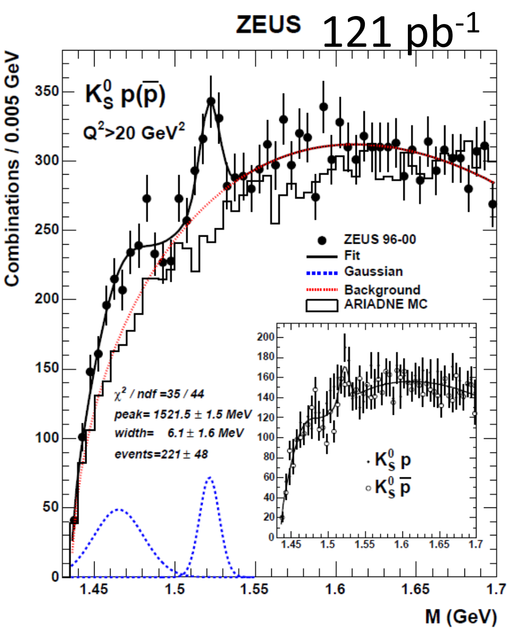
# Paper Presentation of HERA-II PQ analysis

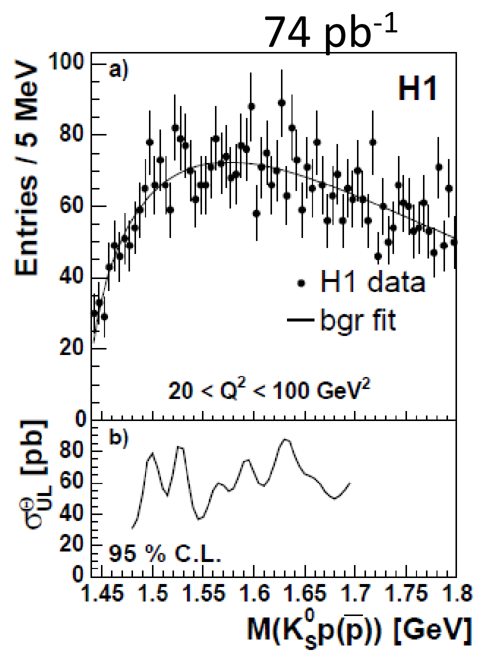
Ryuma Hori (KEK)

# Analysis Backgrounds

- ZEUS published the evidence of Θ(1530) -> $pK_s^0(\overline{p}K_s^0)$with HERA-I data (Phys. Lett. B591, 7-22 (2004)). H1 did not find a peak structure and set limit on Θ (Phys. Lett. B 639 (2006) 202, DESY Note 06-044). We need to check with HERA-II data.
- MVD was installed in HERA-II. Protons can be better selected with CTD and MVD dE/dx.

We are looking for pentaquarks DIS event with 20 < $Q^2$ < 100 GeV² in this paper in order to compare with the HERA-I results.



# Recent Status of pentaquark searches in $pK^0s$ mass system

Ryuma Hori and Katsuo Tokushuku (KEK)

- Recent status was presented in the meeting on Jun23/2015.
  - Link https://indico.desy.de/conferenceDisplay.py?confId=12663

- Standardize some cuts (Zvtx, $Q^2$ etc…): Done.
- Comparison with my private ntuple(DF) and mini-ntuple (CN)
  - Not so many overlap
  
  ⇒ this was the concern. $pK_S^0$ track selection was modified aiming for better matching: only minor improvement but the obtained cross section limit was almost same.
- The draft notes was already distributed.
- Comparison with HERA-I results: Done.
- Paper draft was circulated. (thanks for many comments)
- Made PQ analysis web page (protected with the normal zeus internal safety password)
  - https://www.desy.de/~ryuma/PQanalysis.html

# Event selection

# Data Set (private ntuple)

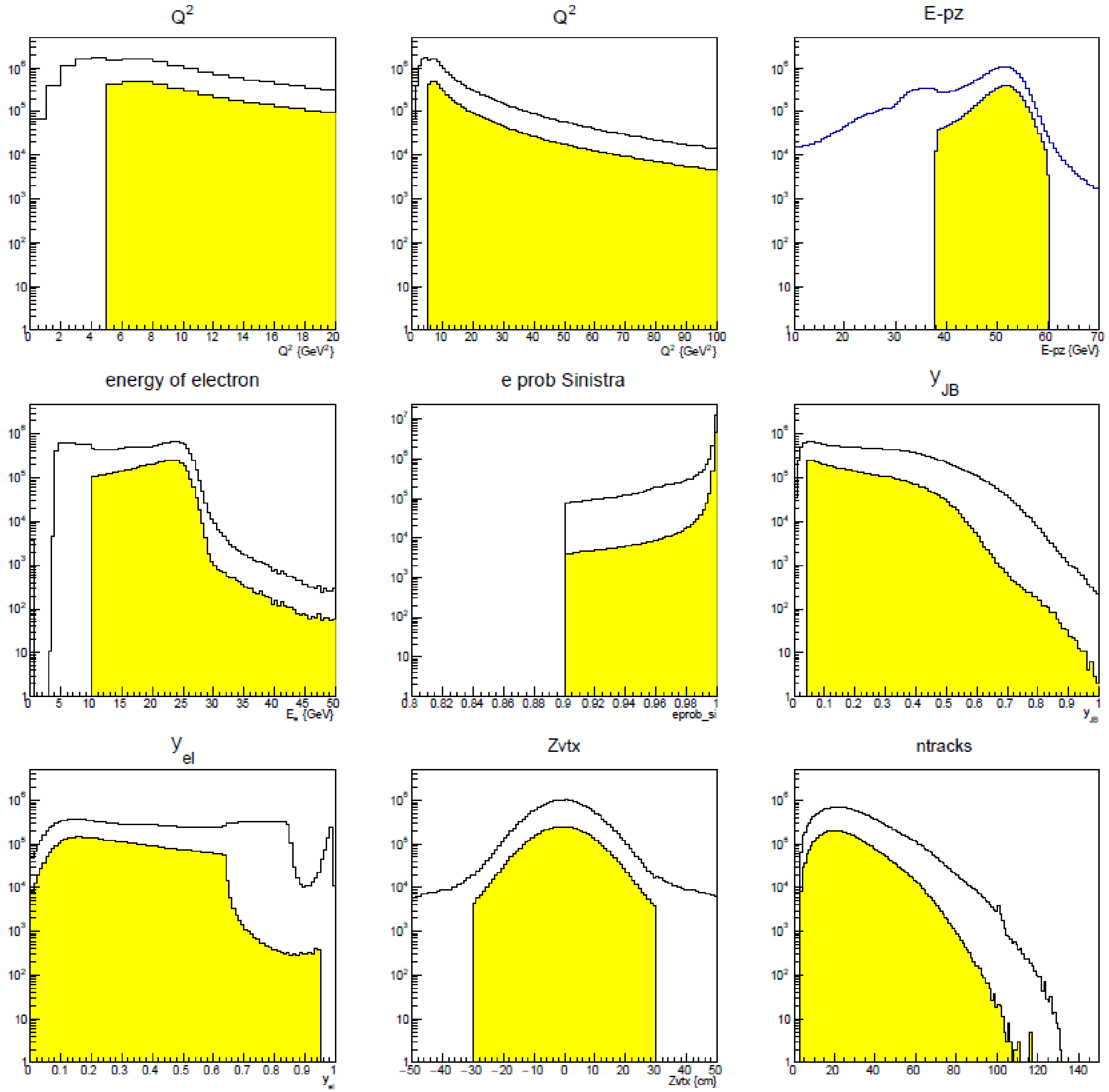
- HERA-II GR data
- Orange 2009a.1
- Pre-selections (ZesLite)
  - Common Section
    - Number of track > 0
    - |Zvtx| < 52cm
    - Number of V0lite ($K_S^0$) > 0
    - For DIS
      - DSTb9
      - Sinistra's number of electron > 0
    - Tracking RT+DAF (default tracking setting)

| | Luminosity($pb^{-1}$) |
|---|---|
| 2004$e^+p$ | 37.55 |
| 2005$e^-p$ | 135..47 |
| 2006$e^-p$ | 51.03 |
| 2006,7$e^+p$ | 135.87 |
| total | 358.93 |

# Event selection

- DIS event selection for ntuple
  - $Q^2 > 5$ GeV$^2$
  - $E_e$ > 10 GeV
  - 38 < E-pz < 60 GeV
  - $y_{el}$ < 0.95
  - $y_{JB}$ > 0.04
  - Electron Probability > 0.90
  - Electron position |x|> 12cm |y|> 12cm
  - |Zvtx| < 30cm
  - Number of track > 2 & < 400
  - At least one track from the primary vertex
  - TLT triggers (SPP02 SPP09)

# DIS variables

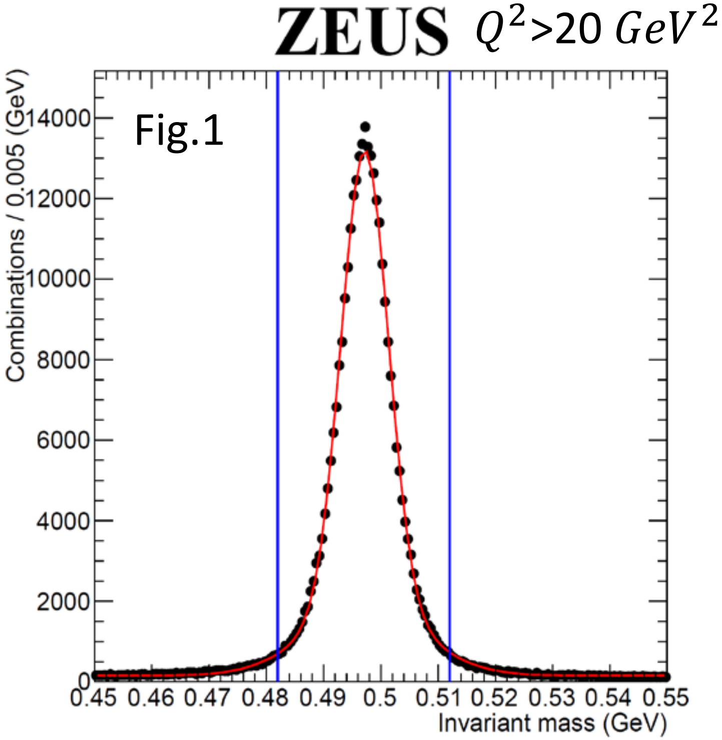



White: pre-selected

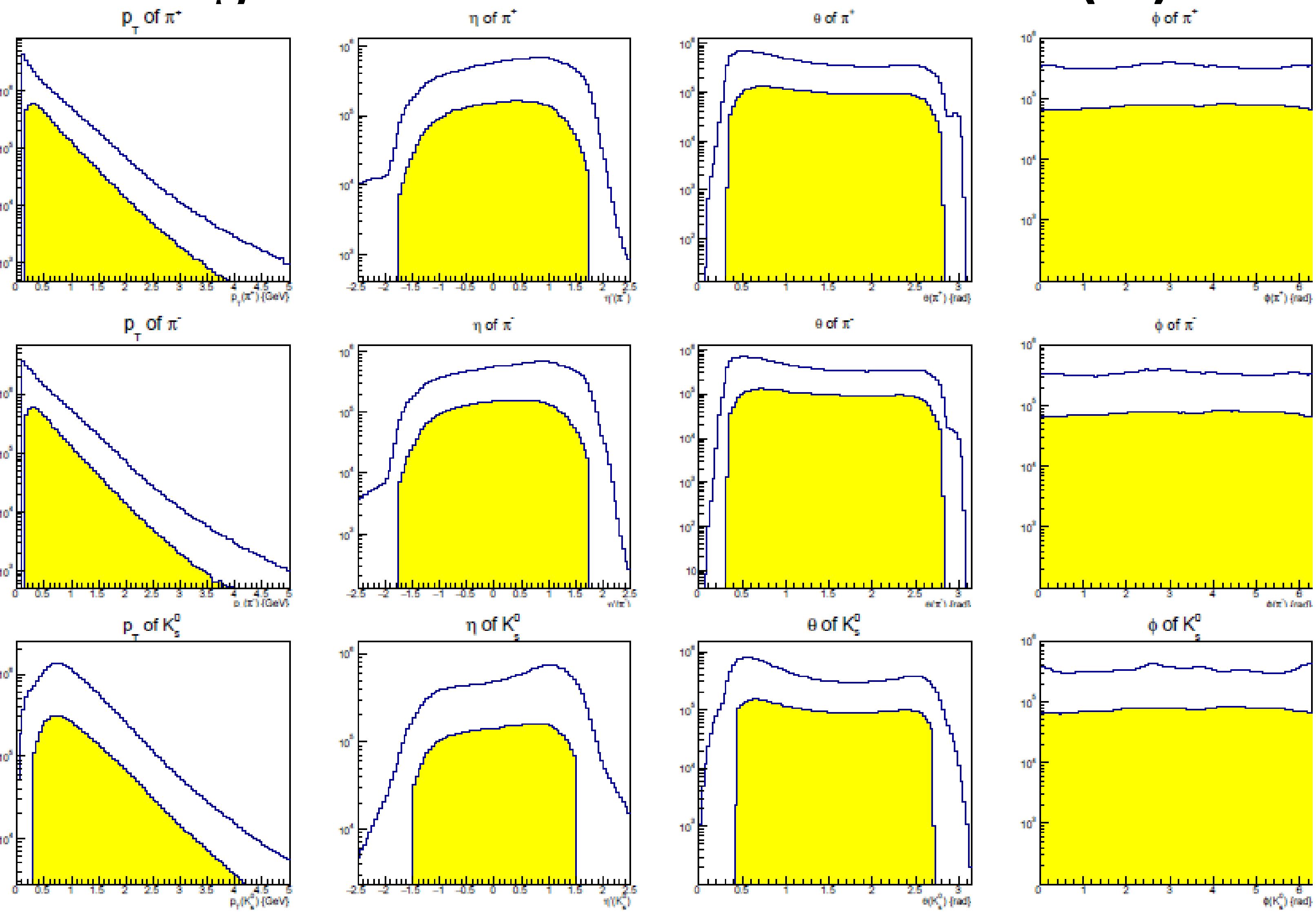
Yellow: after DIS selection

# $K_S^0$ selection

- Two tracks with opposite charge
- $p_T$(π) > 150MeV
- |η(π)| < 1.75
- π track's MVD hit > 2
- $p_T$(ππ) > 250MeV
- |η(ππ)| < 1.6
- $\chi^2$ < 5.0 (of the two tracks refit with V0lite)
- DCA between two tracks < 1.5 cm (V0lite)
- DCA to beam spot > 0.2 cm (V0lite)
- 2D co-linearity < 0.06 rad
- 3D co-linearity < 0.15 rad
- $K_S^0$ decay length (DL) > 0.5 cm
- When we assign the electron mass to the track, M(ee) > 70MeV
- When we assign the proton mass to one of the tracks, M(pπ) > 1.121GeV
- Finally, we set a mass window (482MeV < M(ππ) < 512 MeV, blue line).

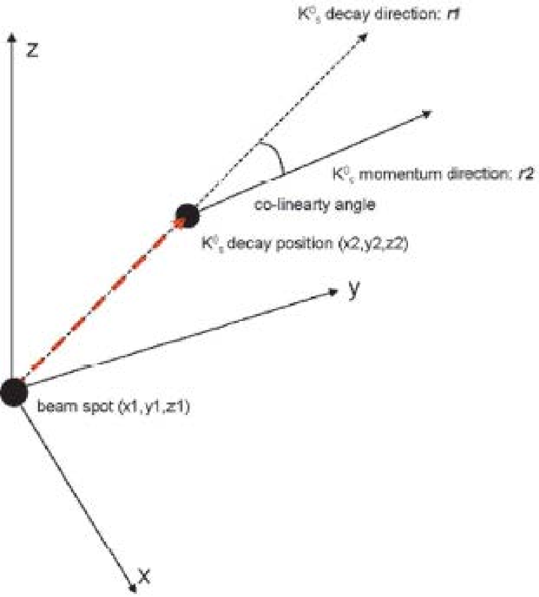


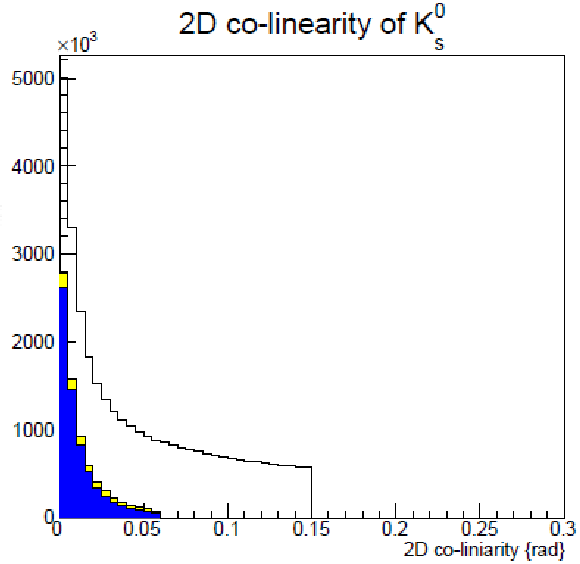
# $K_S^0$ Kinematic variables (1)

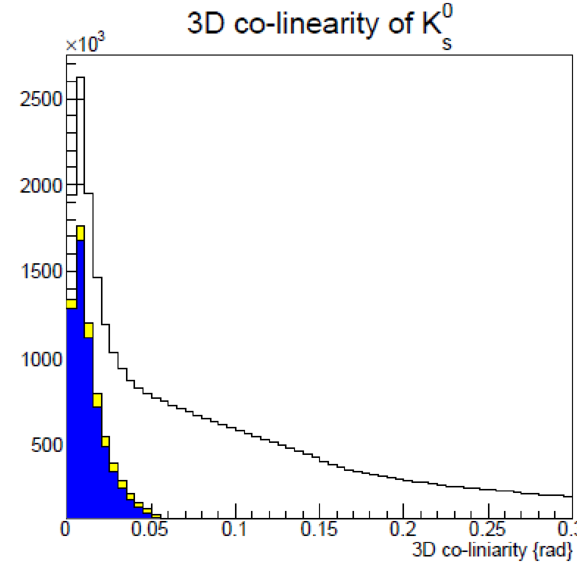


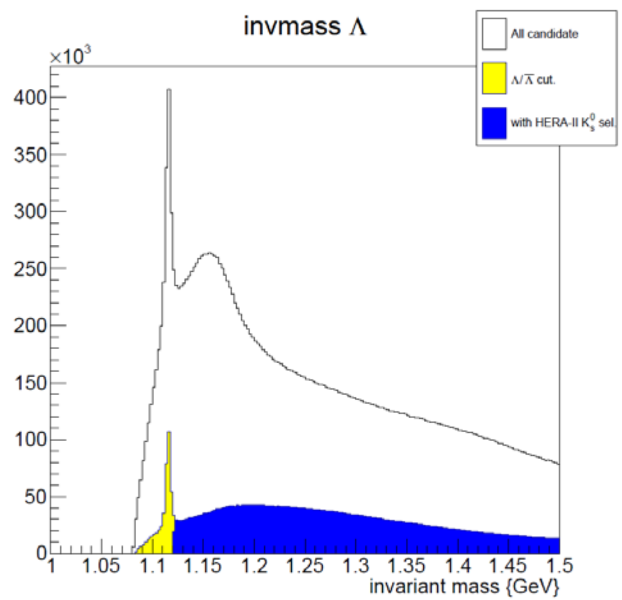

White: before $K_S^0$ selection, Yellow: after the selection.

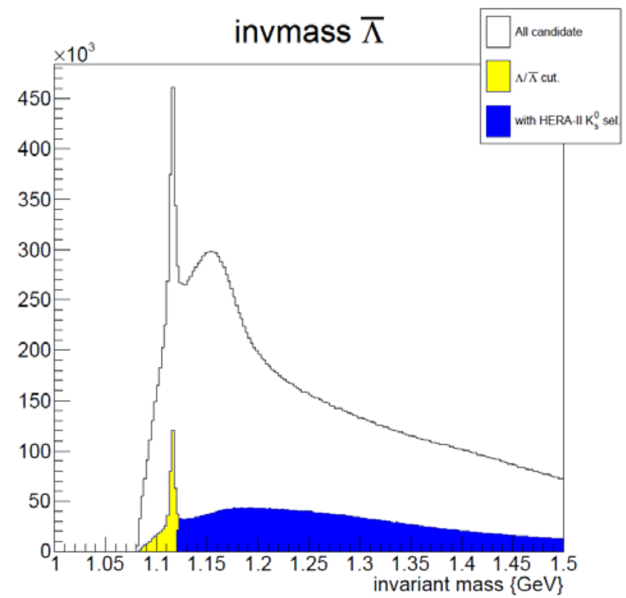
# $K_S^0$ Kinematic variables (2)



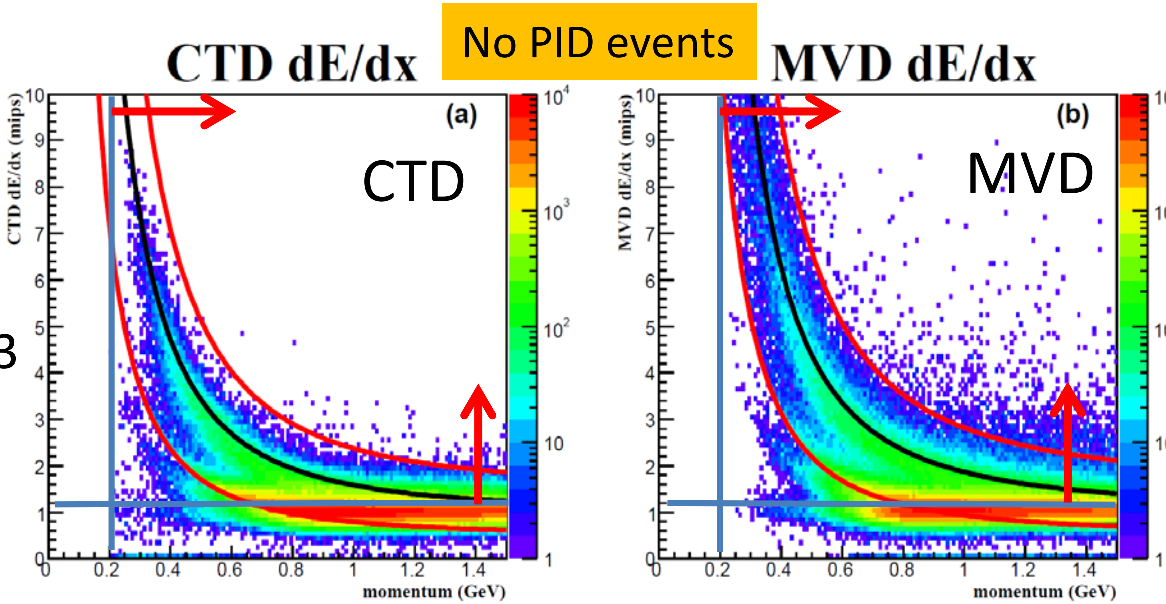



# Proton identification for DATA

- Track selections
  - not used as π of $K_S^0$
  - 0.2 < p(p) < 1.5 GeV
  - CTD innermost layer = 1
  - CTD outermost layer >= 3

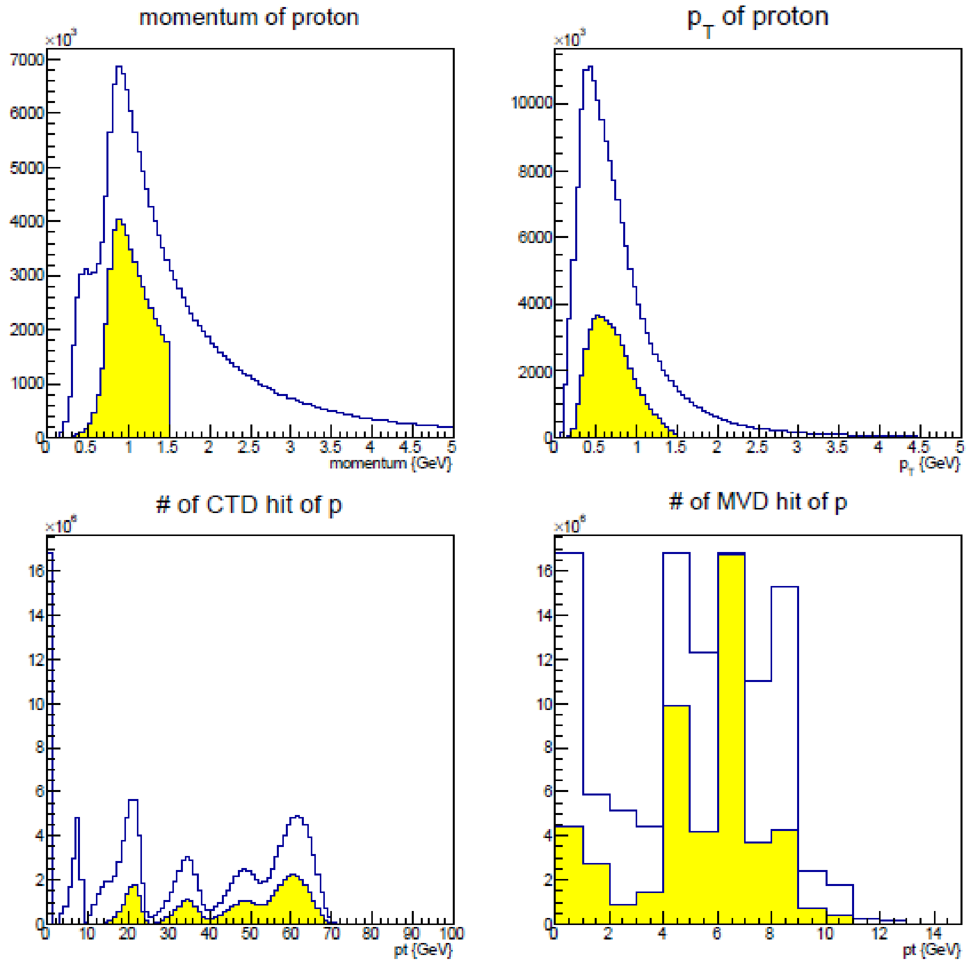



- dE/dx requirements
  - protons had to be within a band centered at the expectation of the parametrized Bethe-Bloch function F. The band is defined 0.5F < dE/dx < 1.5F.
  - dE/dx should be greater than 1.15 in units of mips
  - dE/dx probability likelihood of proton > 0.3.
- PID requirement
  - If CTD dE/dx is valid, both CTD and MVD dE/dx are in the proton bands.
    - If no CTD dE/dx due to saturation, only MVD dE/dx is required.



