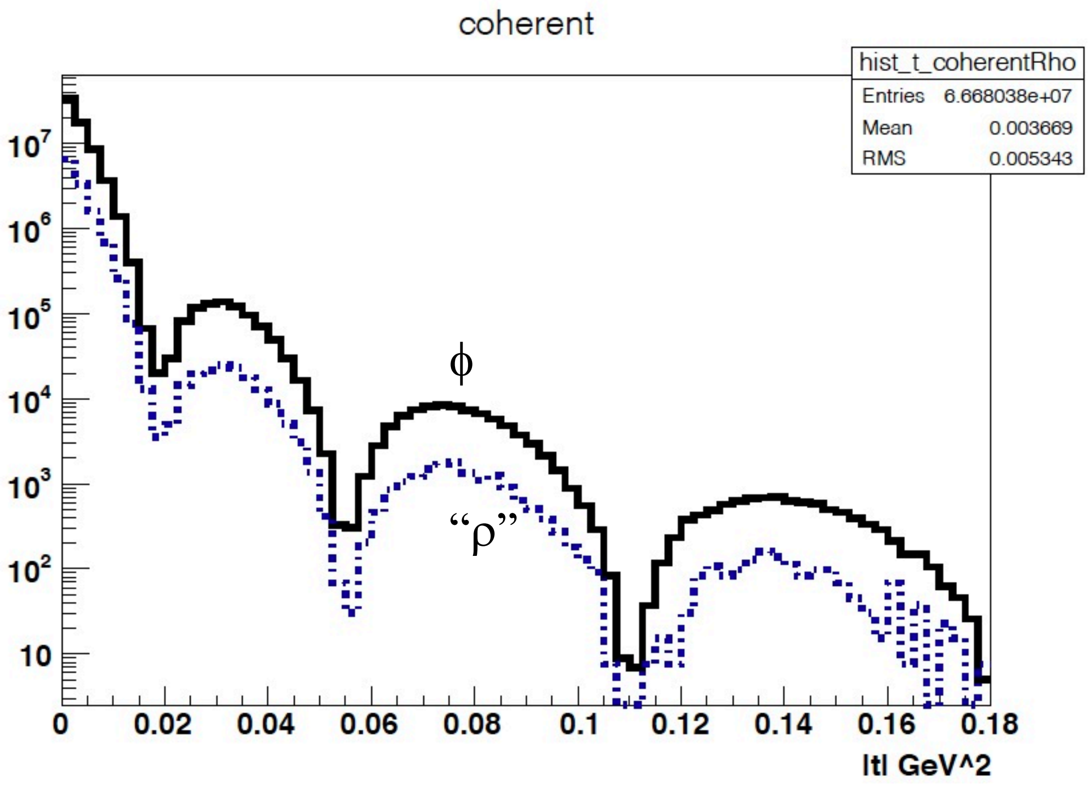
Table 2: The results of fitting Eq. 2 to the data. The parameters p_0 and p_1 are for the polynomial background.