With this logic, we can save more low momentum protons.

# Proton kinematic variables



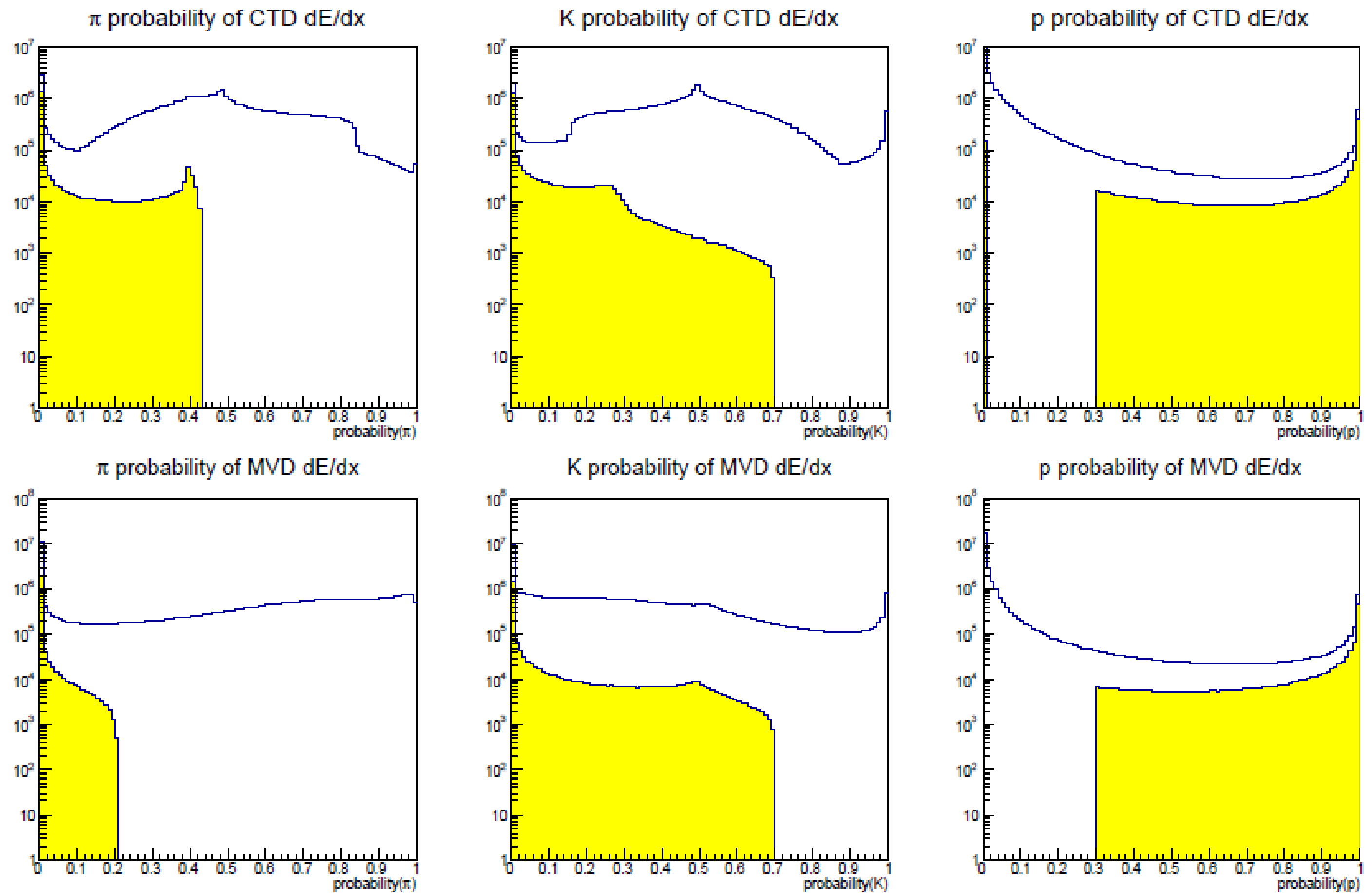

White: pre-selected

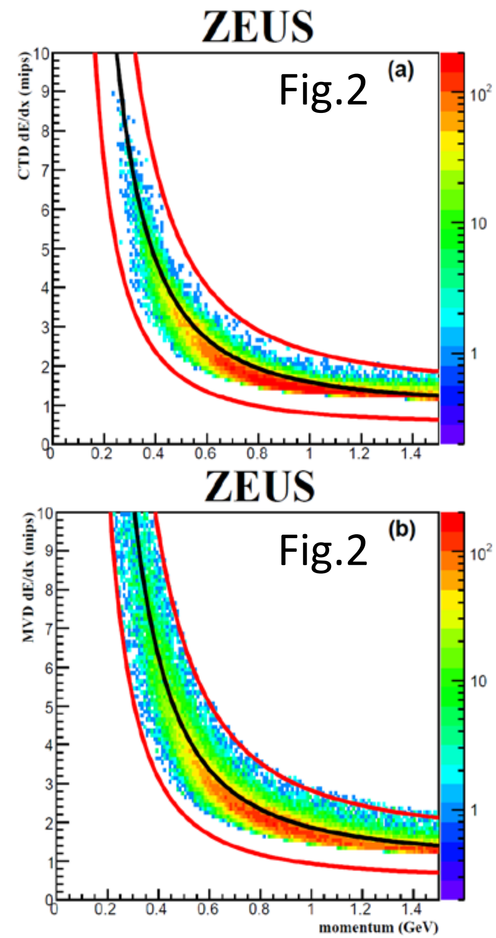
Yellow: after proton selection

# proton PID

White: pre-selected

Yellow: after proton PID



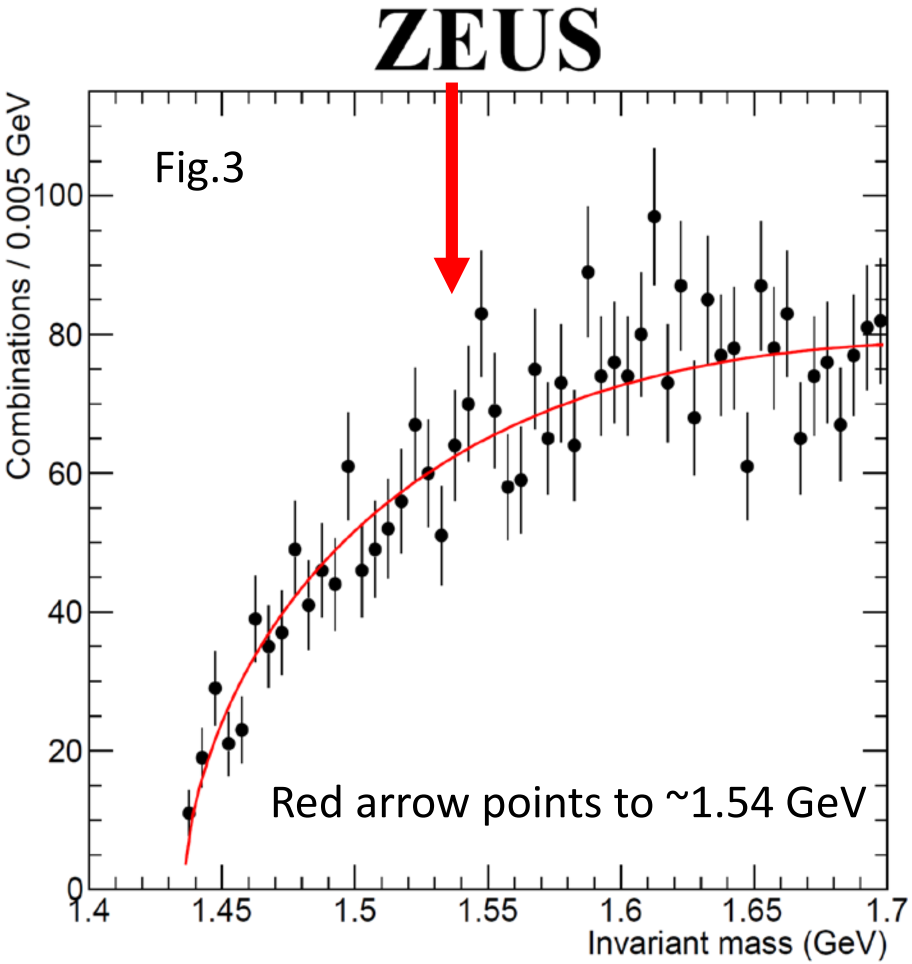

- dE/dx proton probability likelihood of PID;
  - dE/dx resolution was ~10% for both detectors.
  - defined $L(p) = prob(p)/\sum_i prob(i)\ \ (i = \pi, K, p)$.
  - can select purely proton.

# PQ Selection and Mass distribution

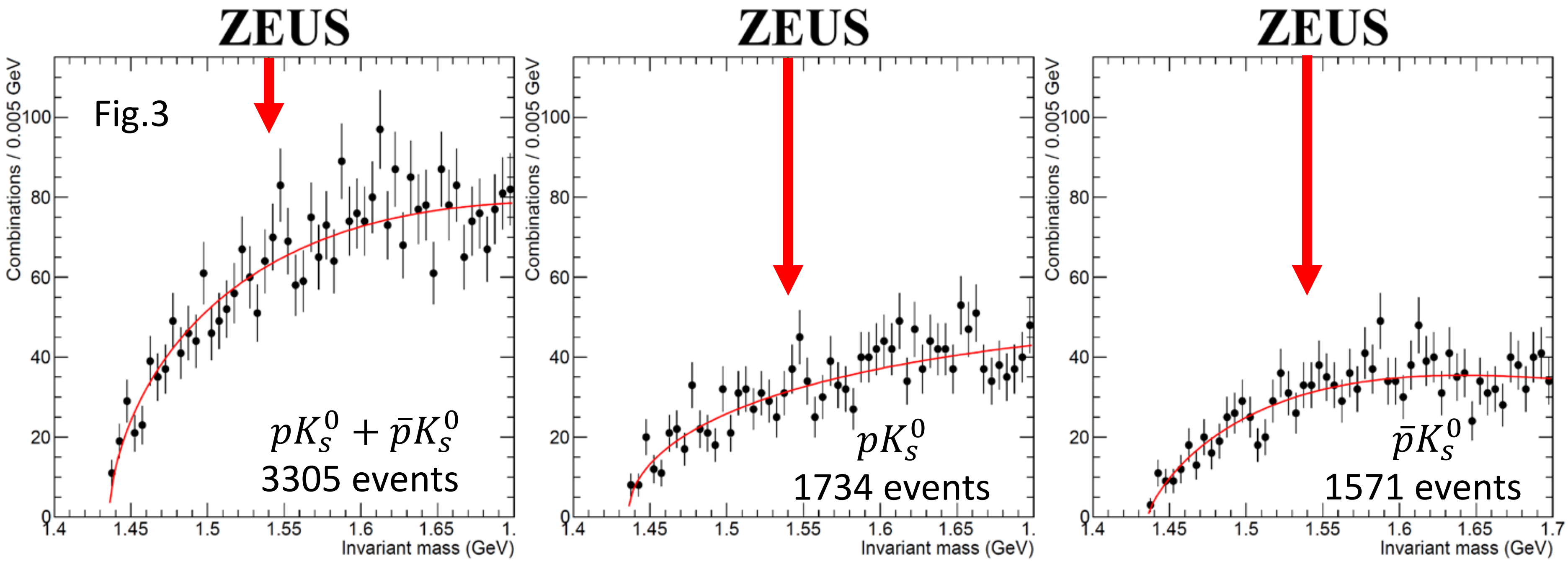
- $Q^2$ requirement
  - $20 < Q^2 < 100$ GeV²
- $pK^0s$ requirements
  - $0.5 < p_T < 3.0$ GeV
  - $|\eta| < 1.5$

- PQ mass peak is not seen

=>calculate production cross section limit.



# Mass distribution with charge separation

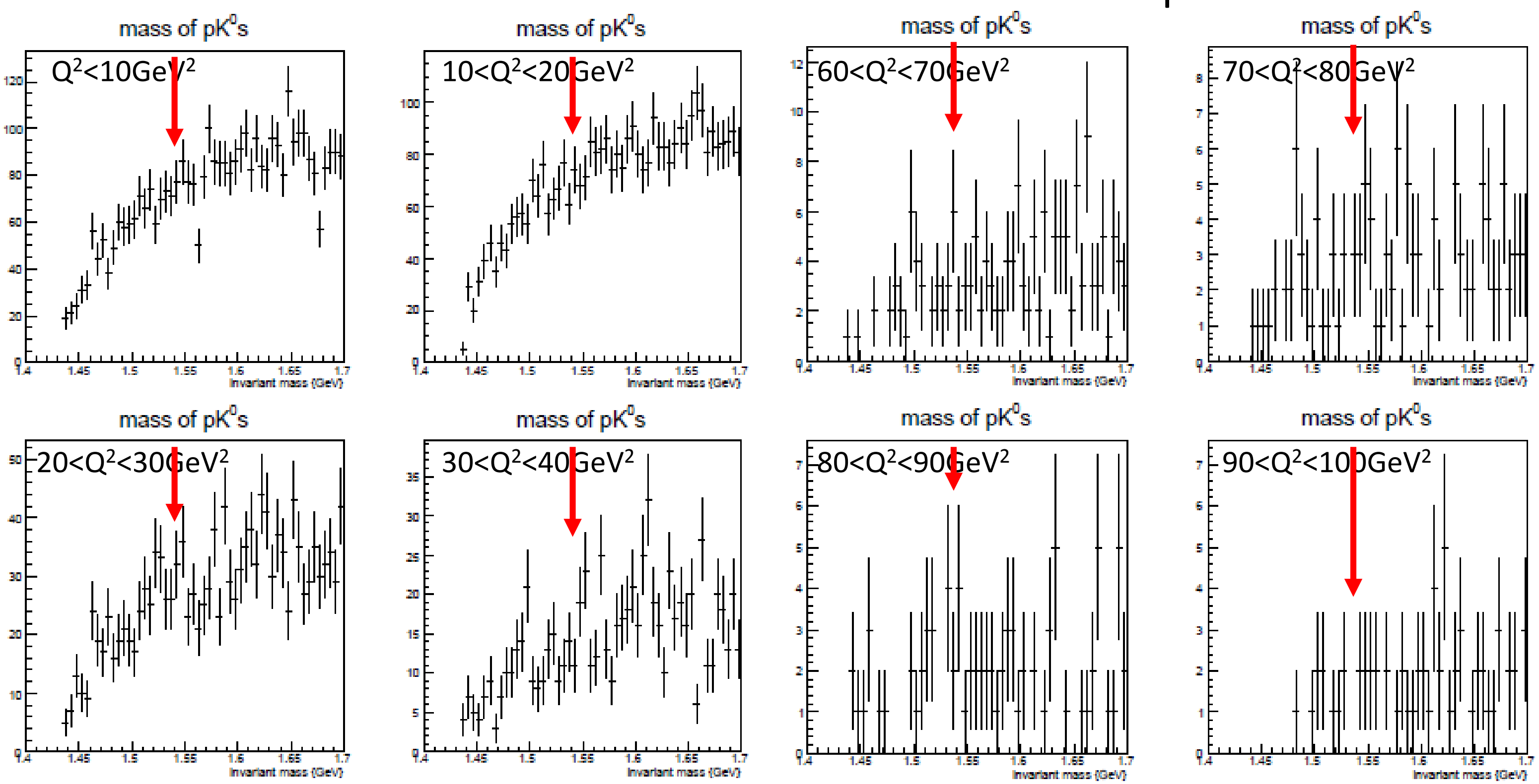


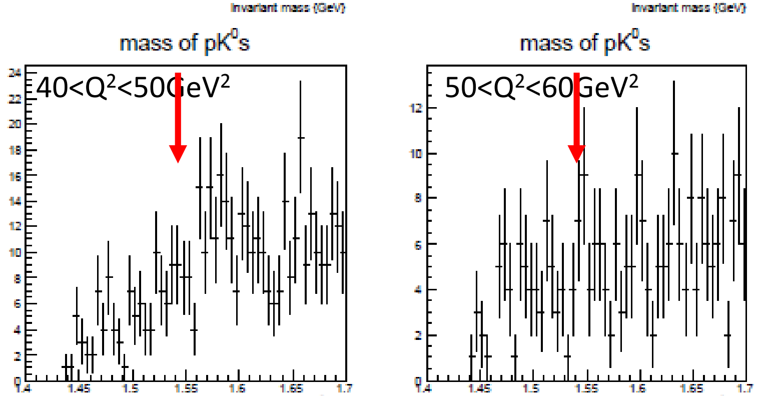

Red arrows point to ~1.54 GeV

- Charge separation;
  - Fitted by the same function as shown in p.25.

# Mass distribution (sliced by $Q^2$)

Red arrows point to ~1.54 GeV




- Events are check with $Q^2$ slice 10 GeV$^2$ step from 0 to 100 GeV$^2$
- Any peak is not seen.

# Efficiency calculation

# Mass weighting Procedures

- For each $pK_S^0$ candidate, a weight(ε) is determined to correct for;
  - (1) Efficiency of proton identification.
  - (2) Acceptance of Θ:

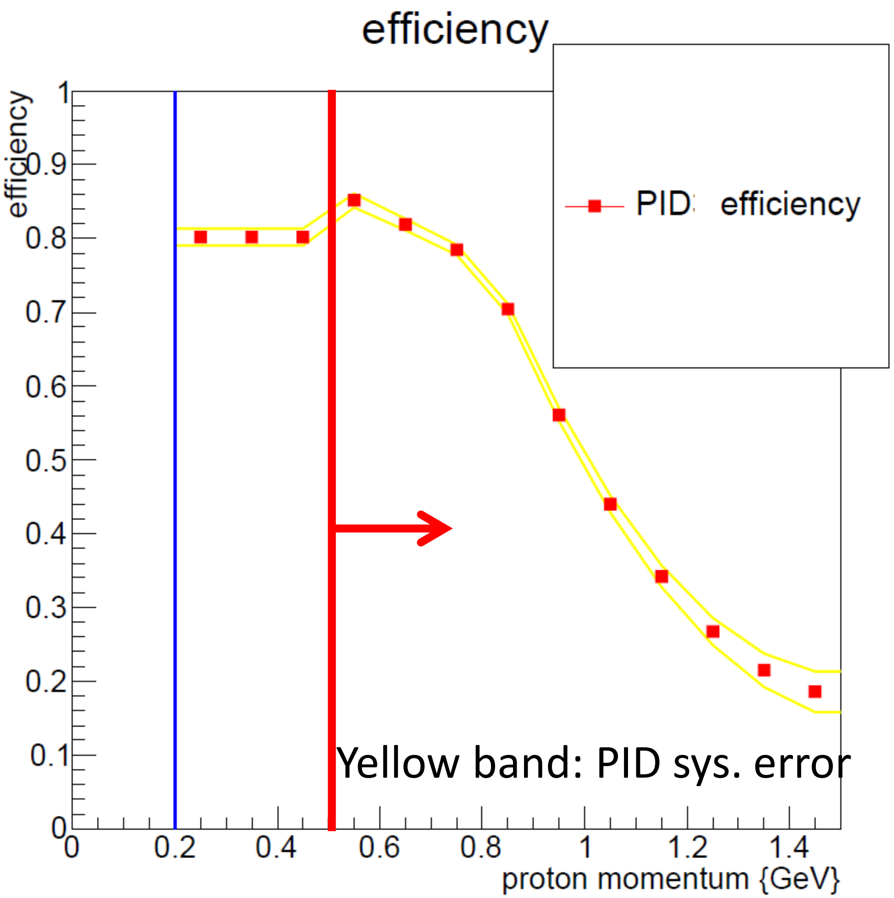
    correction for decay angle assuming isotropic decay.

$$\varepsilon = \varepsilon_{\text{proton PID}}(p^{\text{proton}}) * \varepsilon_{\text{decay angle}}(p_T^{pK}, \eta^{pK})$$

  - (3) In addition, acceptance of DIS selection is calculated.

In the following slides, we will explain these one by one.

# (1) Proton PID efficiency with the data using Λ(1115)



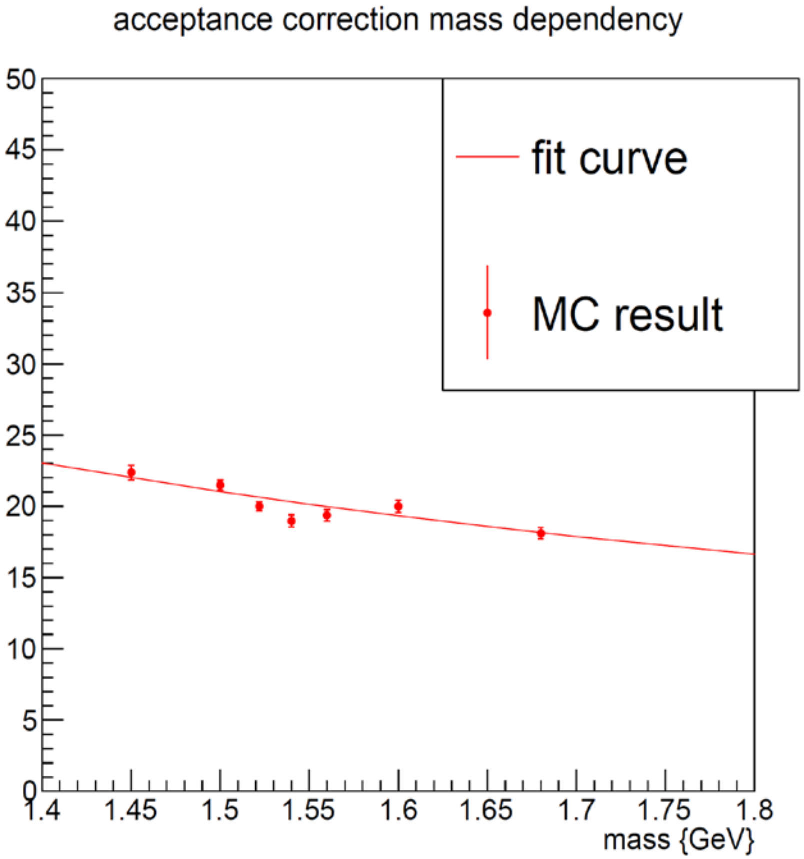

Λ sample selected from DATA sample by V0lite routine which used only track information (Λ mass plots shown in backups p.60)

**Efficiency $\varepsilon_{\text{proton PID}}(p^{\text{proton}})$**

**= (# of Λ w PID)/(# of Λ wo PID)**

- p(p) < 0.5 GeV
  - Use 0.5GeV bin's value.
- 0.5 GeV < p(p) < 0.8 GeV
  - Use the measured values.
- p(p) > 0.8 GeV
  - Use a quadratic function as shown in the figure.
- PID Proton purity study is on going; by estimation of π contamination.

# (2) $\varepsilon_{decay\ angle}(p_T^{pK},\eta^{pK})$ mass dependency




- For each $(p_T, \eta)$ bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic error, the factor is fitted with a linear function and a quadratic function. But, the difference between fit function is very small .

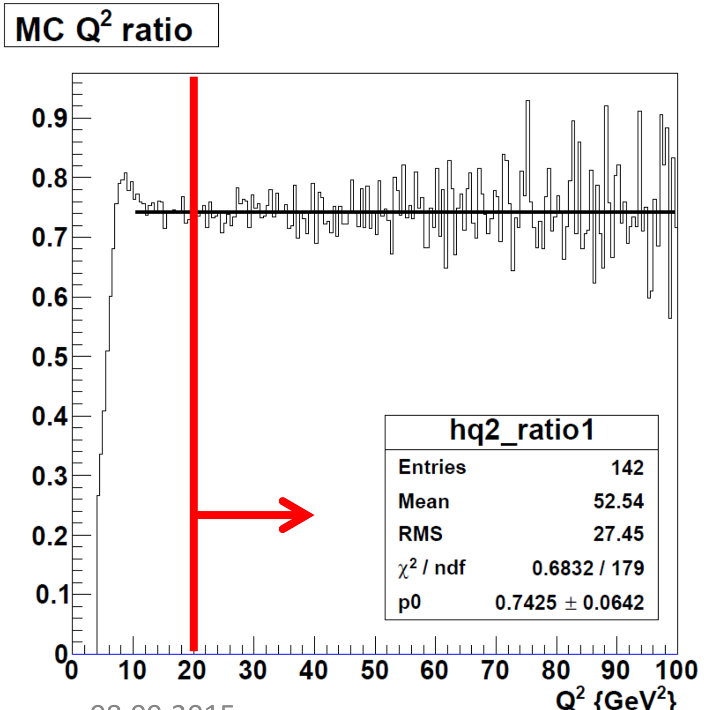
$$\varepsilon_{decay\ angle}^{pol1}(p_T^{pK},\eta^{pK}) = A*M_{\Theta} + B$$

- $p_T$ reweighting performed to estimate systematic error coming from PQ momentum changing (detail in backup p.32)

# (3) DIS efficiency

- DIS efficiency estimated by $Q^2$(DA) of PQ MC sample

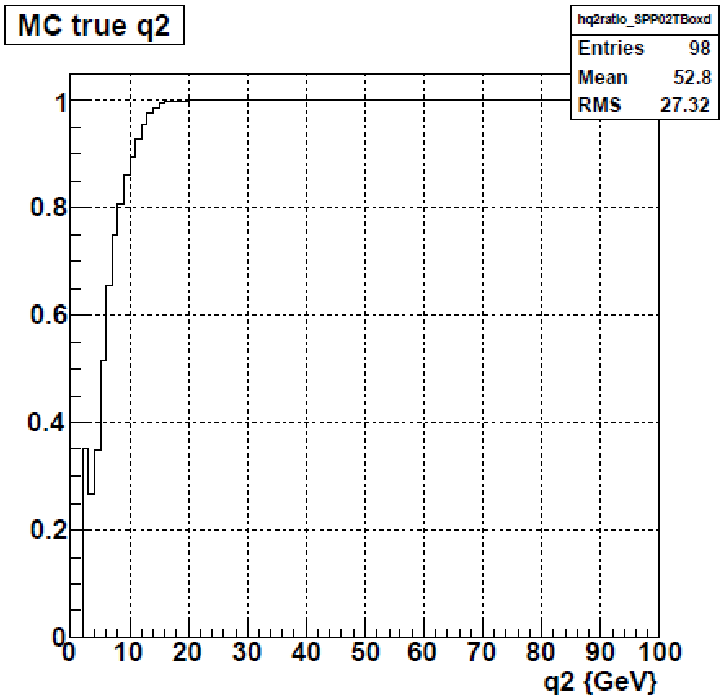
  ε = # of after DIS selection/# of before DIS selection (MC true information).
- Calculate as $Q^2$ function.
- $20 < Q^2 < 100$ GeV$^2$ in order to compare with HERA-I analysis




- For $Q^2 > 20$ GeV$^2$: acceptance can be regarded as flat ($\varepsilon_{DIS} = 0.7425 \pm 0.0642$).
- TLT efficiency ~ 100% for these $Q^2$ (next page)

# Etc; TLT trigger efficiency

- **TLT trigger efficiency is estimate by MC.**
- **In HERA-II, SPP02 is used to take DIS event . But SPP02 is pre-scaled in 2006, SPP09 is also used to take DIS event.**
- **-2005**
  - **SPP02** Inclusive DIS prescale 1
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 12x12cm cm
- 2006-
  - **SPP02** Inclusive Low $Q^2$ DIS prescale 10
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 12x12cm cm
  - **SPP09** Inclusive (a bit less) Low $Q^2$ DIS prescale 1
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 15x15cm cm




- TLT Trigger efficiency

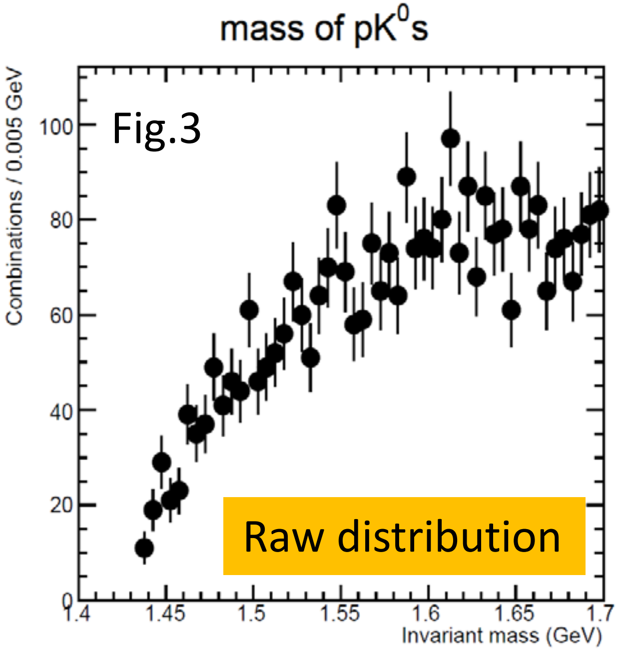
  = # event pass Box15x15cm/ # event pass Spp02taken
- In $Q^2$ > 20 GeV² TLT trigger efficiency ~ 1.

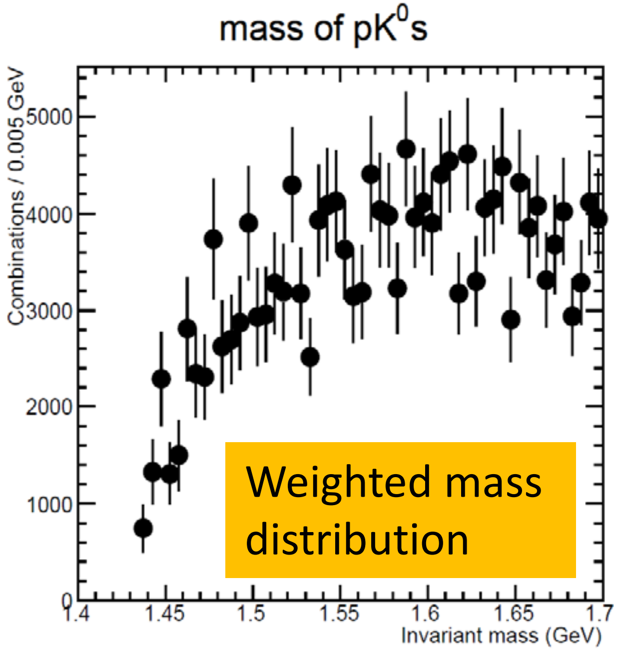
  => can ignore trigger pre-scale factor (introduced in higher $Q^2$ from 2006)

  => can use full luminosity 364.20pb$^{-1}$

# Setting of PQ cross section limit calculation

- Limit setting with the well identified phase space.
  - (DIS 20 < $Q^2$ < 100 GeV², $p_T$ of $pK_S^0$ : 0.5-3.0 GeV , η of $pK_S^0$: -1.5 – +1.5)
  - Acceptance correction ASSUMING the $p_T$/η spectrum of pentaquark is similar to $\Sigma^+$(1189). : Some systematics with different $p_T$ slopes.
  - With 2 sets of Gaussian mass width (6.1MeV as seen in HERA-I and 12.2 MeV.)



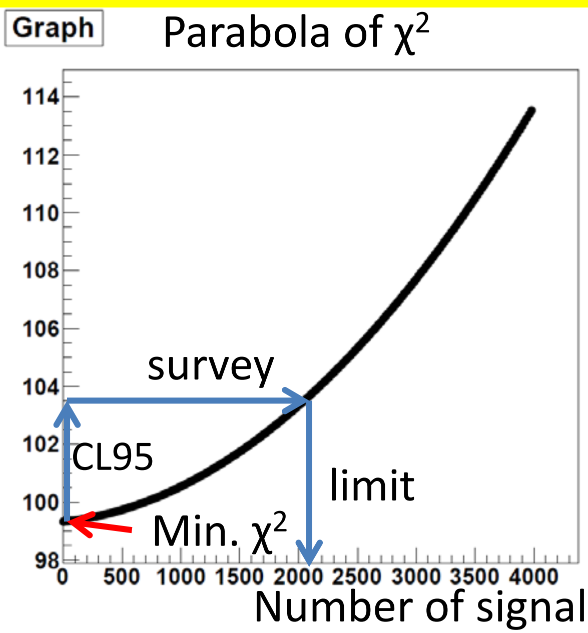



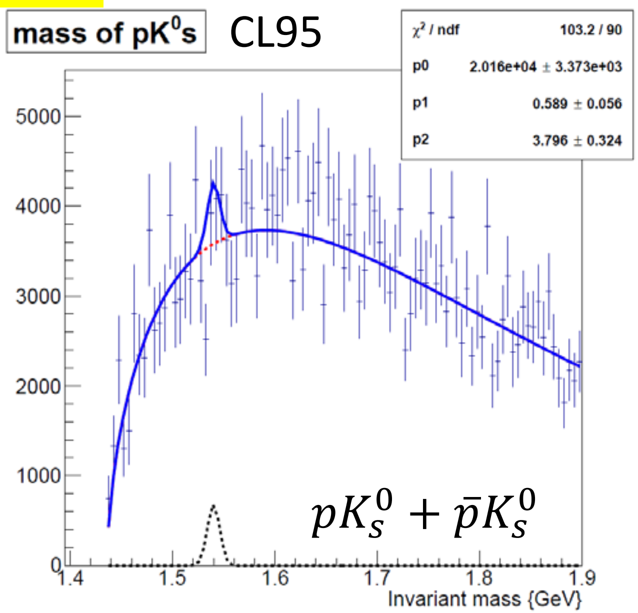
# Cross section limit calculation

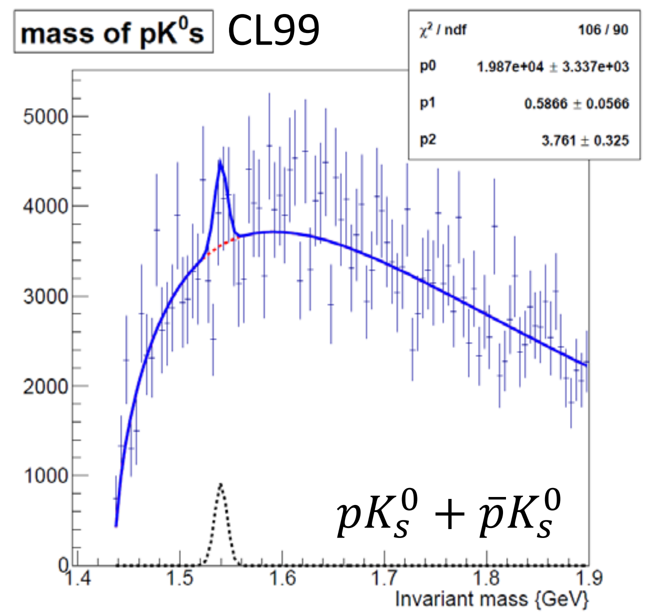
# Fitting method for the calculation

- Signal: Gauss function (6.1 MeV as seen in HERA-I and 12.2 MeV.)
- B.G.: $p0*(M_{pk0}-M_p-M_{K0})^{p1}*e^{\{-P2*(Mpk0-Mp-MK0)\}}$
- Blue: fixed signal function + B.G..
- CL90 = $\chi^2_{min}$ + 2.71, CL95 = $\chi^2_{min}$ + 3.84, CL99 = $\chi^2_{min}$ + 6.63

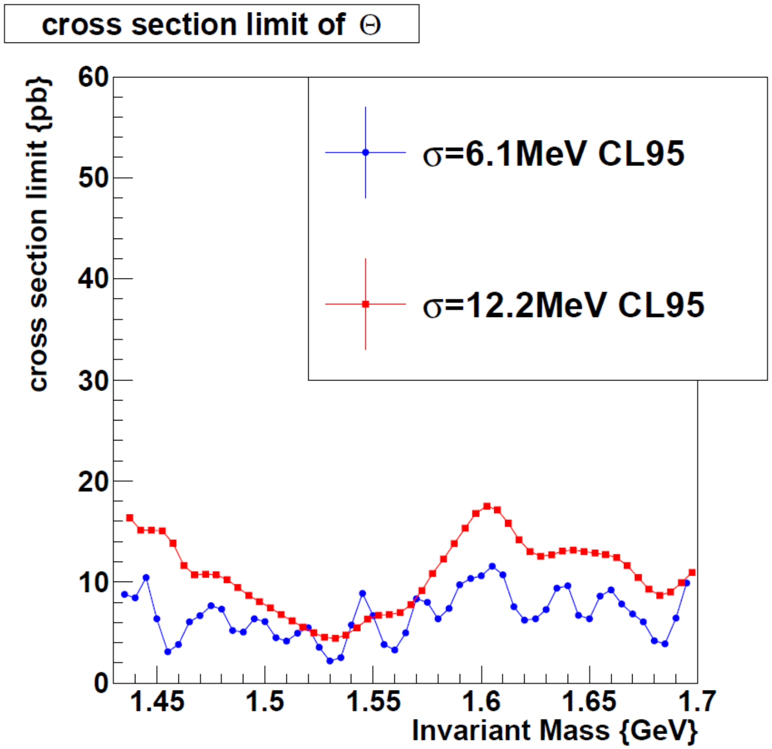
Ex. mass 1540 MeV with σ=6.1MeV

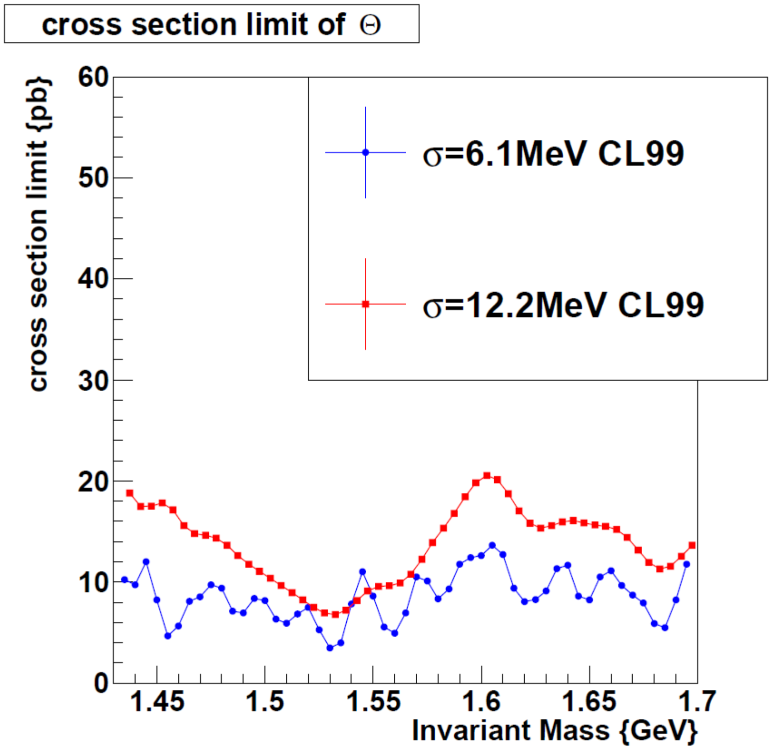


# Result of Cross section limit calculation



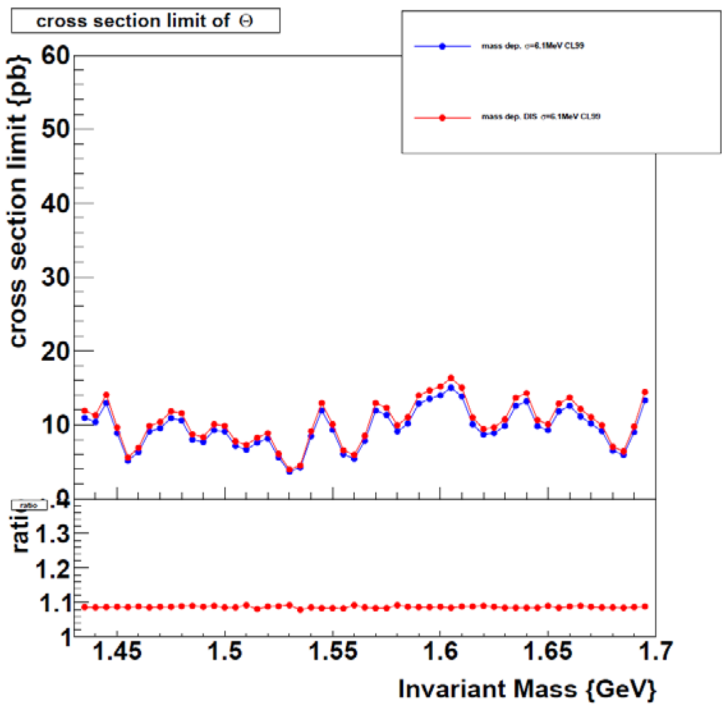

- Cross section limits are calculated for HERA-II total luminosity 358.93pb$^{-1}$

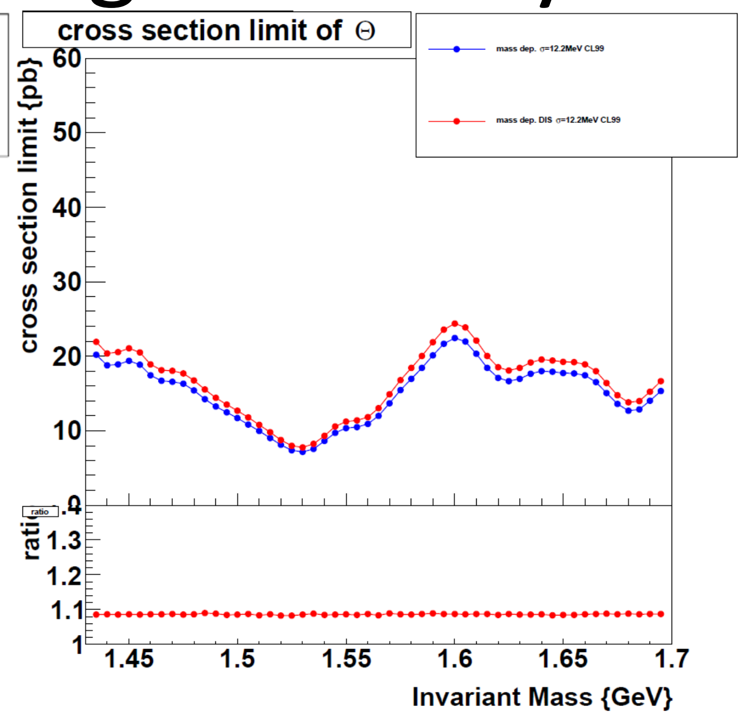
=> Calculate systematic errors.

# Systematic errors

- Estimate 5 components;
  - DIS electron finding;
  - Proton identification (PID); explained in p.19
  - accept. different ($p_T$, η) binning;
  - accept. mass dependency;
  - $p_T$ distribution re-weighting.

# Systematic errors estimation: DIS electron finding efficiency

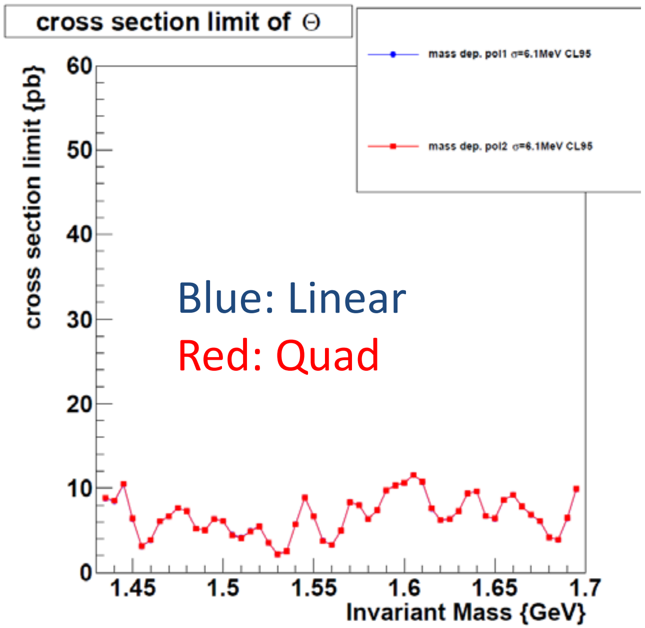


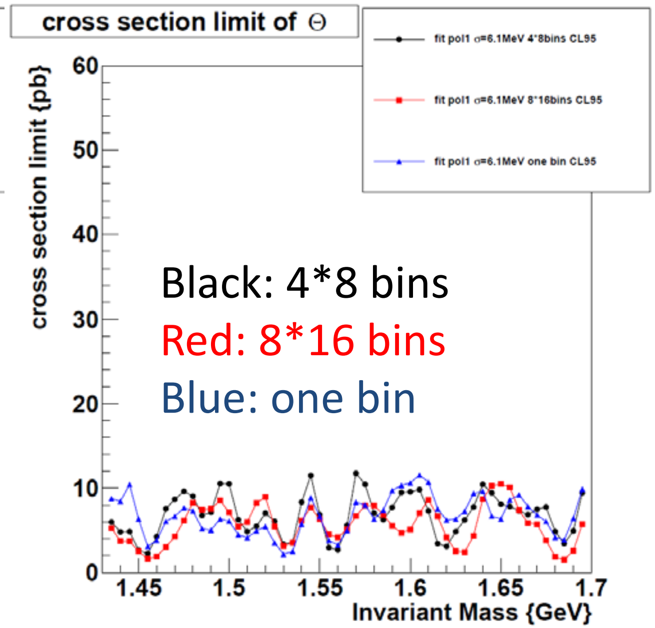

- Mass dependency of DIS electron finding efficiency is small.