STAR PRC2017
Ignore omega term

Misidentified $\rho \rightarrow \pi\pi$ as $\phi \rightarrow KK$



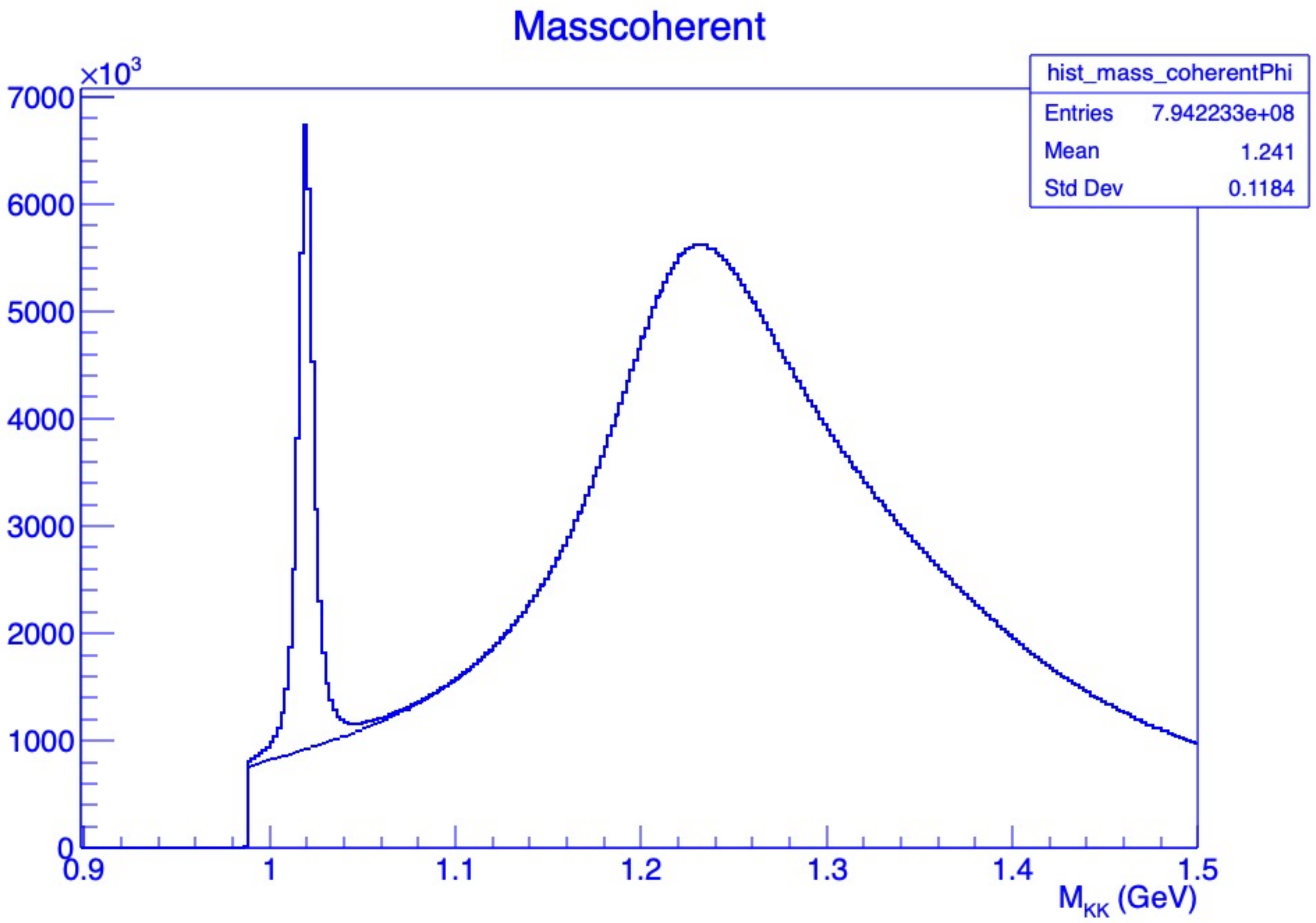
Ignore other VM (ω, ρ') contaminations for now