# Systematic errors estimation: Binning

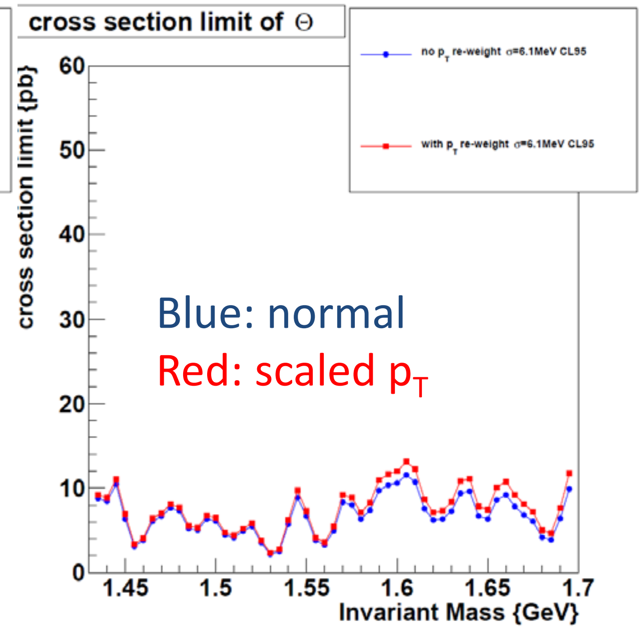
- Acceptance mass dependency (linear(default) or quadratic function)
- Different ($p_T$, η) binning : 3 patterns (1X1(default), 4X8, 8X16 )
- $p_T$ Spectrum correction (default, scaled with Mass)




Acceptance/ mass dependency




Acceptance / different Bin

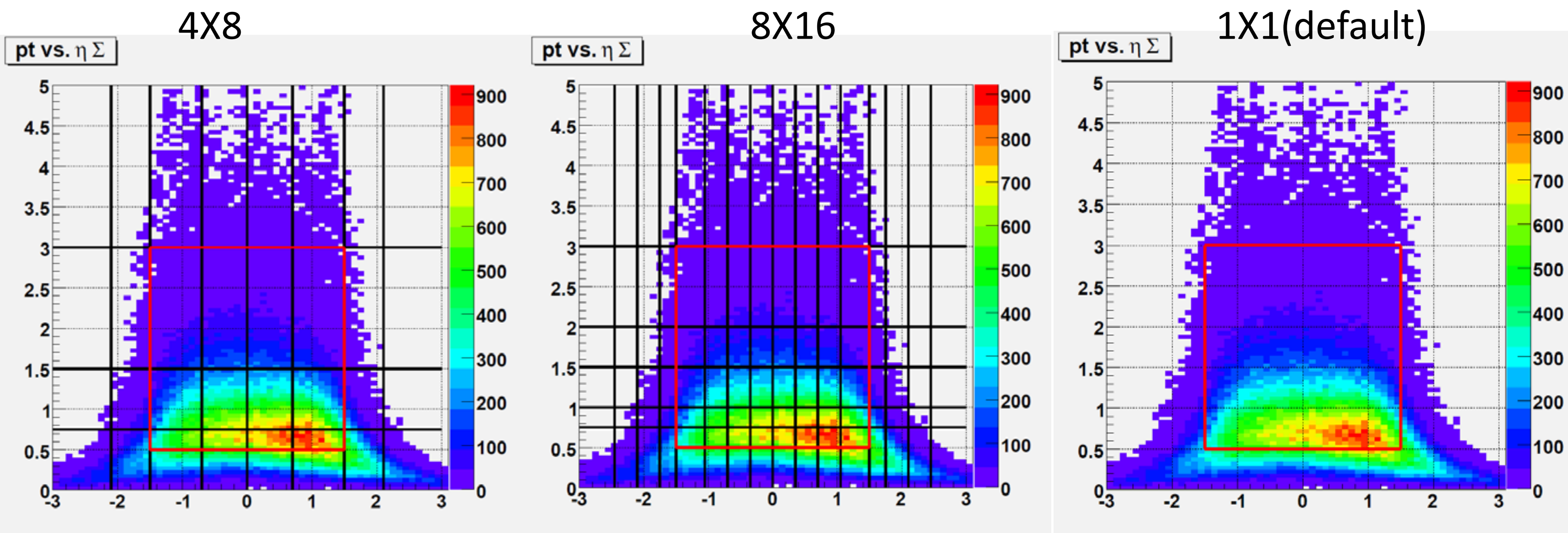



$p_T$ reweighting

: all result are almost consistent.

: the difference are added in quadrature to indicate the systematics.

# Systematic Estimation: Binning

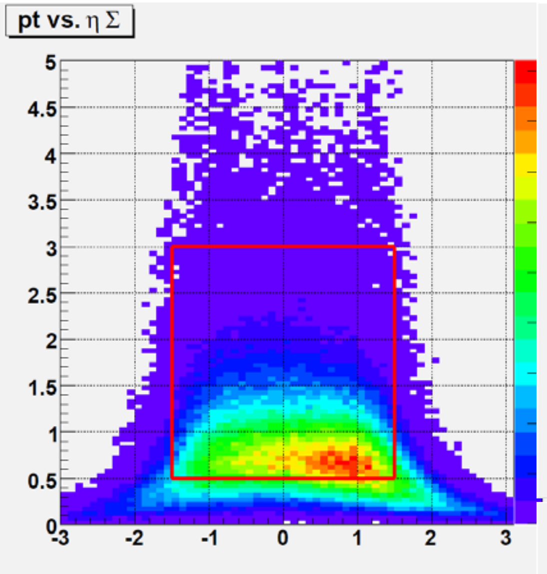


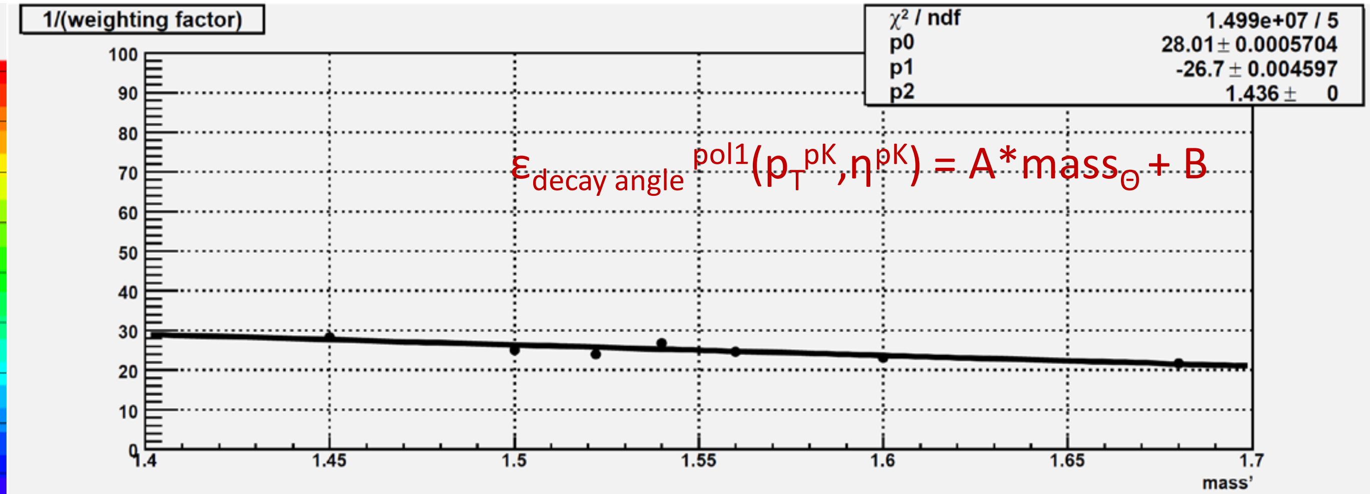

- For each ($p_T$, η) bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic, the factor is fitted with a linear function (above) and a quadratic function (shown backup). The difference is uses as systematic errors.

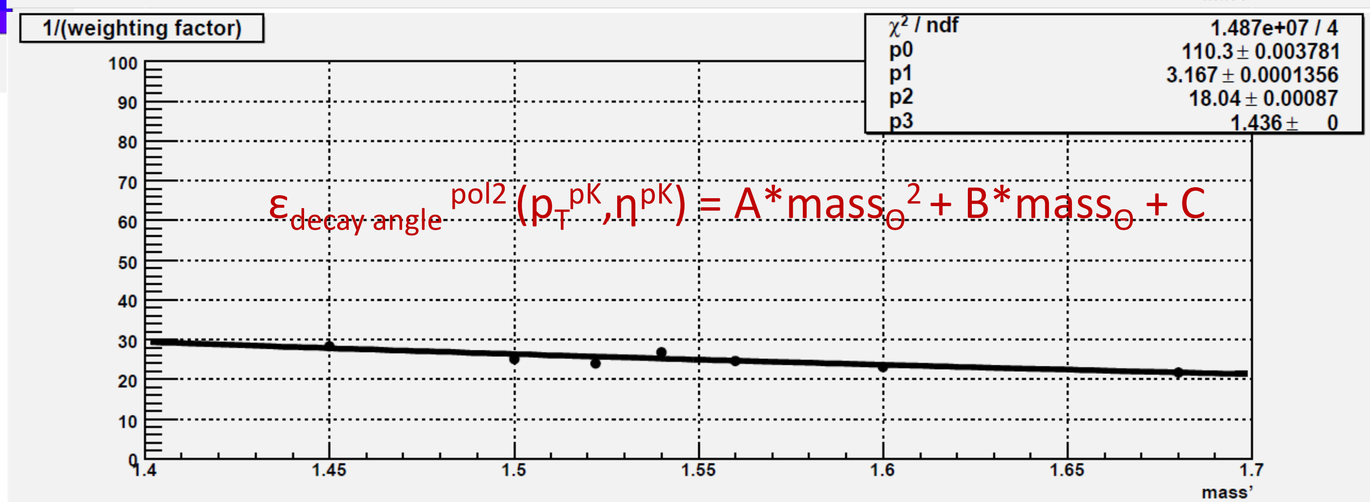
i.e. $\varepsilon_{decay\ angle}^{pol1}(p_T^{pK},\eta^{pK}) = A*mass_{\Theta} + B$

in this figures.

# Example: Acceptance mass dependency (Binning 3)



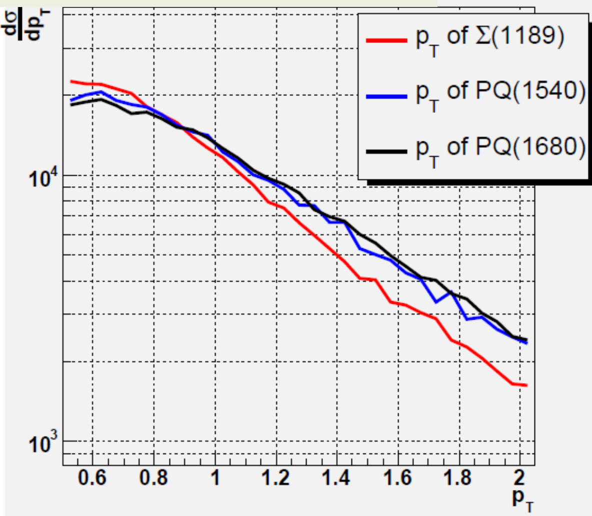



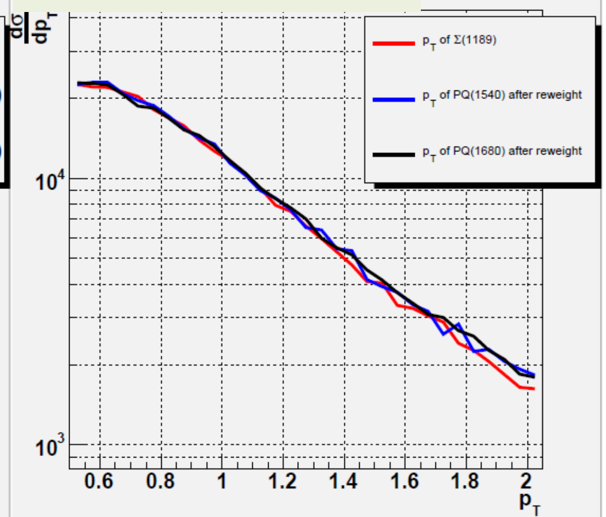

- For each ($p_T$, η) bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic, the factor is fitted with a linear function and a quadratic function.

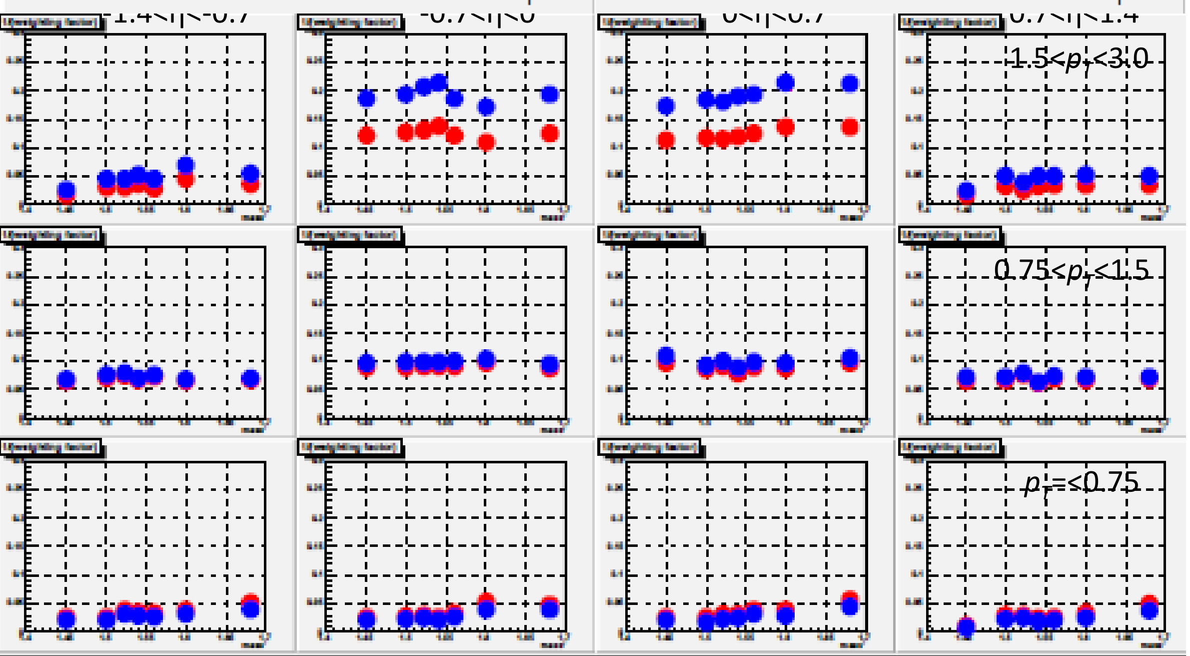
# Systematic Estimation: $p_T$ spectrum

Before Re-weighting




After Re-weighting



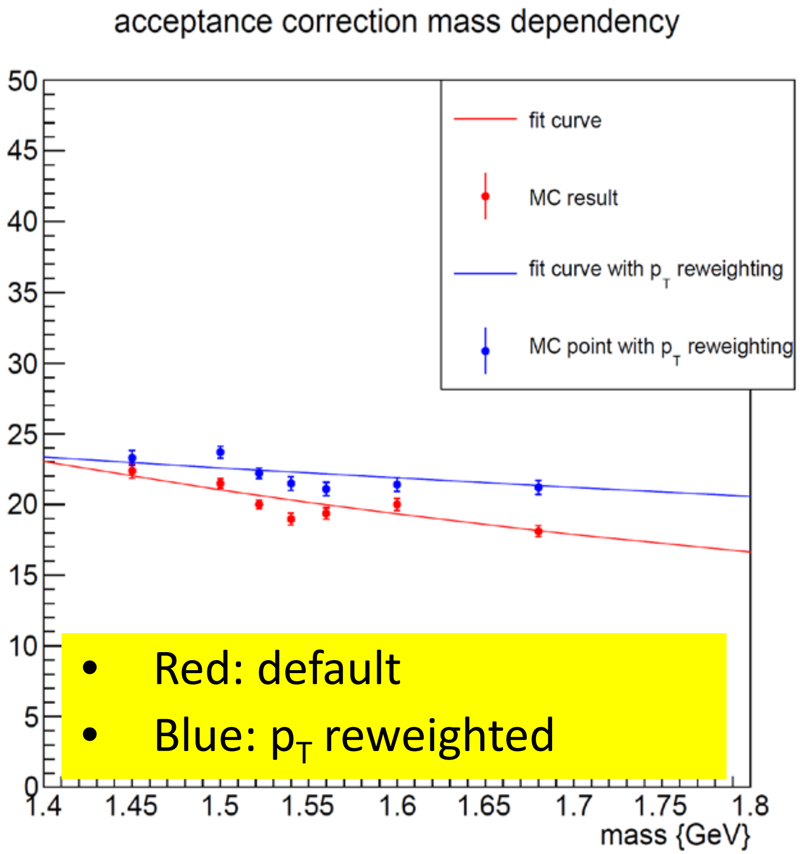




- The detector acceptance depends on the $p_T$-distribution of the penta-quarks (PQ). Two different $p_T$ models were tested.
  - 1. (default) as generated by RAPGAP 3.10 by replacing the Σ(1189) to PQ(X). (upper figure) $d\sigma/dp_T$ slopes changes as a function of the PQ mass. (The lighter, the steeper).
  - 2. A constant $p_T$-slope independent to the PQ mass. (uniformed by reweighting the RAPGAP MCs. $\Sigma^+(1189)$'s slope was used as standard.)

Below:

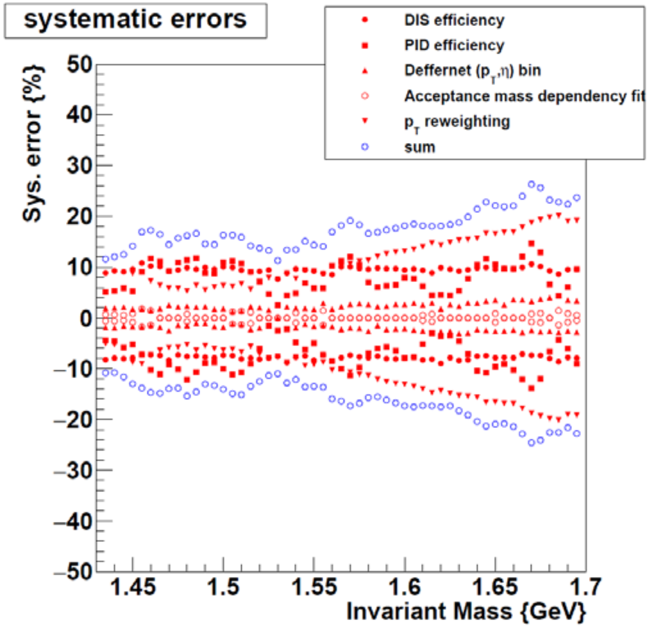
- Acceptance correction factors for the two distributions for each $p_T$/η bins.
  - Red: before reweighting
  - Blue: after reweighting
- Larger difference at higher $-p_T$ (~50%). But the more yield is expected at lower $p_T$.

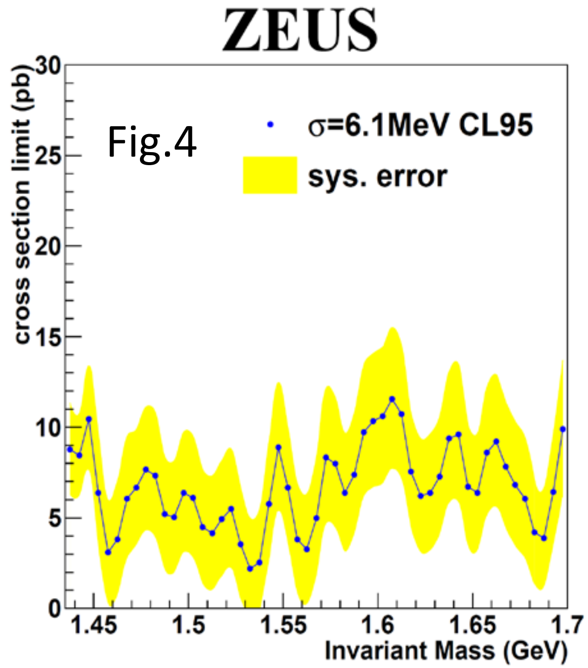
# Systematic Estimation: $p_T$ spectrum

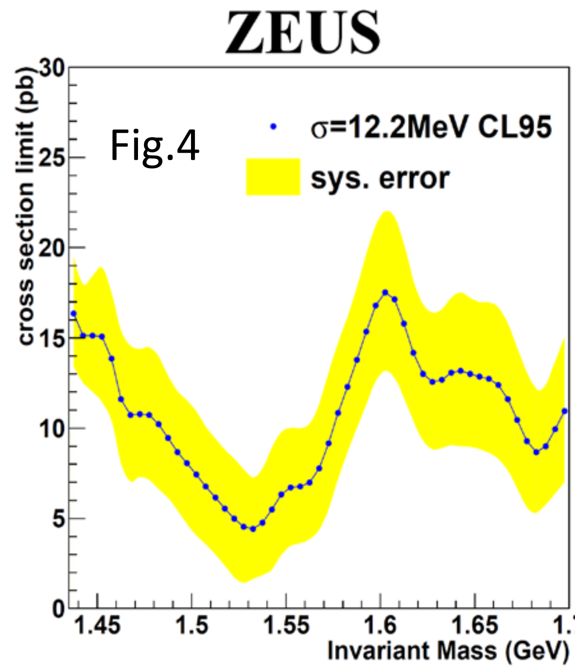



- For each ($p_T$, η) bin, a correction factor is calculated as a function of the Θ mass. $\varepsilon_{\text{decay angle}}^{\text{pol1}}(p_T^{pK}, \eta^{pK}) = A*M_\Theta + B$
- $p_T$ reweighting performed to estimate systematic error coming from PQ momentum changing.

# Final result with systematic errors

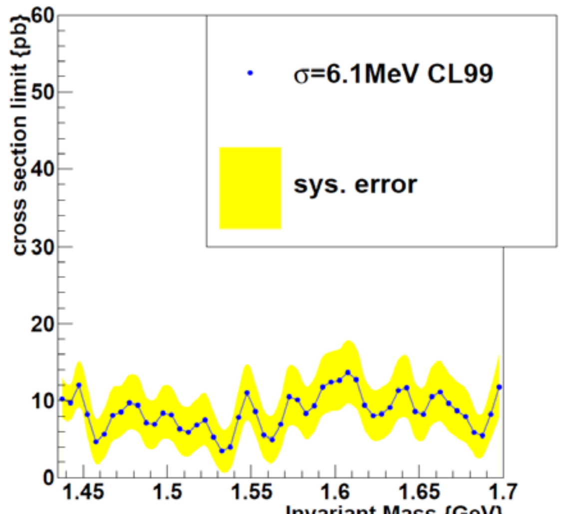


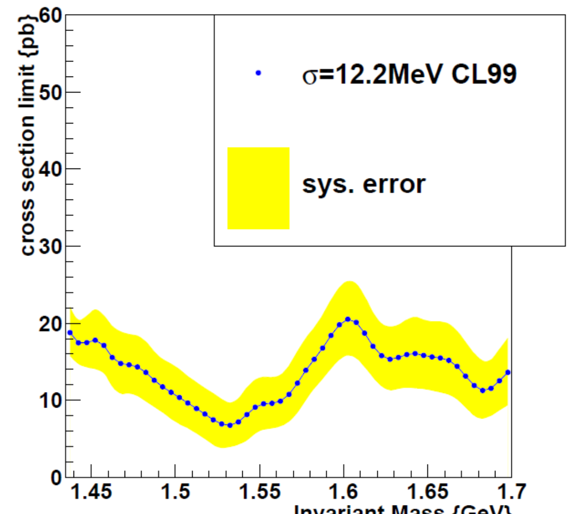



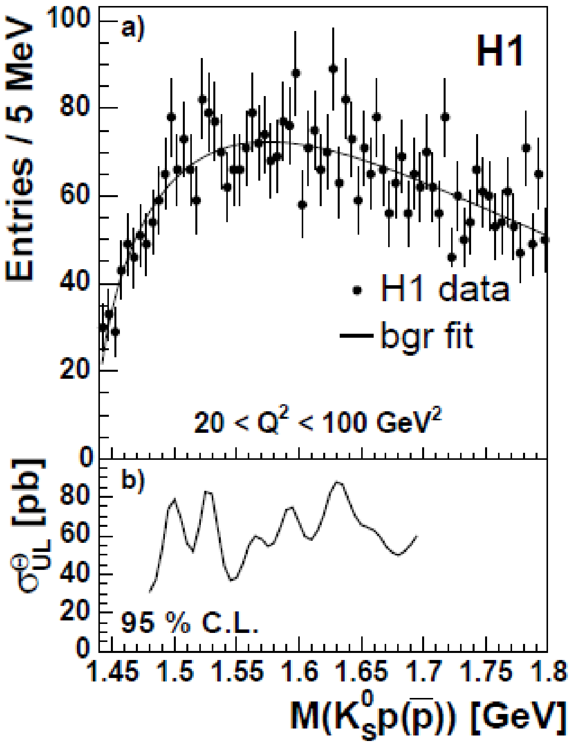

Systematic errors (more detail)

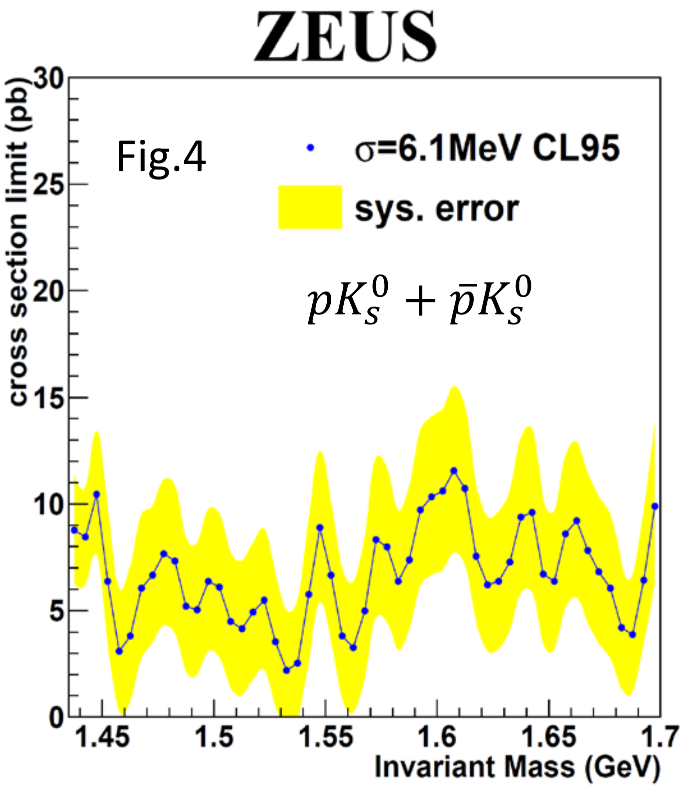
- DIS (in p.18)
- PID (in p.21)
- accept. different ($p_T$, η) bin (in p.30)
- accept. mass dependency (in p.31)
- $p_T$ re-weighting (in p.32)



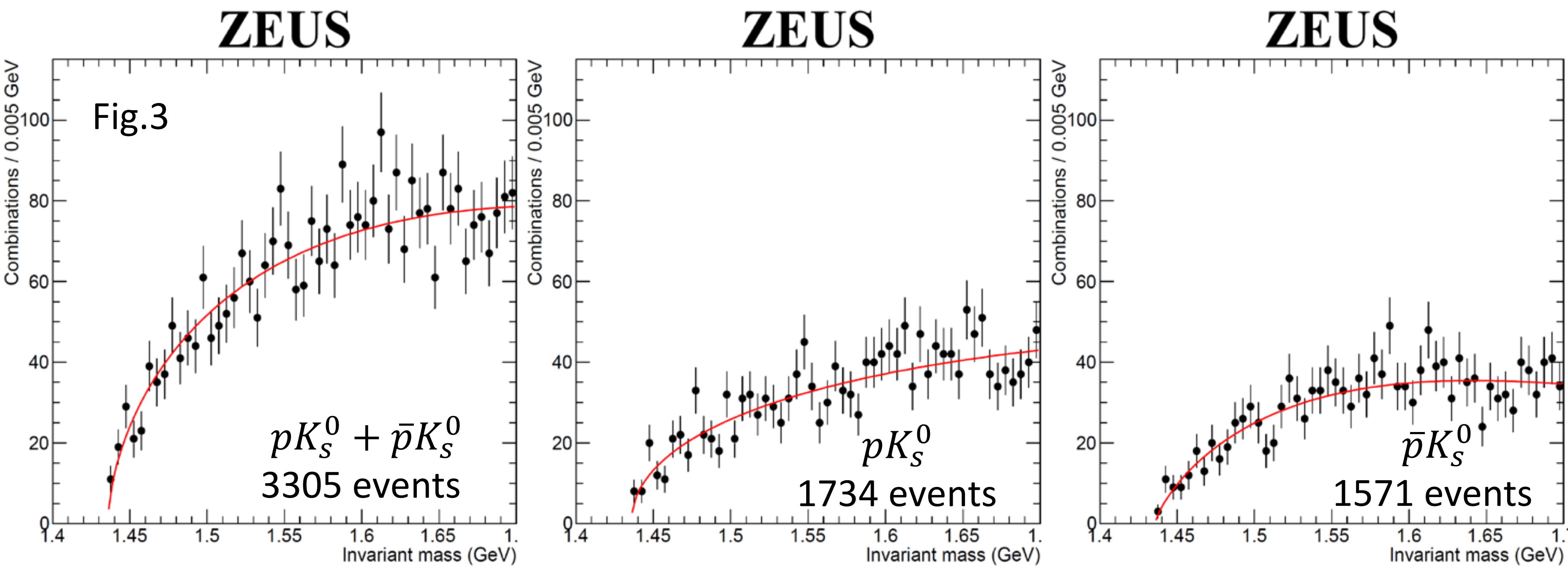
# Cross section upper limit: comparison with H1 result in HERA-I



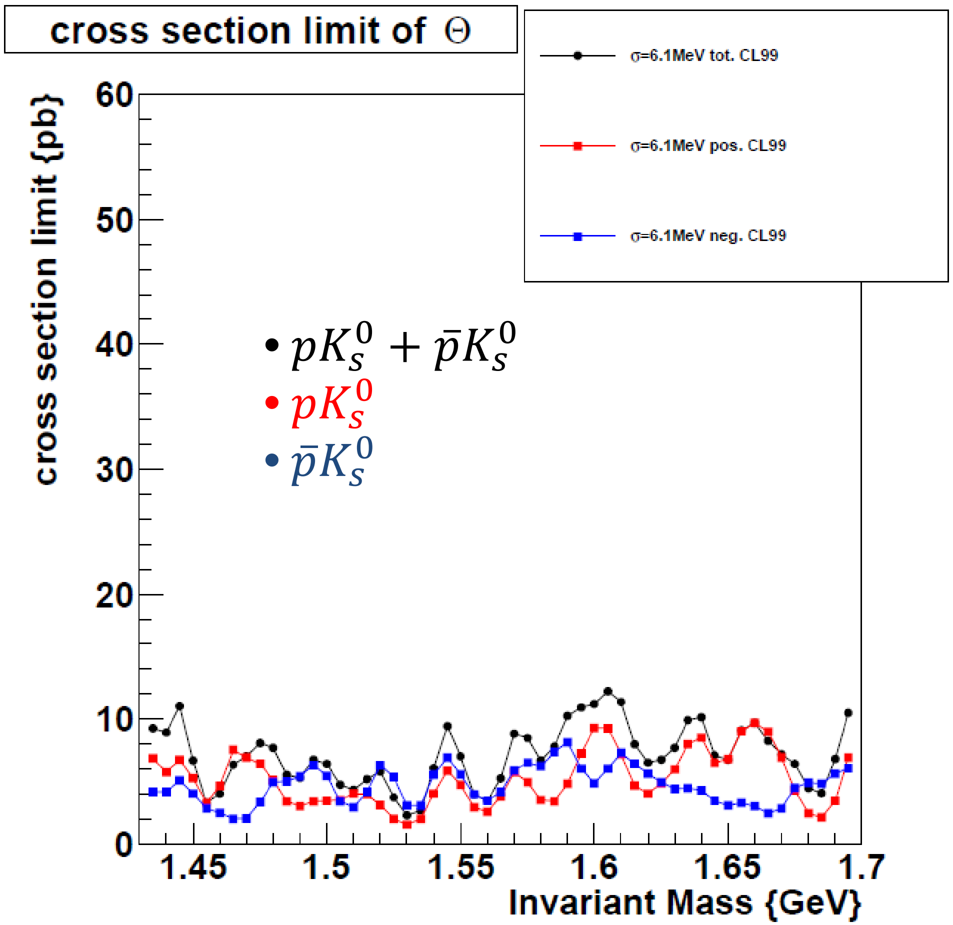

- HERA-I ZEUS result of production cross section is 125±27(stat.)$^{+36}_{-28}$ (sys.)pb$^{-1}$ Cf. the ICHEP conference paper in Beijing(2004),
  mass resolution σ=6.1 MeV
- H1 reported the C.S. limit (used σ = 4.8-11.3MeV)
- The obtained HERA-II ZEUS upper limit is significantly lower than HERA-I results.

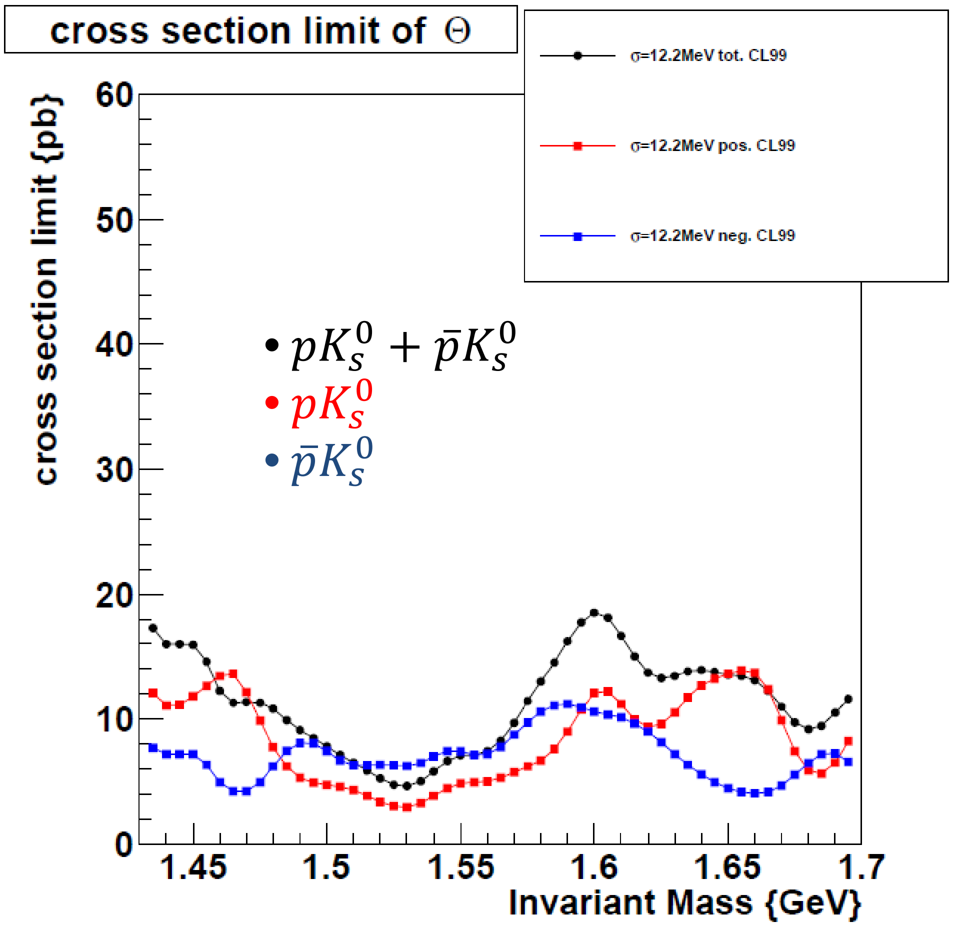
# Mass distribution with charge separation (reminder)



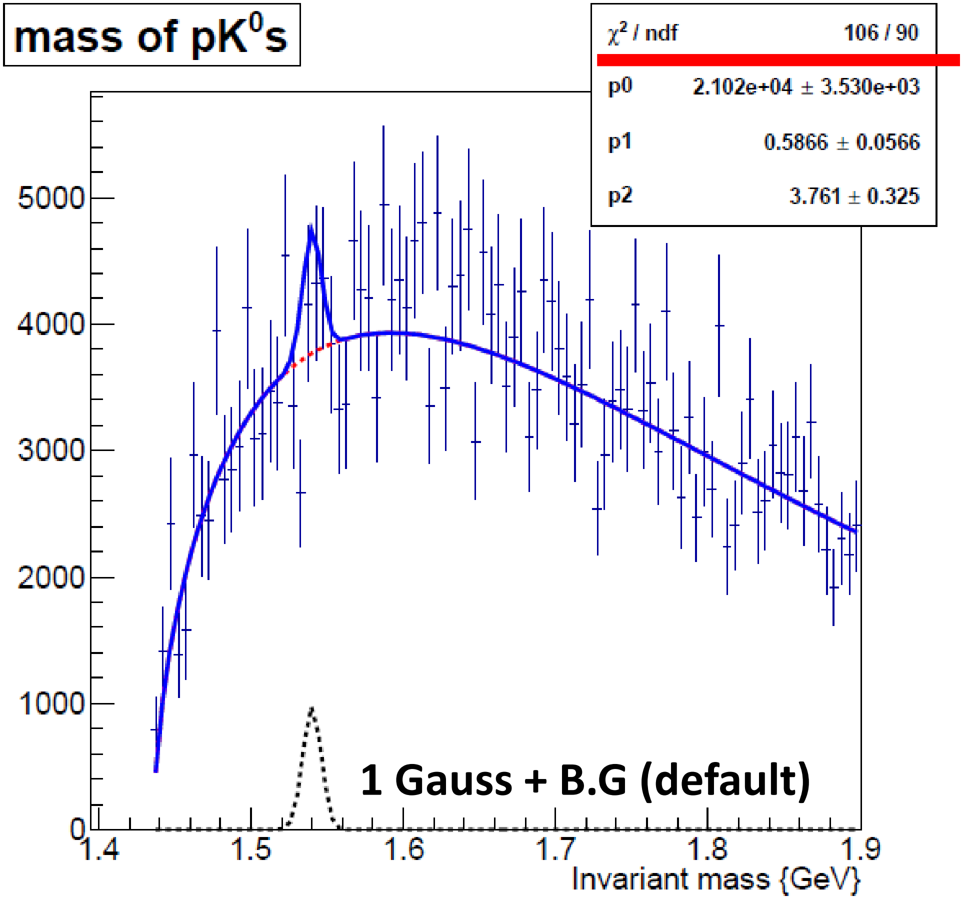

- Charge separation;
  - Fitted by the same function as shown in p.25.

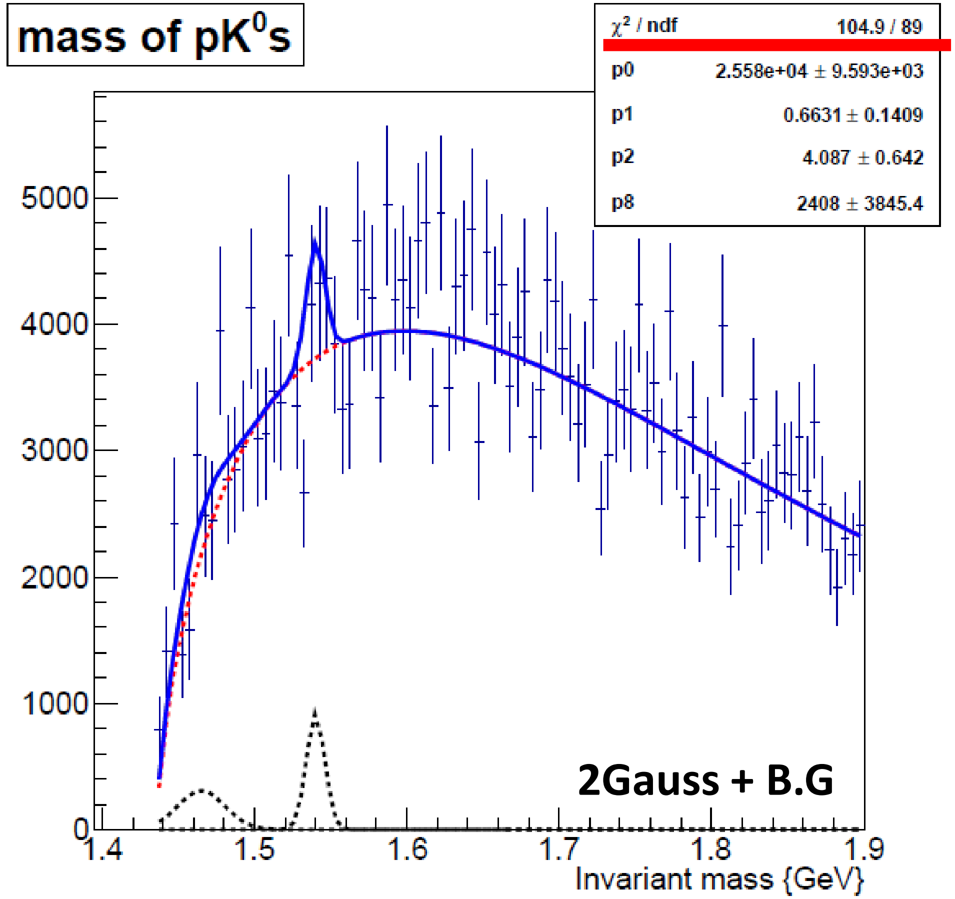
# C.S. limit with charge separation CL95



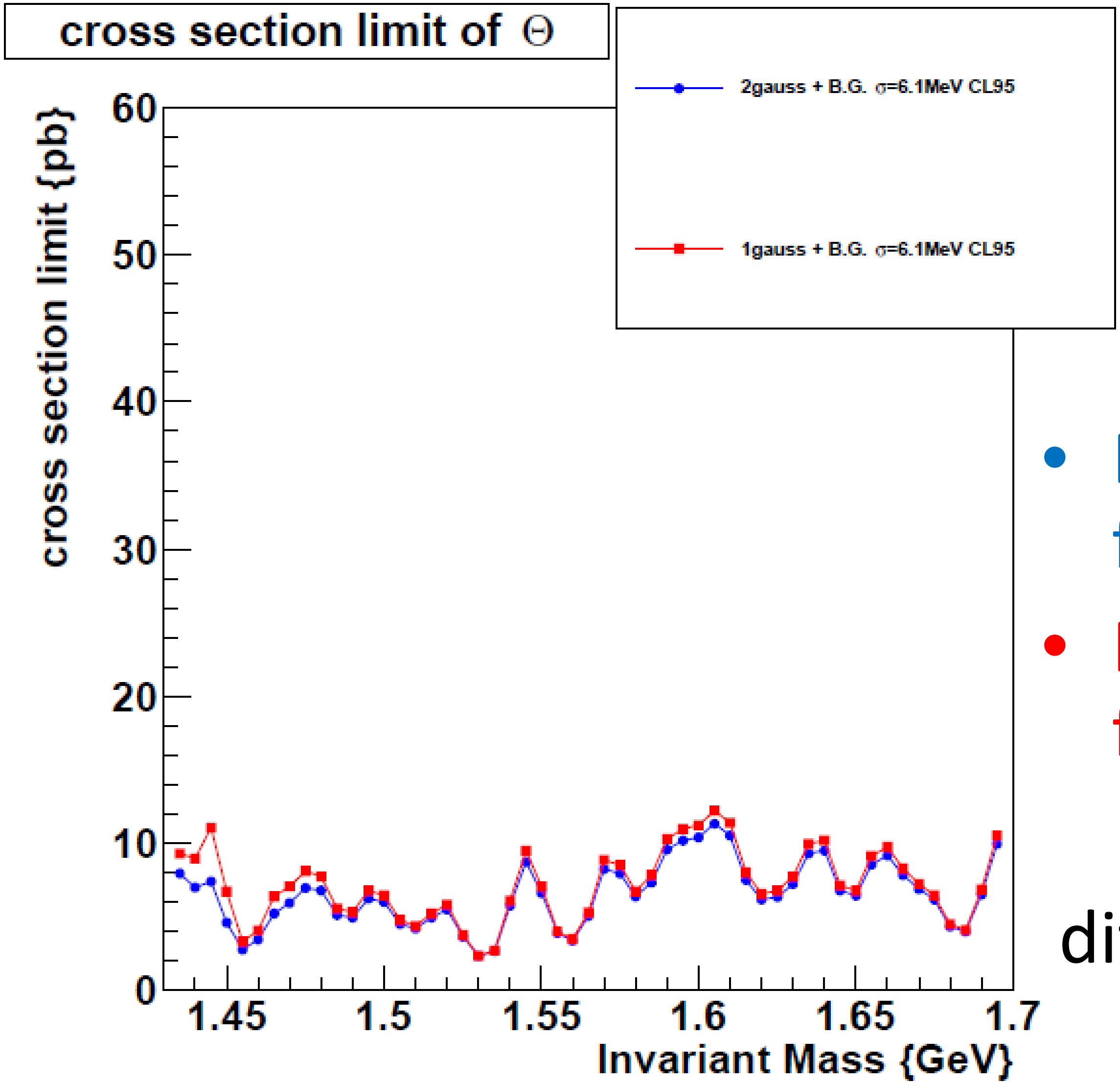
# Comparison of fitting function on mass distribution @1540 MeV (C.L. 99)




- Added 2ndary Gauss function ($\sigma$=15.5MeV $\mu$=1.465 GeV, these values come from HERA-I analysis.) to fitting function.
- The value of the added function becomes slightly better.