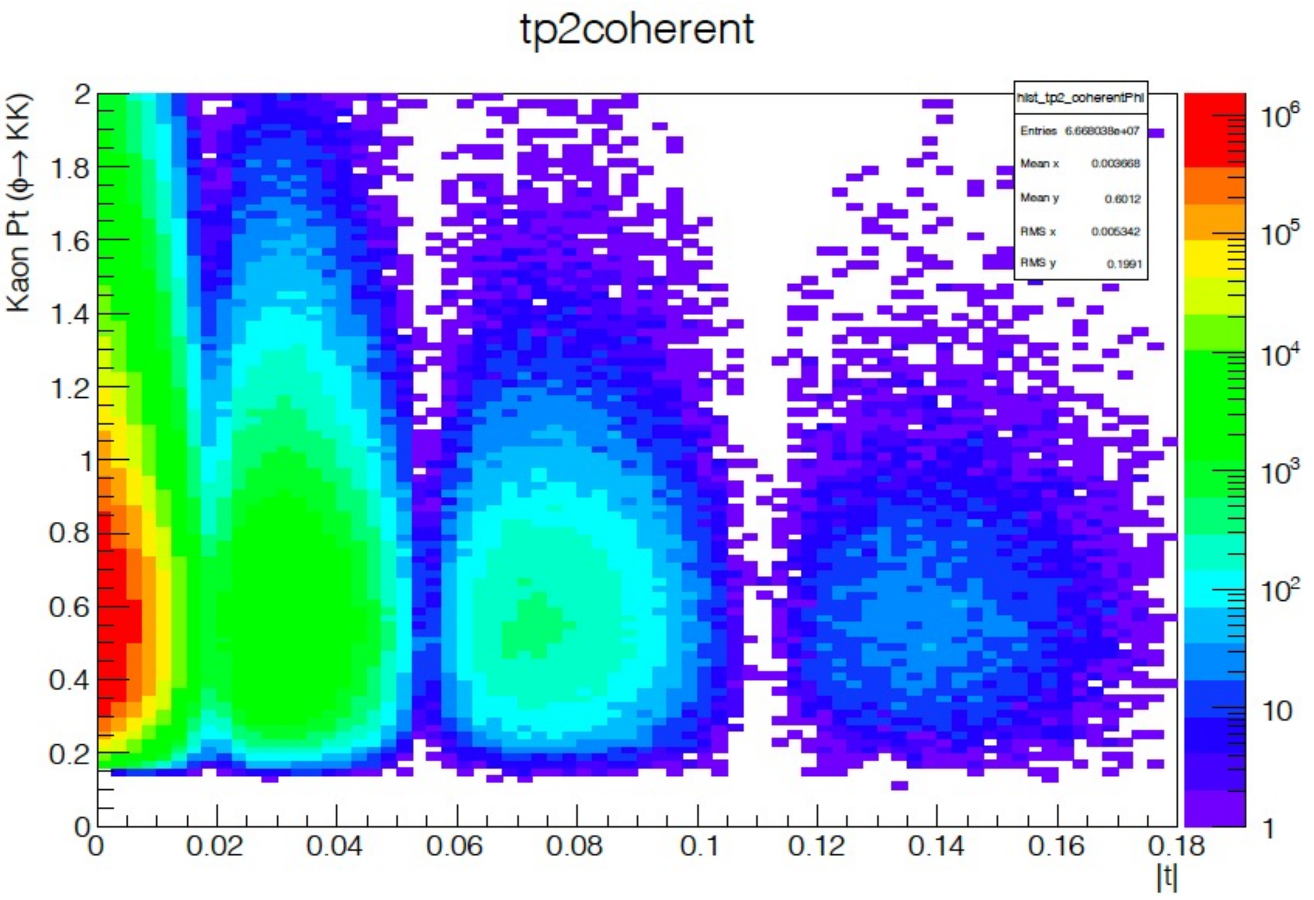
Mass window +-20MeV

Rho/phi cross section is 7.6

15%, consistent with H1 result


Masscoherent
hist_mass_coherentPhi
Entries 7.942233e+08
Mean 1.241
Std Dev 0.1184
×10^3
7000
6000
5000
4000
3000
2000
1000
0
0.9
1
1.1
1.2
1.3
1.4
1.5
M_KK (GeV)