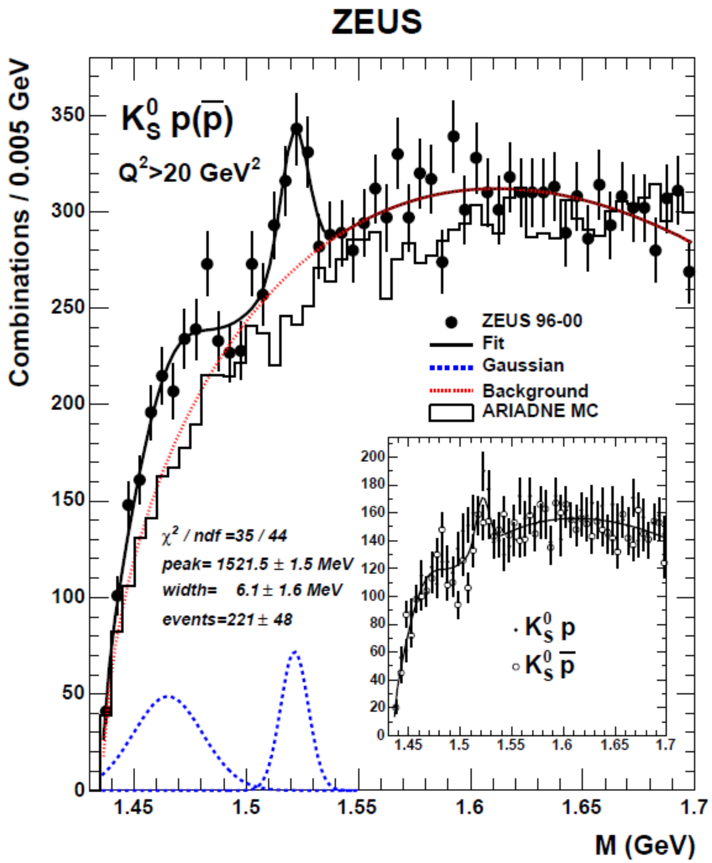
# Comparison of C.S. limit

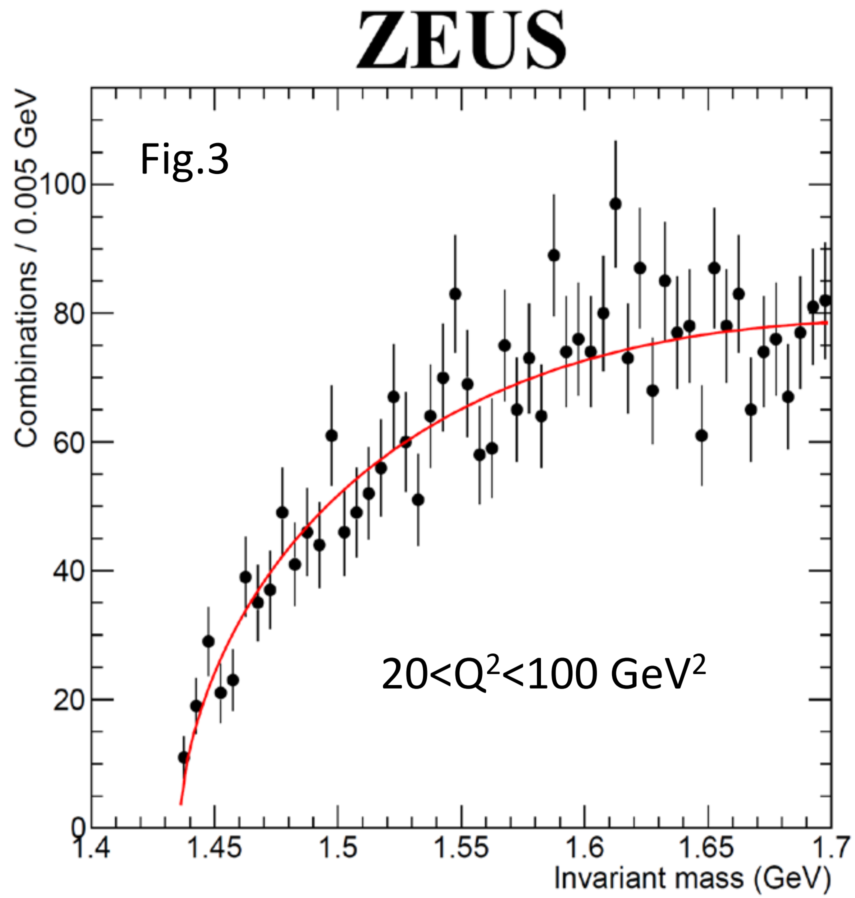



- Blue: 2 Gauss + B.G fitting
- Red: 1 Gauss + B.G fitting

difference is negligible

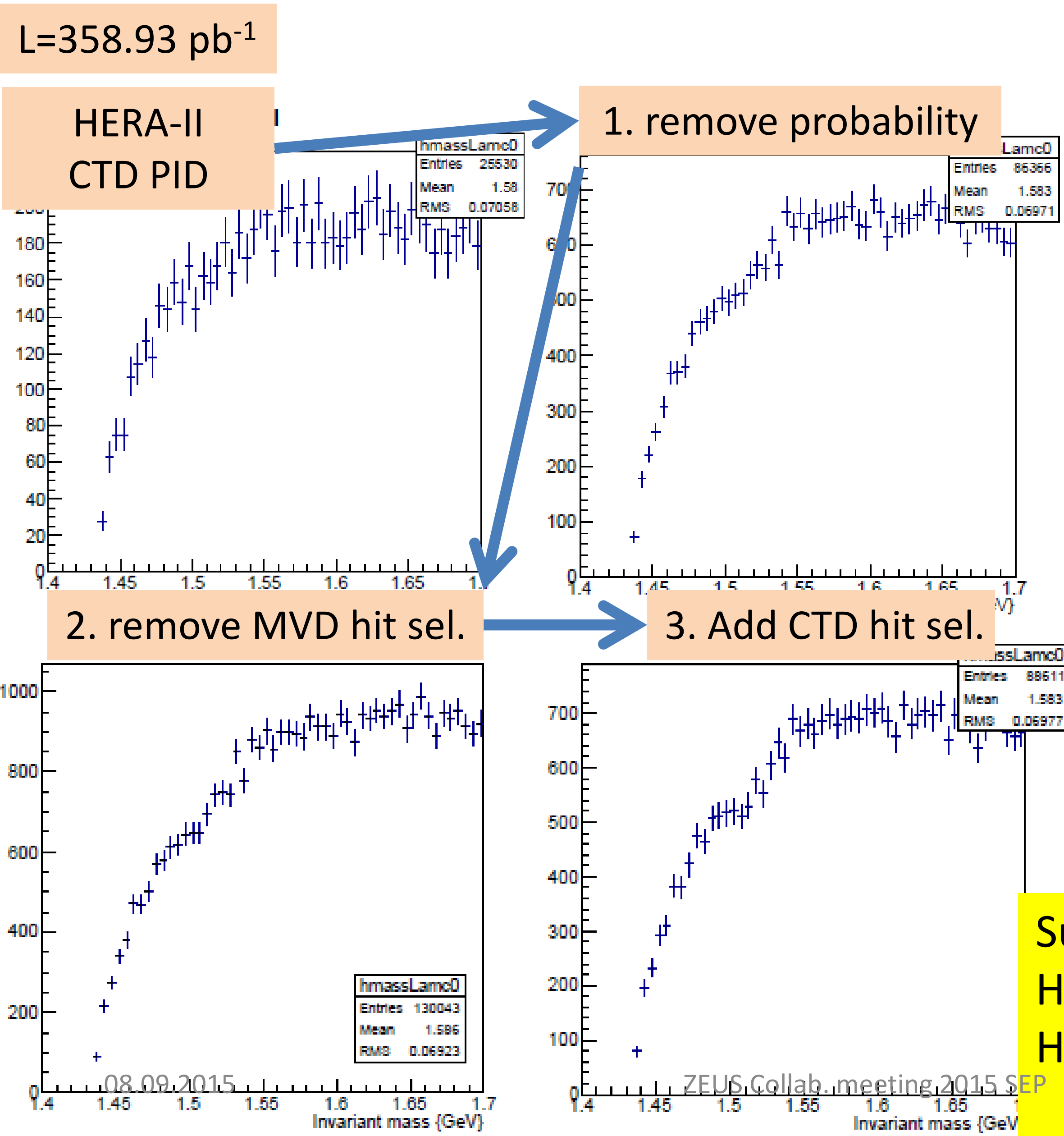
# comparison with ZEUS result in HERA-I




- Number of final sample is 1/3~1/4 in spite of the fact that HERA-II luminosity (358 pb$^{-1}$) is 3 times larger than HERA-I's (121 pb$^{-1}$).
- HERA-II event yield per luminosity is ~1/13 of HERA-I. The main reason seems that HERA-II proton PID is much tighter than HERA-I. (detail in next page)

# Modification of CTD PID selections to HERA-I logic




- Modify PID to HERA-I logic following 3 requirements.

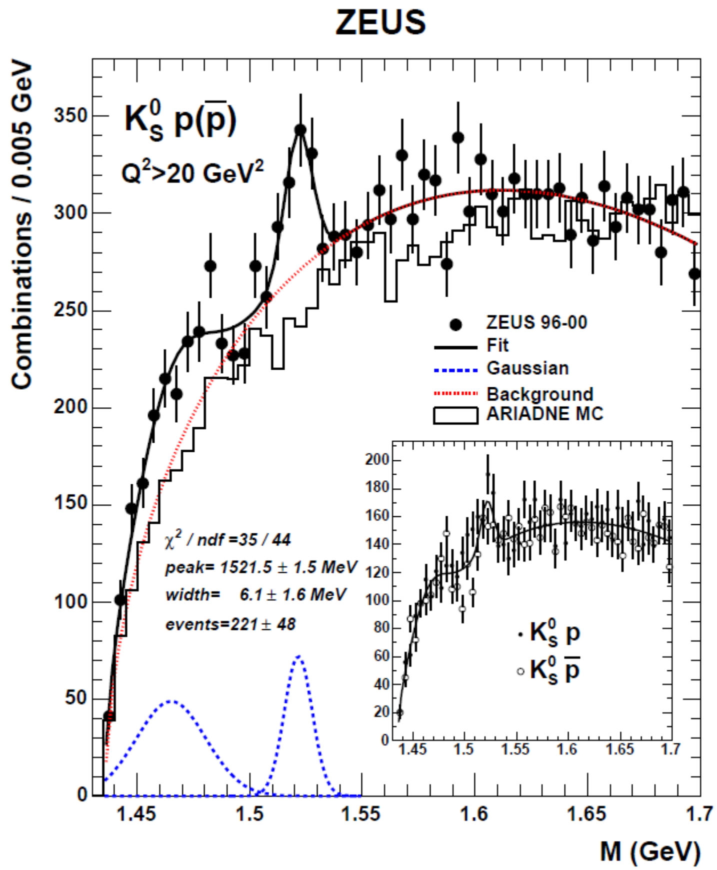
1 Remove dE/dx Probability prob(p) > 0.3 selection
   - > increase ~3 times (25530->86366evts)

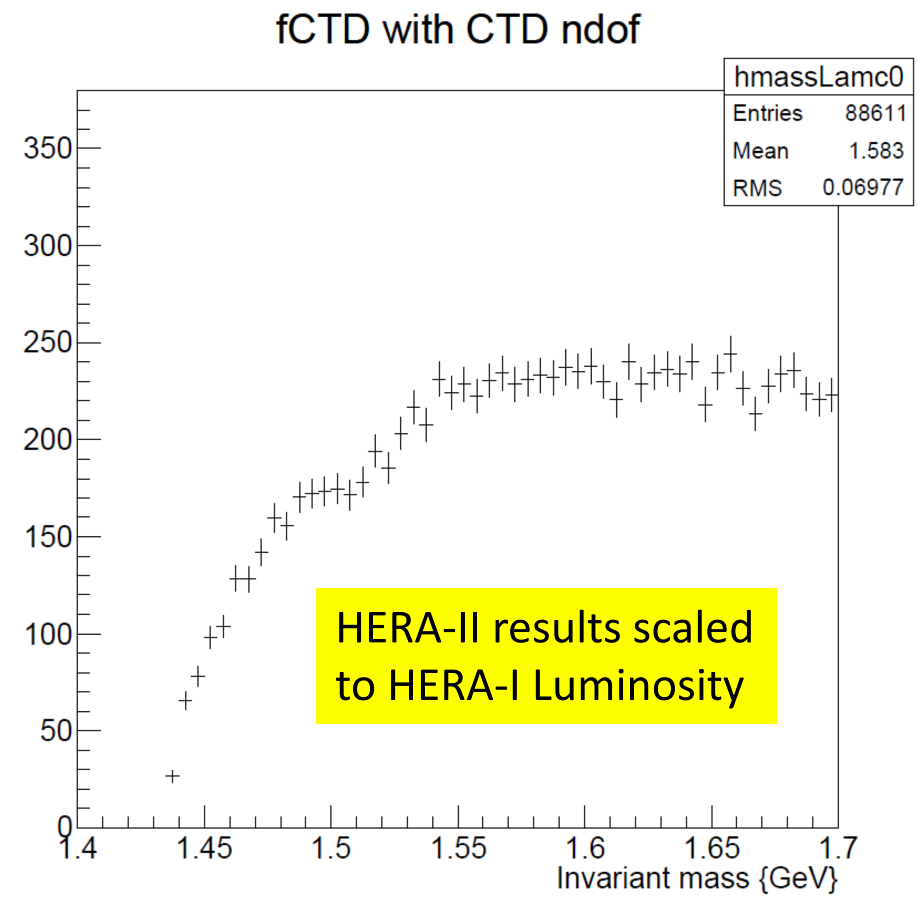
2 Remove MVD hit > 2 selection for pions from $K_s^0$
   - >increase ~1.5 times (86366->130043evts)

3 Add CTD hit > 40 requirement for proton.
   - > decrease ~0.7 times (130043->88611evts)

Summary:
HERA-II(MVD+CTD) : 10604 Events
HERA-I -like: 88611 Events
-> x 8.4 times increase

# Summary of event yield comparison




- If we use only CTD PID as same selections in HERA-I analysis as possible, the number of event increases back to ~75% of HERA-I yield.

# Discussion
# (quick results)

# Event number estimation from PQ results at ICHEP2004

## 6 Results

The cross section for the $\Theta^+$ baryons and their antiparticles measured in the kinematic region given by $Q^2 \geq 20\,\mathrm{GeV}^2$, $0.04 < y < 0.95$, $p_T > 0.5\,\mathrm{GeV}$ and $|\eta| < 1.5$ was:

$$\sigma(e^\pm p \to e^\pm\,\Theta^+\,X \to e^\pm\,K^0 p\,X) = 125 \pm 27(\mathrm{stat.})^{+36}_{-28}(\mathrm{syst.})\ \mathrm{pb}.$$

Figure 2 shows the cross section integrated above $Q^2_{\mathrm{min}}$. Figure 3 shows the ratio of this cross section to that of the $\Lambda$ cross section integrated above $Q^2_{\mathrm{min}}$, where the ratio, defined in the same kinematic region as above, is

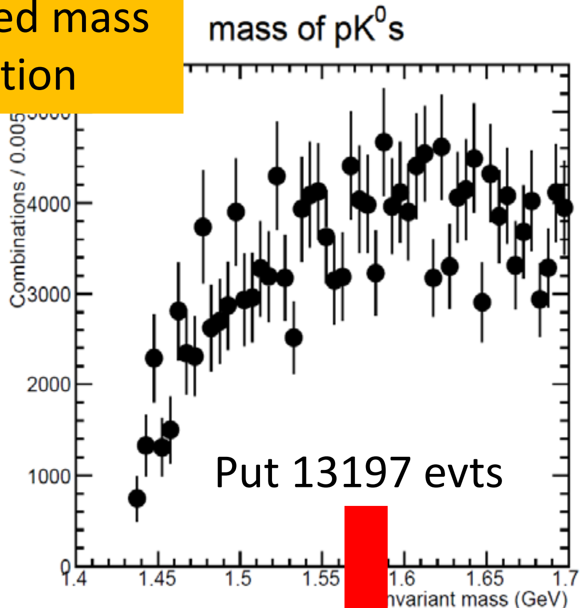
$$\mathrm{ratio} = \frac{\sigma(e^\pm p \to e^\pm\,\Theta^+\,X \to e^\pm\,K^0 p\,X)}{\sigma(e^\pm p \to e^\pm \Lambda X)}.$$

This ratio, for $Q^2_{\mathrm{min}} = 20\ \mathrm{GeV}^2$, is $4.2 \pm 0.9(\mathrm{stat.})^{+1.2}_{-0.9}(\mathrm{syst.})\%$ and, in the current data, shows no significant dependence on $Q^2_{\mathrm{min}}$. Since the $\Theta^+$ has other decay channels in addition to $\Theta^+ \to K^0 p$, this ratio sets a lower limit on the production rate of the $\Theta^+$ to that of the $\Lambda$-baryon.

- Integrate luminosity;
  - (121 $pb^{-1}$; HERA-I)
  - 358.93 $pb^{-1}$; HERA-II
- Same kinematical Range (y , $p_T$ and η)
- Θ cross section (125 $pb$ )
- Changing factors to event number.
  - Branting mode includes $K_S$ and $K_L$ mode; 0.5
  - $K_S$→π$^0$π$^0$branch correction; 0.69
  - $Q^2$-range change from $Q^2$>20 to 20-100 $GeV^2$ (estimated by MC); 0.85
  - Etc. ?
- Estimation of number of events
  - (HERA-II luminosity)*(cross section) = 44866.9 evts.
  - (HERA-II luminosity)*(cross section)*(factors) = 13197.5 evts
- An artificial peak puts on invariant mass distributions in next page.

# Hera-I Artificial peak on HERA-II

**Weighted mass distribution**



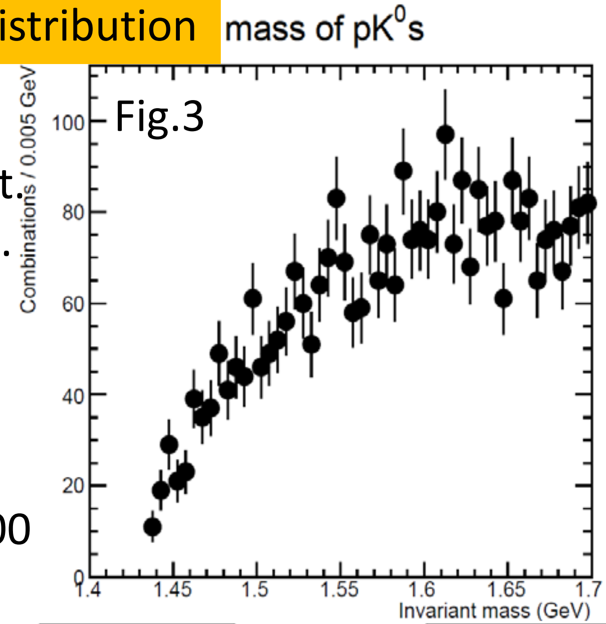

Put 13197 evts

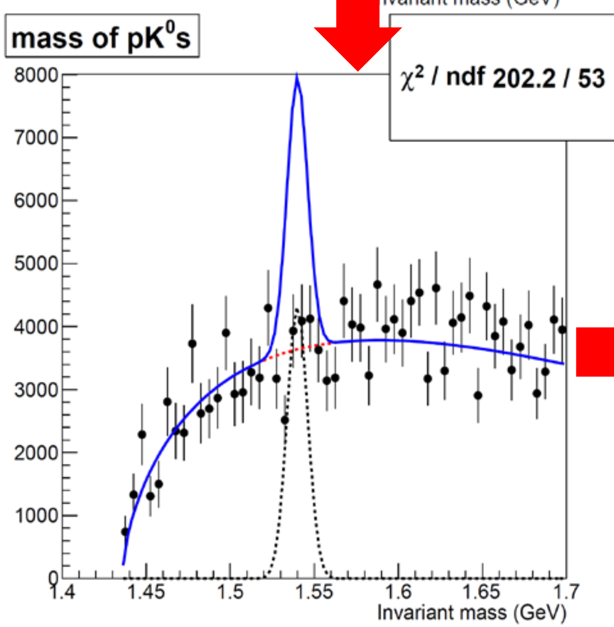
Efficiency weighted dist.
@1.54 GeV ~ 3000evts.

Raw distribution
@1.54 GeV ~ 60 evts.

Weight factor ~ 60/3000

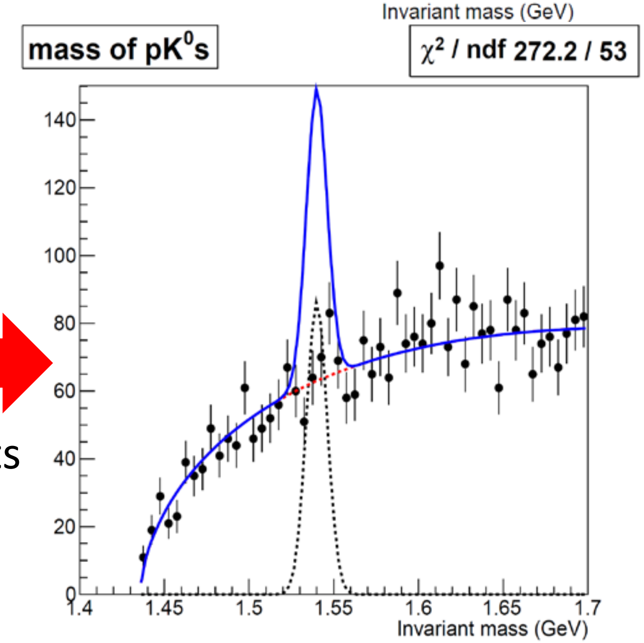
**Raw distribution**




Convert by factor

13197 evts -> 264 evts



# Summary

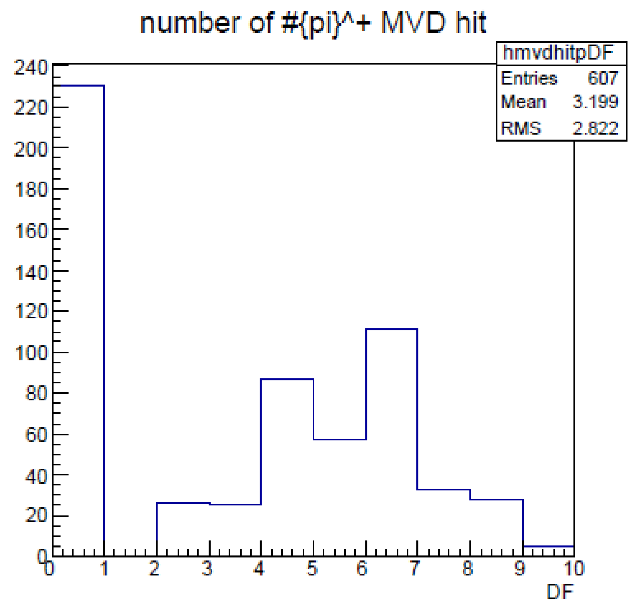
- Search strange PQ on $pK_s^0$ systems in HERA-II data.
  - DIS event; 20 < $Q^2$ < 100 GeV2,
  - System's kinematics; 0.5 < $p_T$ < 3.0 GeV and |η| < 1.5
  - No clear peak are seen on $K_s^0$ invariant mass distributions around 1540 MeV.
  - The number of event in HERA-II is smaller than HERA-I.

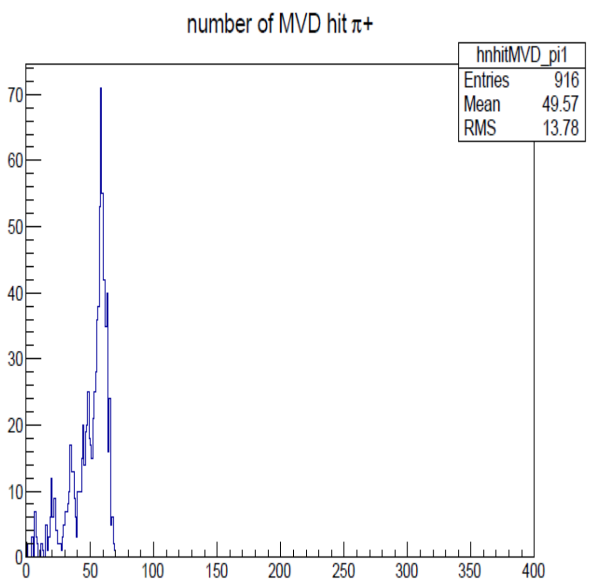
    -> More pure PID and MVD hit requirement.
- Calculate production cross section limit with systematic errors.
  - Compare with HERA-I results.

# Back up slide

# 1) trk_ndof2 miss match

- MVD dEdx hit distributions are different
  - Analysis uses trk_ndof2 orange variable as number of MVD hit.
  - When I created my private ntuple, trk_ndof2 contains the number of MVD hit.
  - But, in the CN, trk_ndof2 seems to have the number of CTD hit
  - > Modified  to use the sum of trk_br, trk_bz, trk_wv and trk_wu



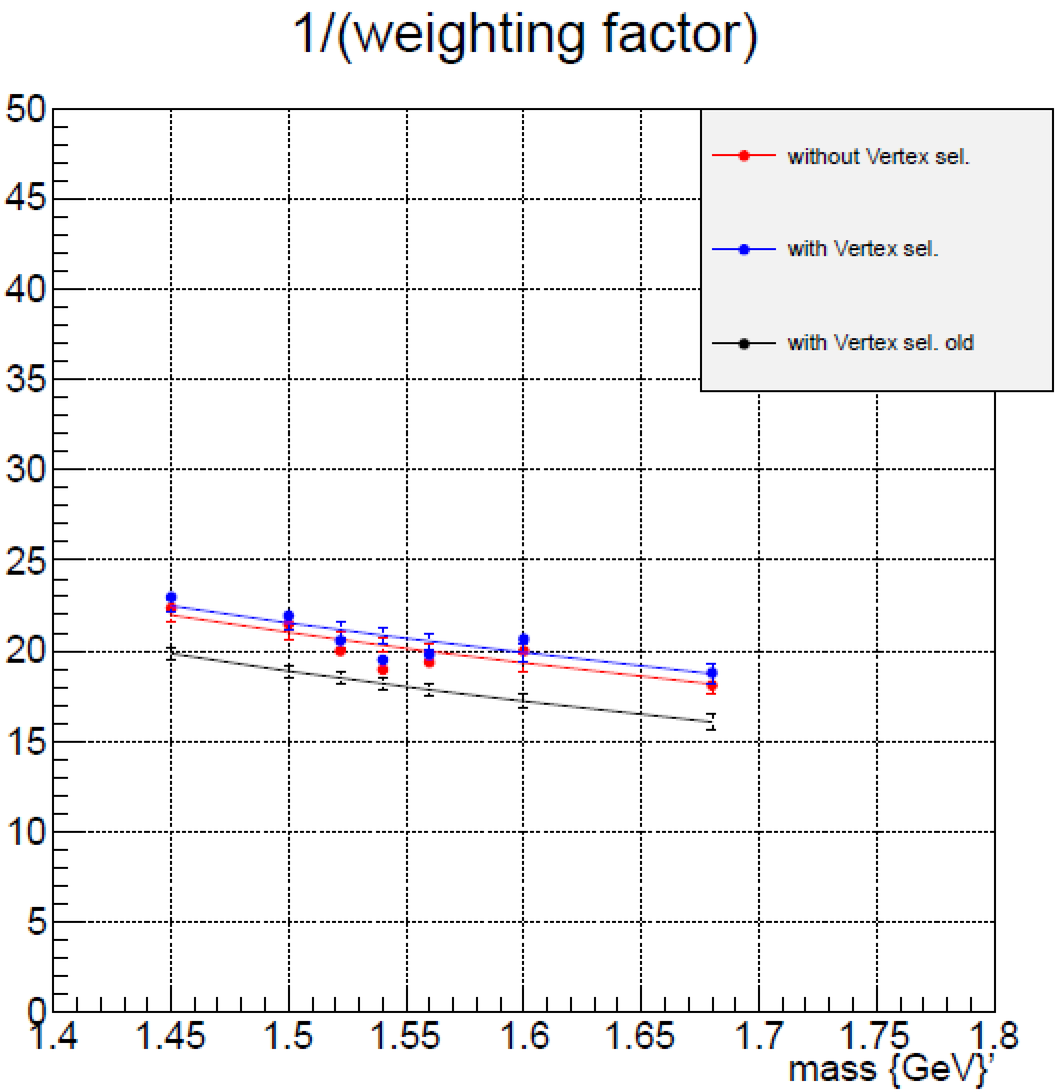



# 2) Primary vertex condition

- In my analysis, $K^0$s are reconstructed with the tracks not associated to the primary vertex, as it is the case for the HERA-1 analysis.
- 62 events (out of 94 mismatched events) are not selected in the common-ntuple sample because one of the pion track of $K^0$s belongs to the primary vertex, tested with the orange variable (trk_prim_vtx).
- Still checking the reason of the difference.

-> probably we modify to remove the non-primary-vertex requirement.

# Check efficiency comparison



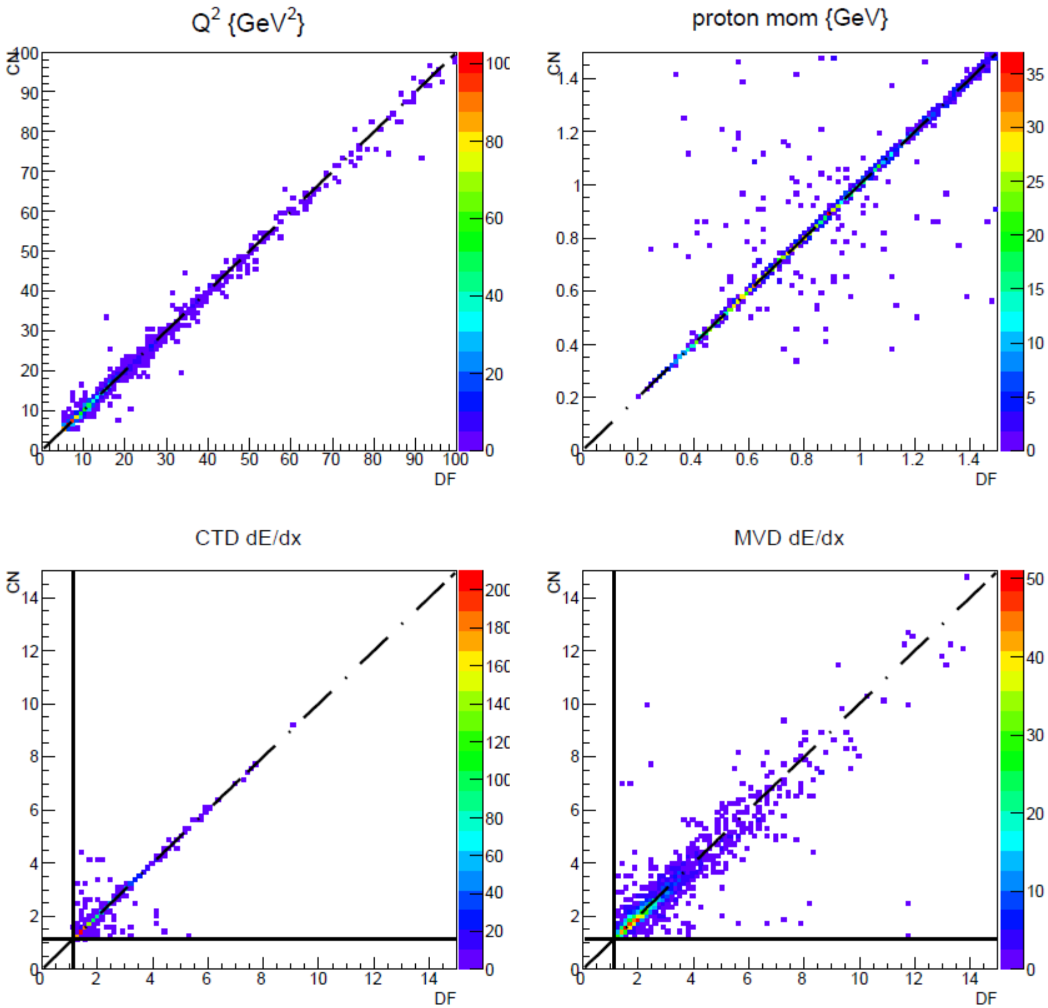

- Re-calculate efficiency.
- Comparison w/o 2ndary Vtx requirement to K0s.
  - Blue: with vtx. Req.
  - RED : without vtx. Req.
  - Black: older calc. with vtx. Req.
- The difference between newer eff.s is not large than before.

# MVD dE/dx calculation difference

- Difference of MVD dE/dx calculation method between my private ntuple and CN
  - My ntuple
    - Calculate dE/dx by using Probability Density Function (my routine)
      - Gaussian convoluted Landau function used as PDF
    - Correct 2ndary angle effect
      - $dE/dx_{hit}=A(1-B\sin^4\alpha)*ADC_{raw}$
    - run-by-run dE/dx correction for each ladder
    - Gain correction
  - CN
    - Calculate dE/dx by truncated mean (orange default)
    - global run-by-run dE/dx correction (i.e. not ladder-by-ladder) : (my routine)
    - Gain correction

=> dE/dx resolution of the two method is shown in the next slide

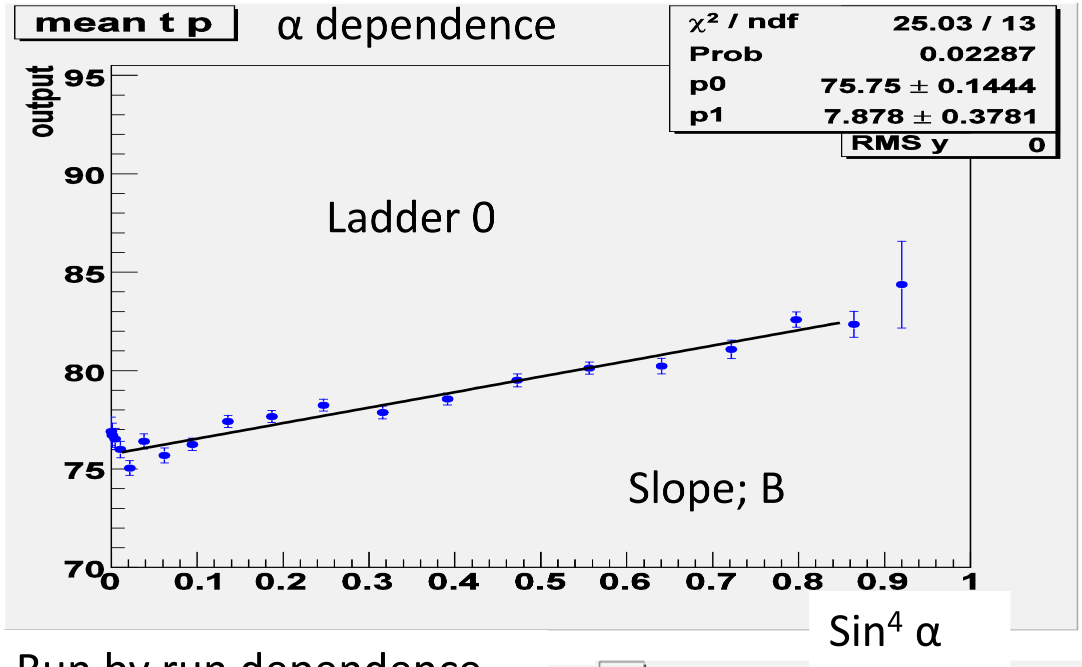
# variables comparison between the 2 ntuples



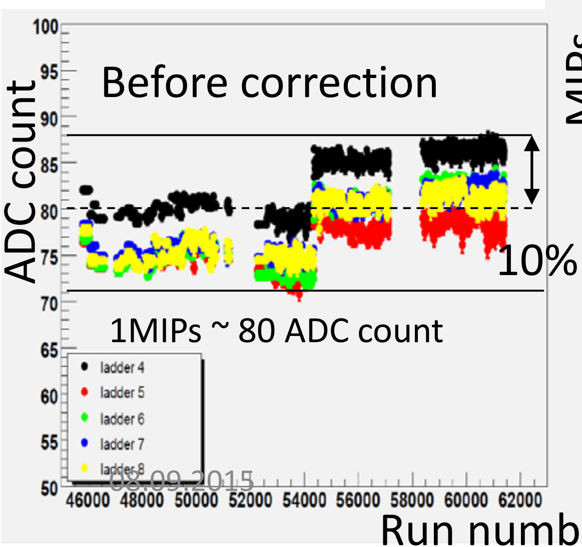

- Compared variables ($Q^2$, pr(p), CTD dE/dx and MVD dE/dx) between DF(m private) ntuple vs. CN.
- p(p) and CTD dE/dx has small differences.
- $Q^2$ distribution is broader a little. (Siq2da)
- MVD dE/dx is the broadest variable than others.
  - This is because I cannot make sophisticated corrections for common ntuples as there are missing MVD hit information.

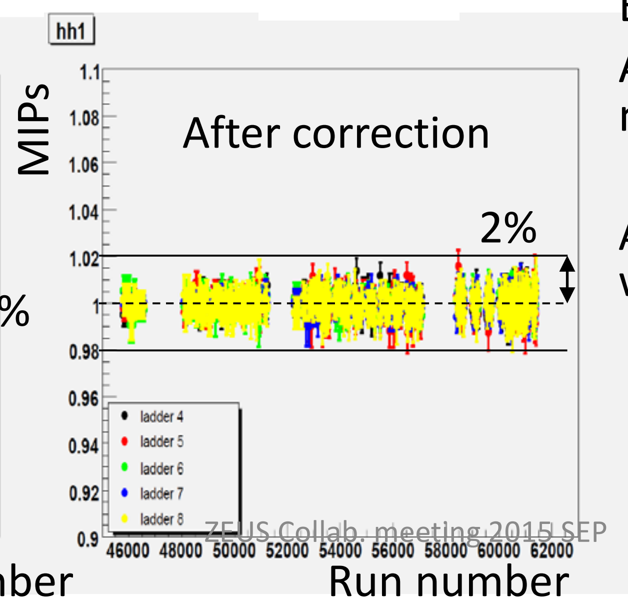
# MVD dE/dx correction

# MVD dE/dx; ladder and run-by-run correction (reminder)




Run by run dependence




At first, I checked remaining MVD angle dependence and run-by-run variation.

α is incident angle to the MVD module.

From the left histogram, I adopted the following function.

$$dE/dx_{hit}=A(1-B\sin^4\alpha)*ADC_{raw}$$

where,

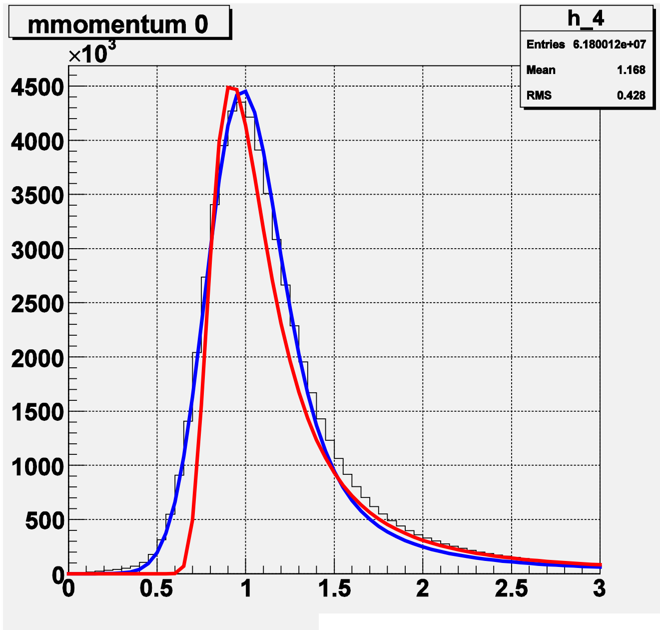
B is a function of ladder.

A is a function of ladder and run number.

After the correction run variation is within ±2%.

# MVD dE/dx; Likelihood (reminder)

Fig.1




MVD hit signal

Fig. 1 dE/dx for each MVD hit point.

($\pi$ 0.5~0.6GeV)

Red: Landau function Fit

Blue: Landau function Fit convoluted with gaussian (gLandau)

([http://root.cern.ch/root/html/examples/langaus.C.html](http://root.cern.ch/root/html/examples/langaus.C.html))

Better description with gLandau. For example the left shape.

σ of gaussian => 0.168 MIP fixed.

Fig.2

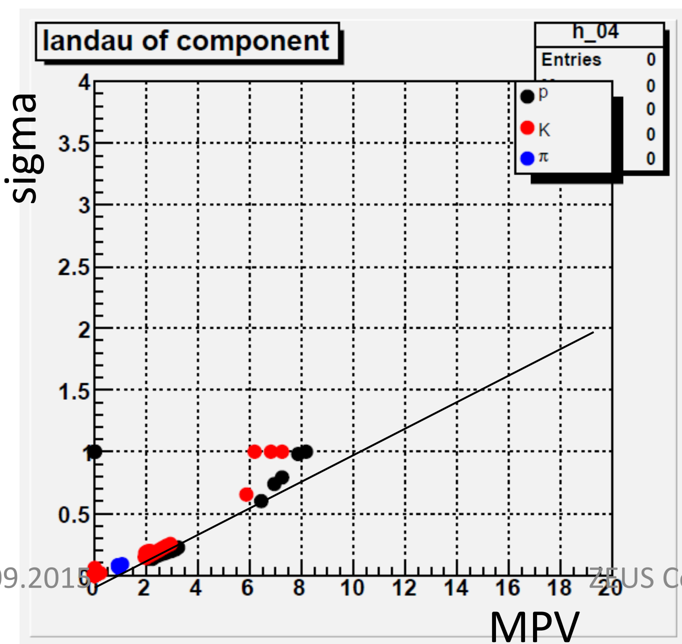


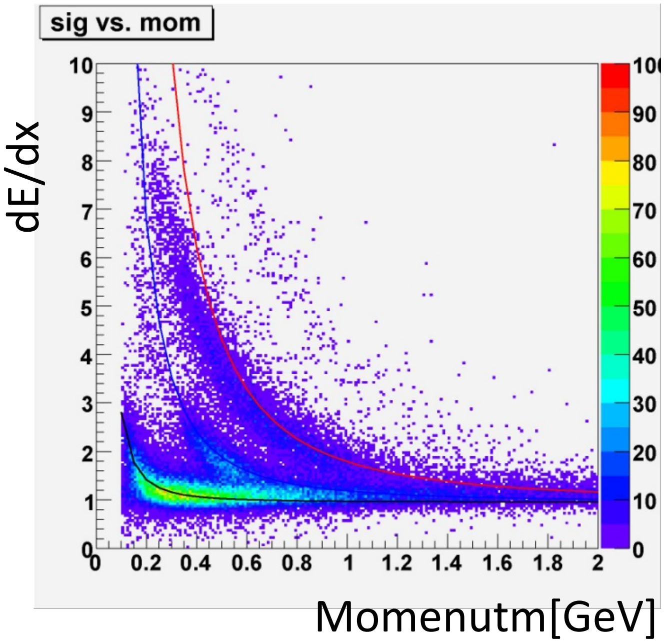

Fig. 2 determination of PDF function。

Hit distribution is fitted with gLandau with Landau MPV point and sigma variable.

Almost linear relation between MPV and sigma.

PDF(x;μ) = gaus(σ=0.17)⊗ Landau(x,MPV=μ,sigma=0.086*μ)

# MVD dE/dx; gain correction (reminder)



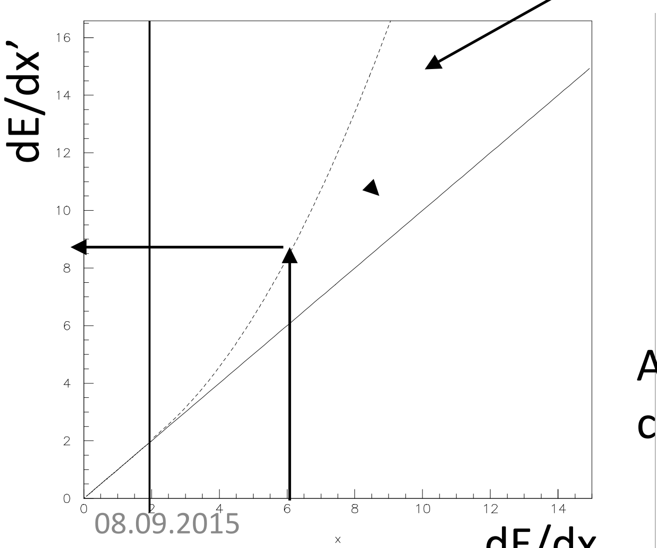

Bethe-Bloch fit can not fit well.
->try to introduce non-linear gain-correction.