Pion/kaon PID

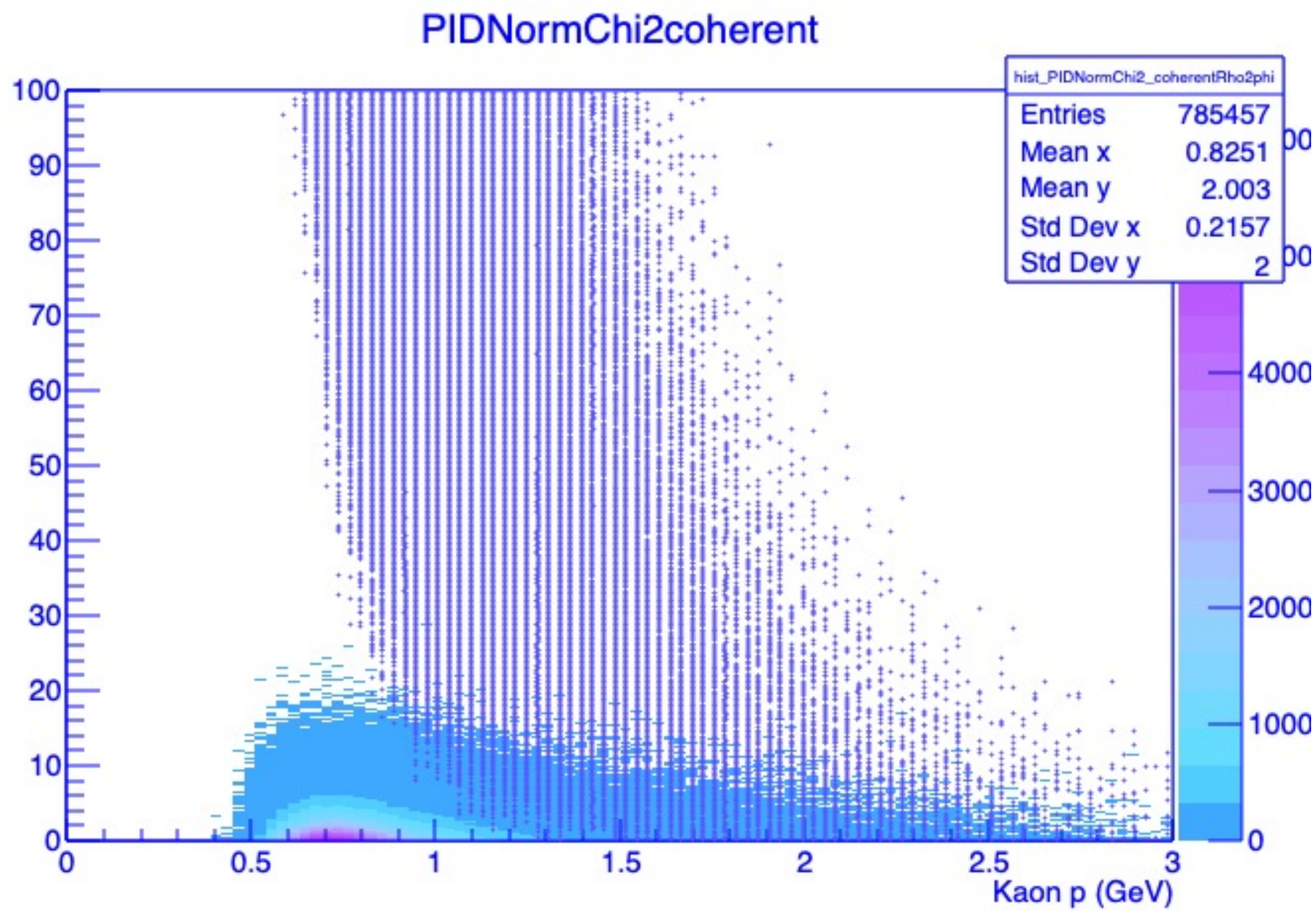


RICH type of detector at 1m, if incident angle is >60^0 , minimum pt reach the detector is 0.9GeV/c