Empirical formula:

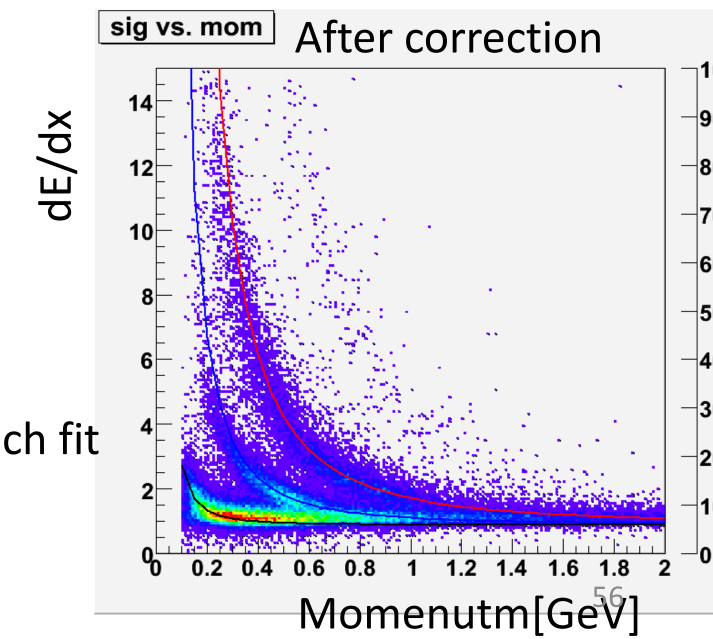
$$dE/dx' = dE/dx + 0.1517(dE/dx-2)^2 \qquad (dE/dx \geqq 2)$$

$$dE/dx' = dE/dx \qquad (dE/dx < 2)$$

dE/dx – dE/dx' (corrected dE/dx)

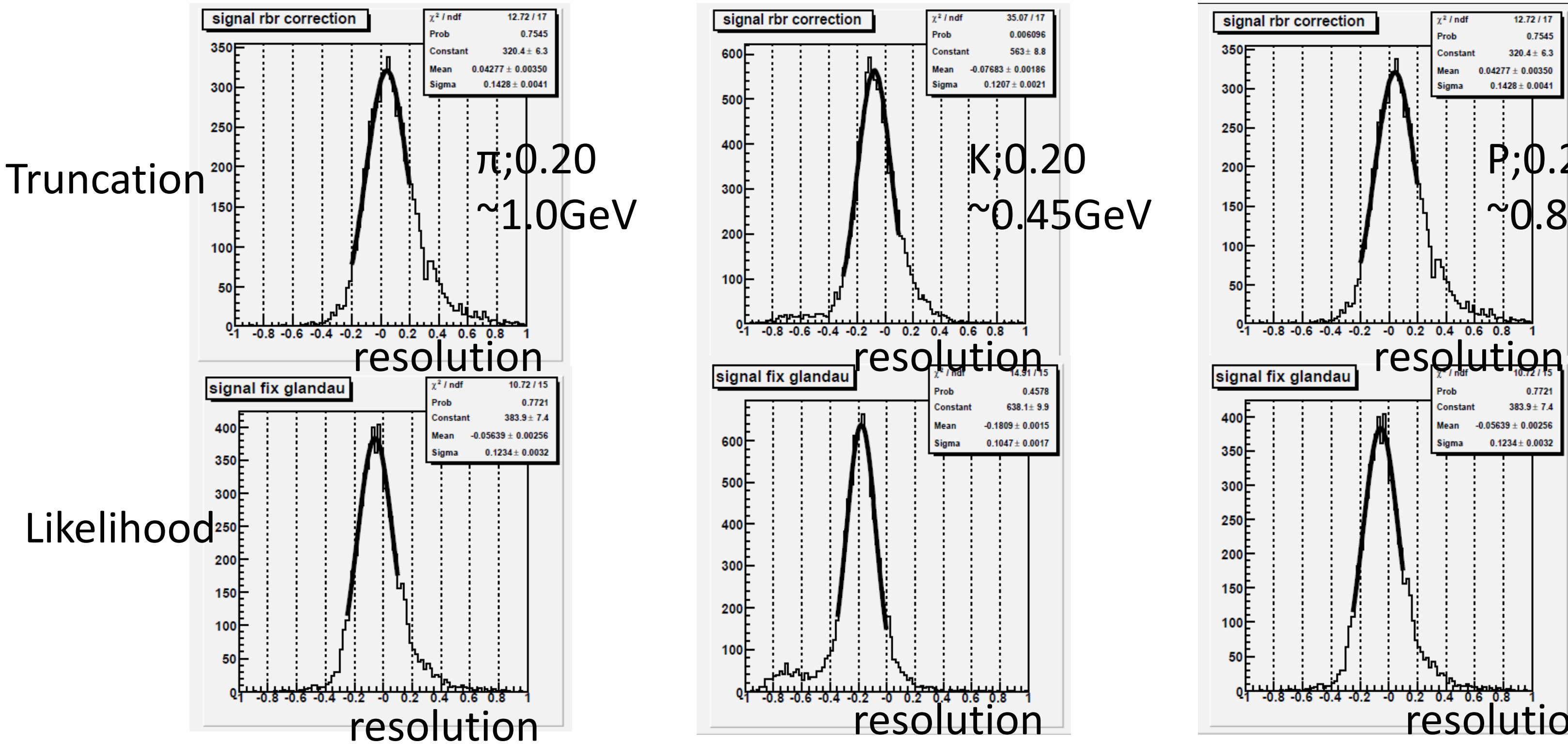



After correction, Bethe-Bloch fit can better describe data.



# Comparison with the standard truncation method (Old study)

* Angle and run-by-run corrections are applied to the both methods..




| | π | K | p |
|---|---|---|---|
| Truncation | 14.3% | 12.1% | 13.4% |
| Likelihood | 12.3% | 10.5% | 11.7% |

- In the analysis with Common ntuple, only global run-by-run correction (i.e. not ladder-by-ladder) is made, so the resolution is worse than this plot.

# dE/dx resolution

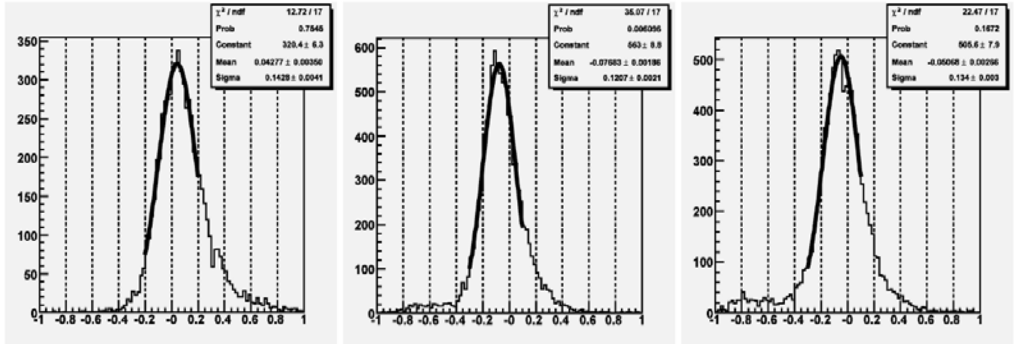


Figure 4.14: typical MVD $dE/dx$ resolutions of the truncation method. Left: $\pi$, Center: $K$, Right: $p$

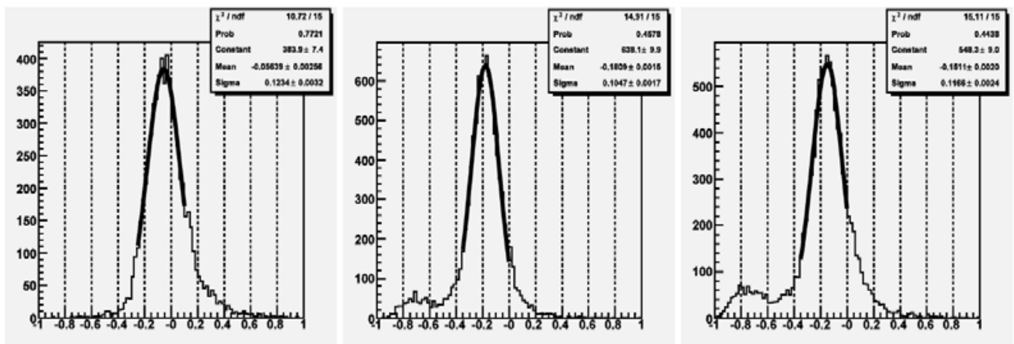
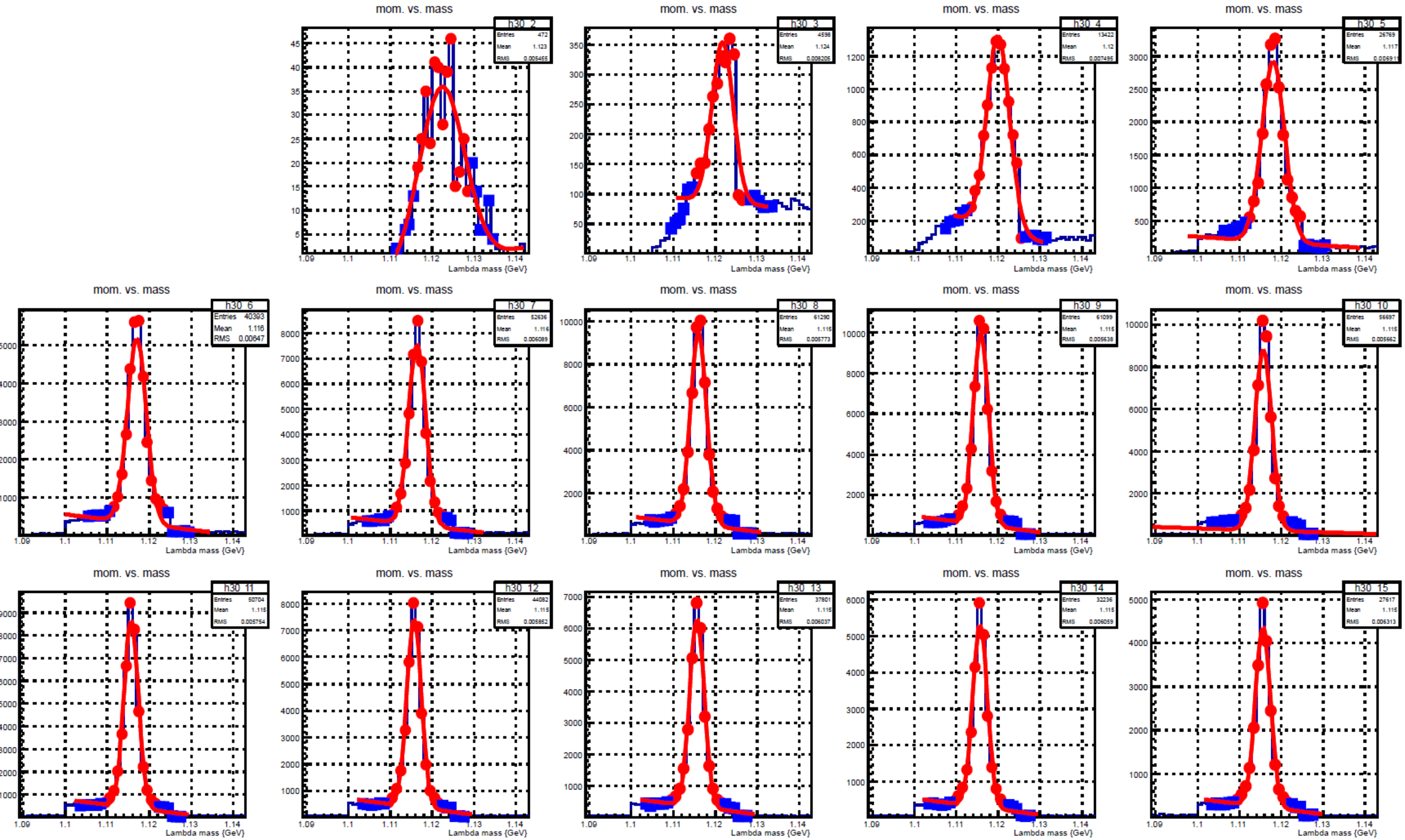


Figure 4.15: typical MVD $dE/dx$ resolutions of the likelihood method. Left: $\pi$, Center: $K$, Right: $p$

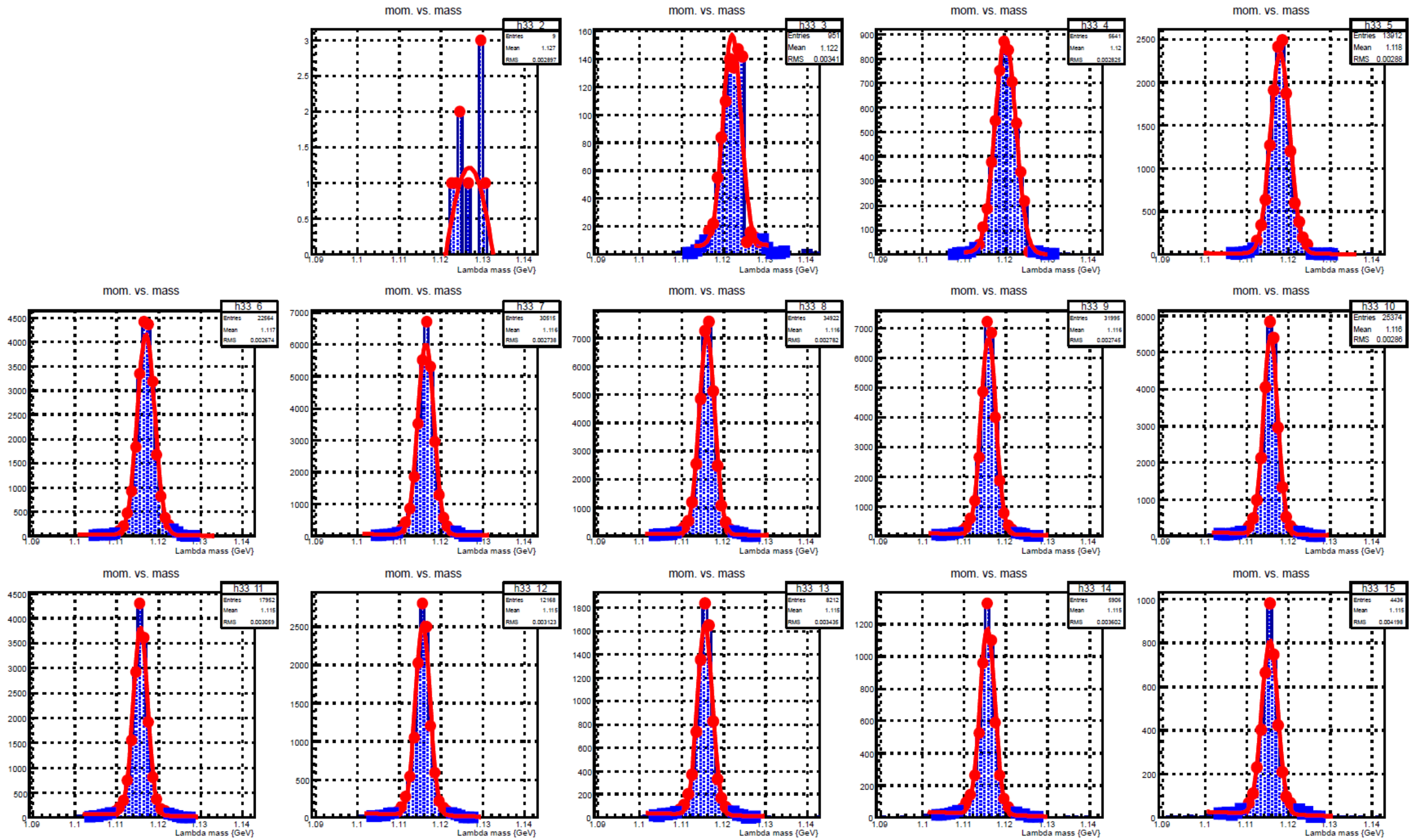
| | The $dE/dx$ resolutions | | |
|---|---|---|---|
| | MVD | | CTD |
| particle | one hit Truncated mean (%) | Maximum likelihood (%) | 30 % Truncated mean (%) |
| $\pi$ | 14.3 | 12.3 | 10.5 |
| $K$ | 12.1 | 10.5 | 10.0 |
| $p$ | 13.4 | 11.7 | 9.4 |

# PID calculation

# Λ sample; 0.1 < p(p) < 1.5 Ge, V0lite selected (sliced proton momentum 0.1 GeV)

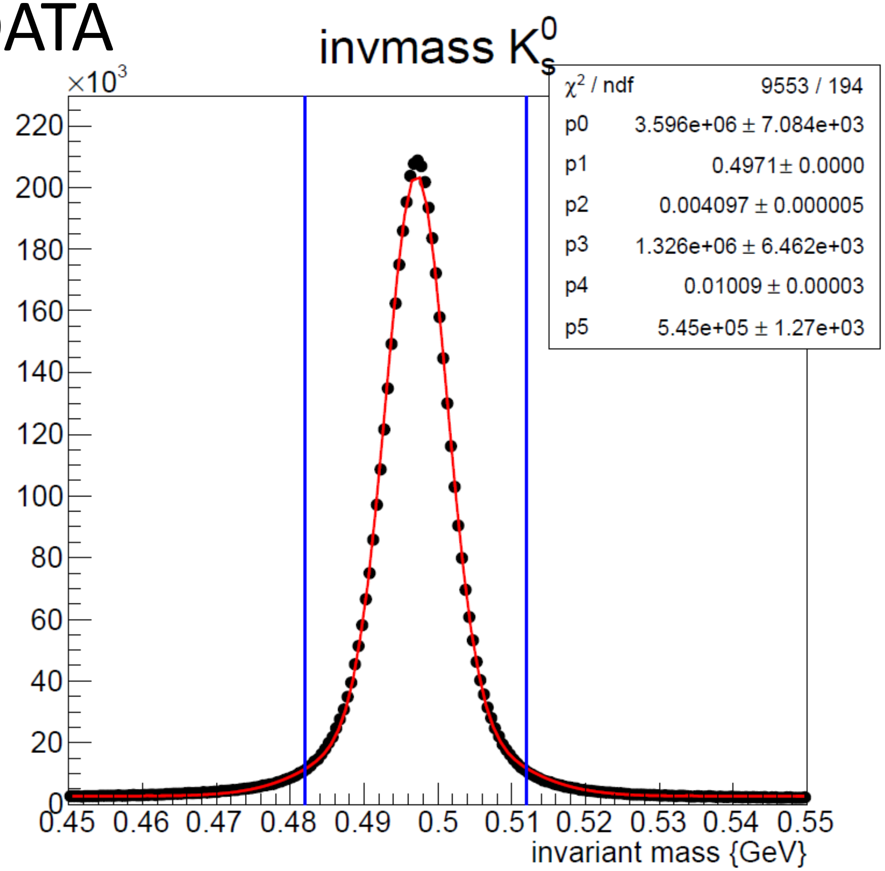


# PID selected Λ; 0.1 < p(p) < 1.5 GeV

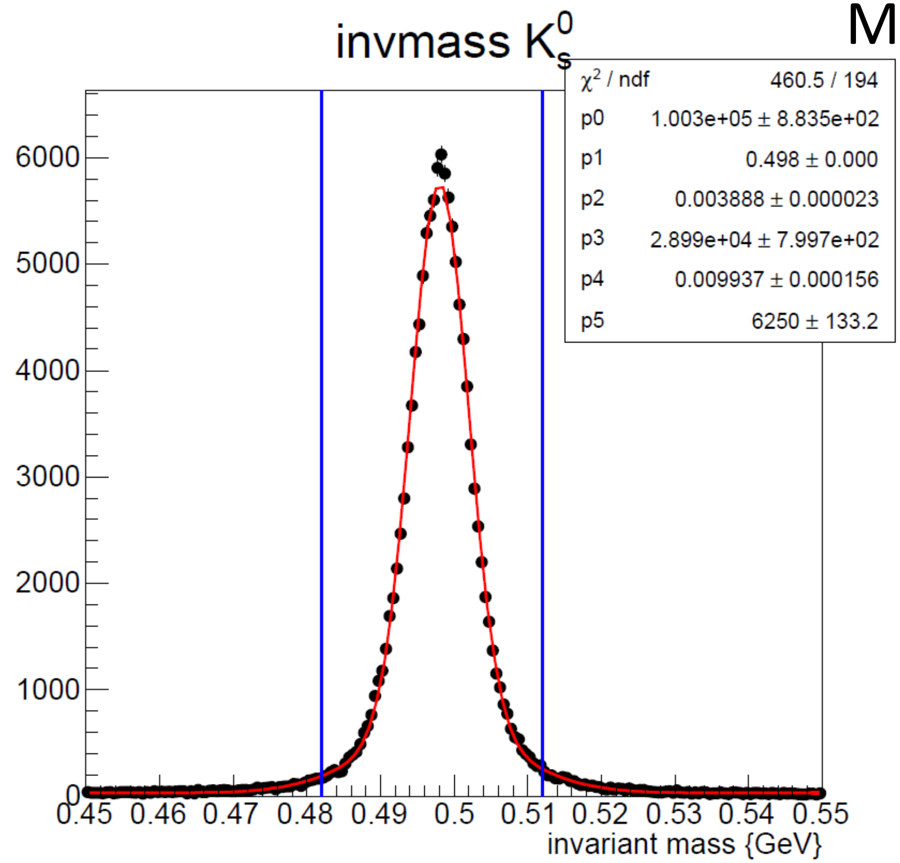


# $K^0s$ final sample

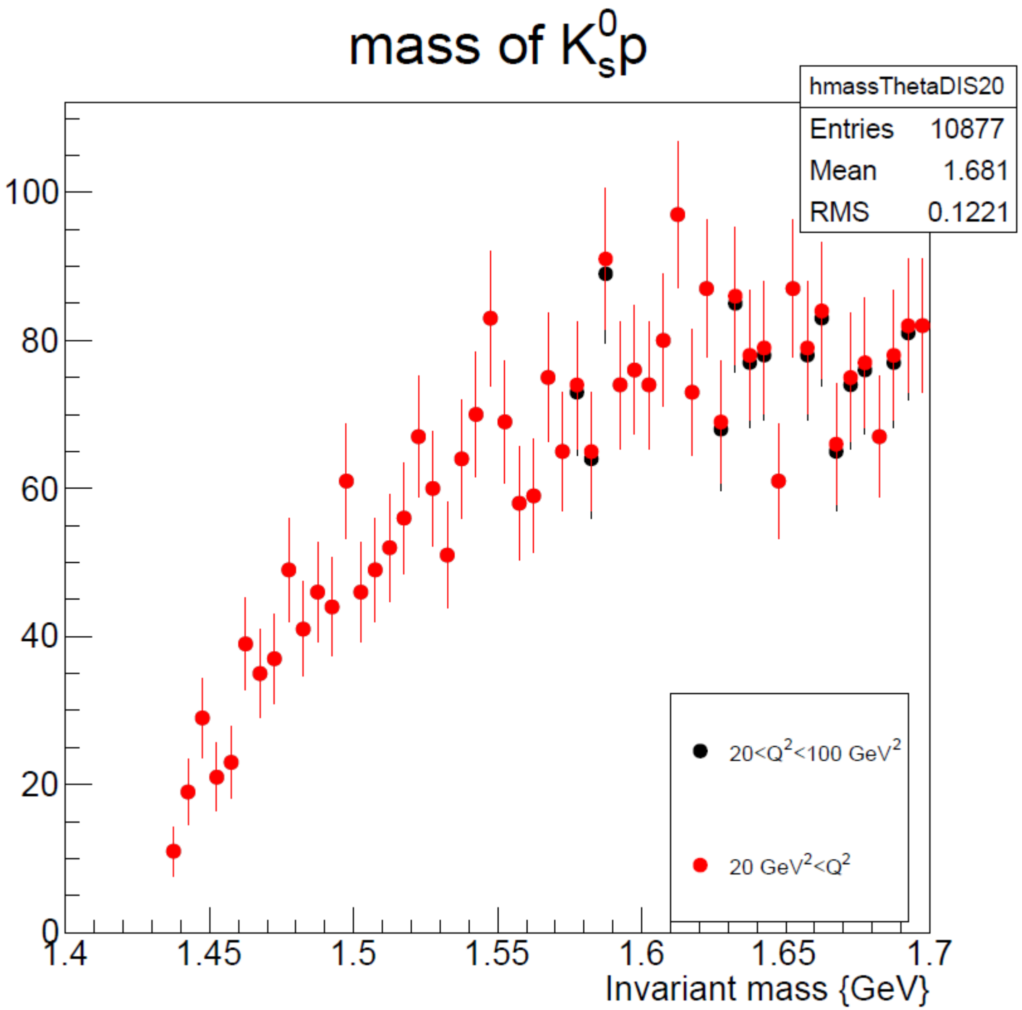
DATA




MC



# Remove $Q^2$ maximum selection




- $Q^2 > 20$ GeV$^2$ sample
- Red: no cut $Q^2$ maximum limit
- Black: maximum $Q^2$ less than 100 GeV$^2$
- The number difference is negligible.

# Event selection (mass)

- DIS selection
  - $Q^2 > 5$ GeV$^2$
  - $E_e$ > 10 GeV
  - 38 < E-pz < 60 GeV
  - $y_{el}$ < 0.95
  - $y_{JB}$ > 0.04
  - Electron Probability > 0.90
  - Electron position |x|> 12cm |y|> 12cm
  - |Zvtx| < 30cm
  - Number of track > 2 & < 400
  - At least one track from the primary vertex
  - TLT triggers (SPP02 SPP09)
- PHP selection
  - TLT triggers (HPP02 HPP09 HPP15 HPP30 HPP14 HPP29 HFL01 HFL05 HFL21)
  - 0.2 < Empz(CAL)/55. < 0.85
  - |Zvtx| < 30cm
  - 0.2 < $y_{JB}$ < 0.85
  - If number of electron > 0:
    - Electron prob. (sira) < 0.90 || eE < 5 {GeV}
    - Electron prob. (sira) > 0.90 && eE>5 {GeV} & $y_{el}$ > 0.85