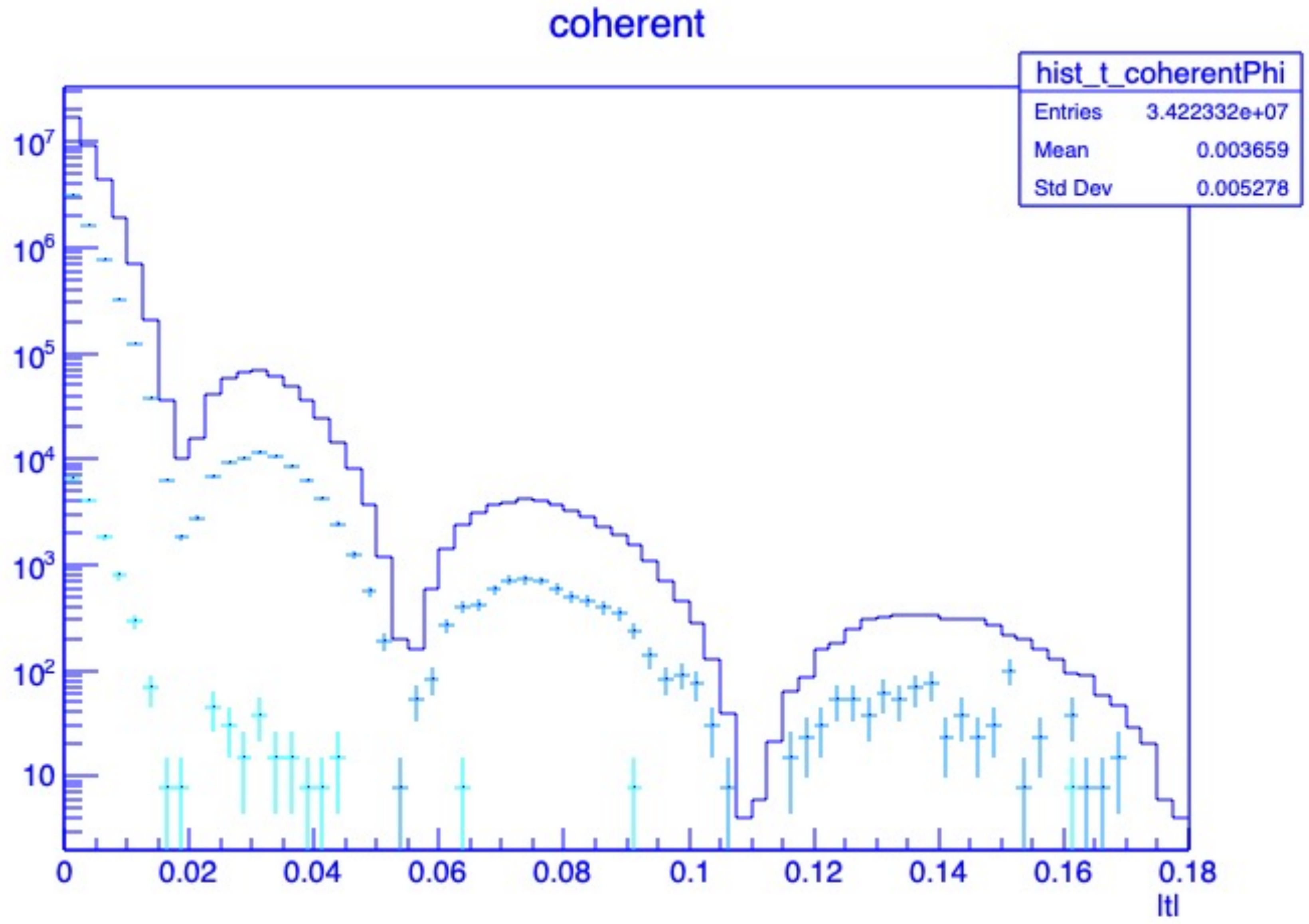
dE/dx type of detector pion/kaon merge around p~=0.6GeV/c

ACLGAD at ~0.5m with 30ps resolution, **three particles in the event, eKK**, will have minimum pt reach of 0.2GeV/c and pion/K separation at 1.2GeV at 3σ. Scale from the existing TOF performance at STAR

Allow reasonable overlap with other PID detectors and meet the YR science goal



PIDNormChi2coherent
hist_PIDNormChi2_coherentRho2phi
Entries 785457
Mean x 0.8251
Mean y 2.003
Std Dev x 0.2157
Std Dev y 2
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
Kaon p (GeV)
4000
3000
2000
1000
0


coherent
hist_t_coherentPhi
Entries 3.422332e+07
Mean 0.003659
Std Dev 0.005278
10^7
10^6
10^5
10^4
10^3
10^2
10
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
|t|

Least Chi2 method of TOF PID

$$\chi2 = \frac{(dt_1 - a)^2}{\sigma_1{}^2} + \frac{(dt_2 - a)^2}{\sigma_2{}^2} + \frac{a^2}{\sigma_e{}^2}$$

$= (dt_1{}^2/\sigma_1{}^2 + dt_2{}^2/\sigma_2{}^2) - (dt_1/\sigma_1{}^2 + dt_2/\sigma_2{}^2)^2\sigma^2$

$dt = t_{TOF} - L/\beta_k$, $\sigma_1 = \sigma_2 = 25ps$, $\sigma_e = 30ps$

$a = (dt_1/\sigma_1{}^2 + dt_2/\sigma_2{}^2)\ \sigma^2$

$1/\sigma^2 = 1/\sigma_1{}^2 + 1/\sigma_2{}^2 + 1/\sigma_e{}^2$

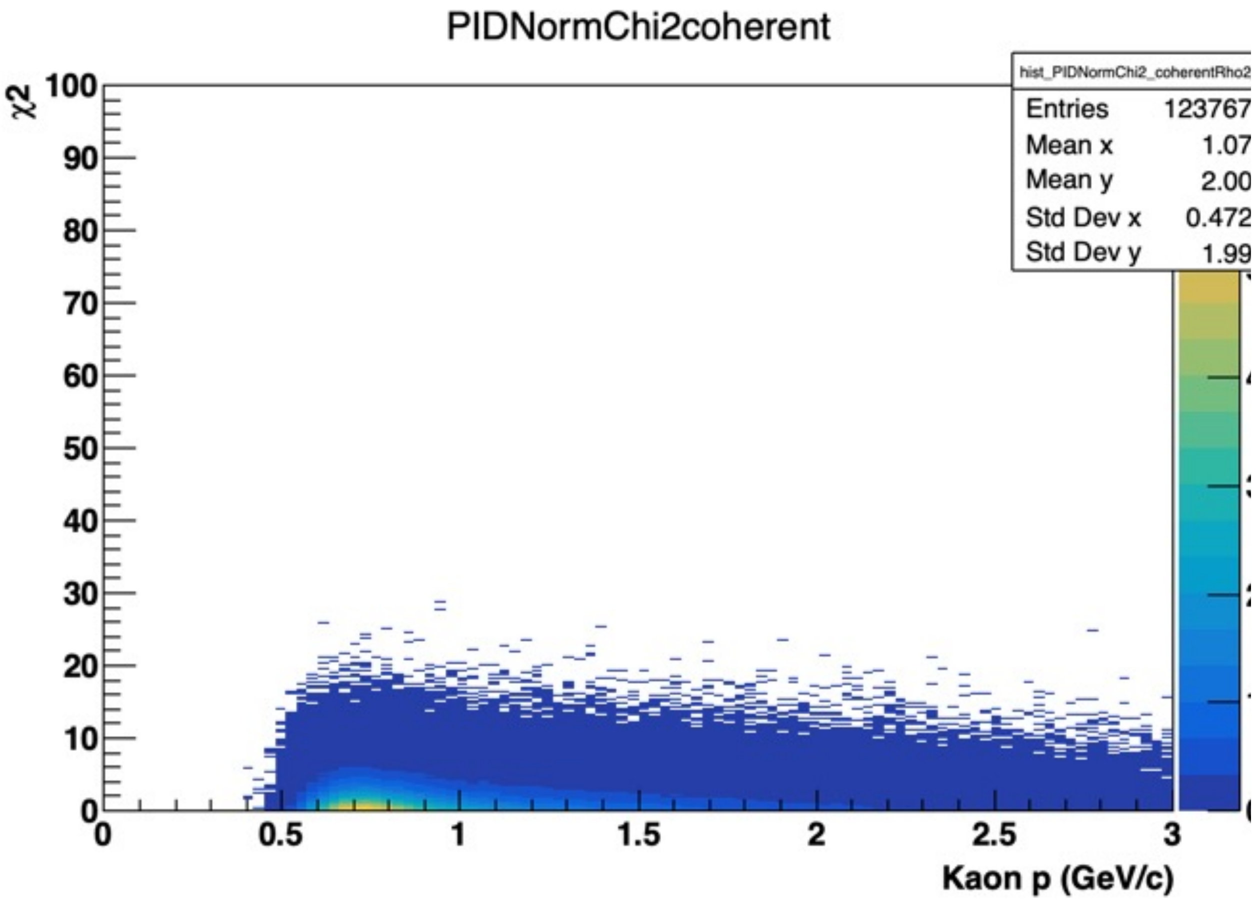
pathlength $L = 2p/(30B) Asin(30B*R/2/p_t)$

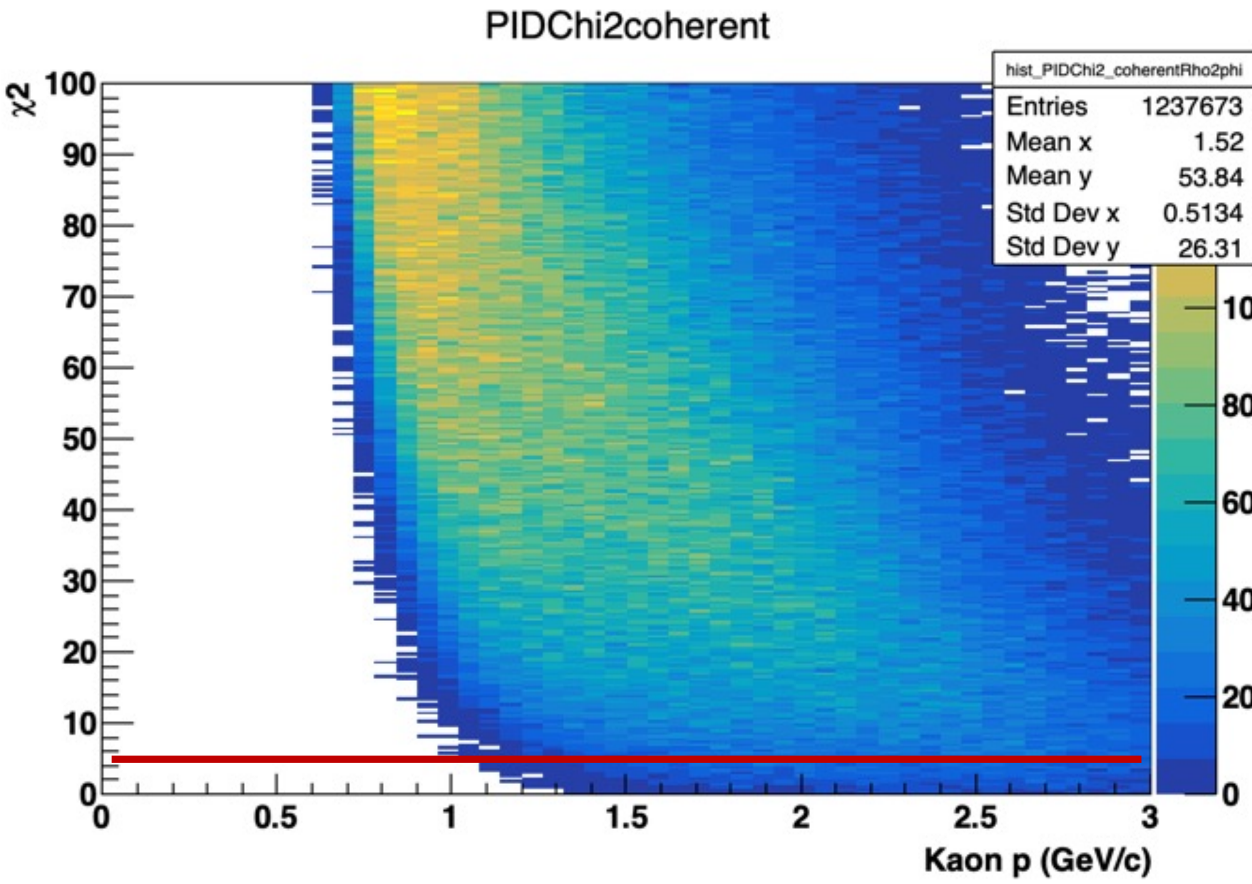
R=50 cm: radial location of LGAD TOF

B=3T Bfield

p, pt: momentum of daughters (GeV/c)

Kaon vs pion pairs

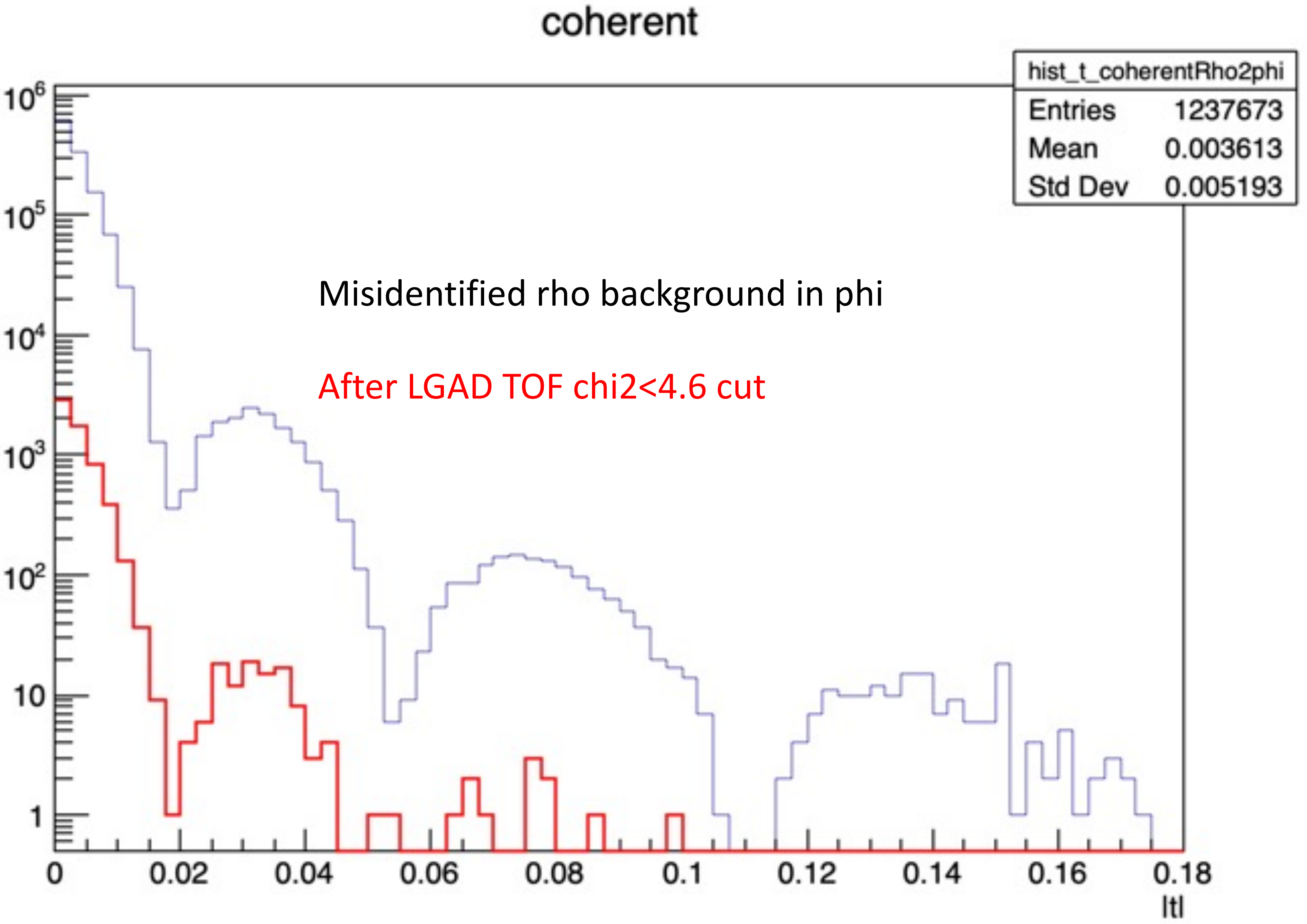




Effective even at p~=3GeV/c

Chi2<4.6 (90% efficiency) for correct pairs

Background rejection power



>100 rejection power
LGAD TOF ALONE

Summary

- A low-pT TOF is required for achieving YR science goals on exclusive VM diffractive measurement
- ACLGAD right outside of silicon tracker will meet the requirement
- More details and realistic simulations are necessary for the proposal but all the simulation and assessments are based on the existing data and simulations

Comments and suggestions I got today at PID meeting

- Physics requirements, what is required in terms of eta coverage?
  From YR, it is from -4<eta<4.
  is this what we need to cover, whole kinematics?
  Current proposal of eta coverage of silicon tracker and LGAD is [-1.54,1.4]
- Scattering electron timing information?
  Do we have the timing for electron detection?
  The electron beam bunch timing?
- If no electron timing, if two daughter momenta are back-to-back, the PID would not work.
  Phase space is small, but it is automatically included in the chi2 distribution (both pion/kaon will produce identical chi2)

Different pseudorapidity range +-2 vs +-4