

# DVCS collaboration meeting

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# The first Rosenbluth separation of $\pi^0$ electroproduction

We need to separate  $\sigma_L$  and  $\sigma_T$  to confirm the large transverse contribution.

$$\frac{d^4\sigma}{dt d\phi dQ^2 dx_B} = \frac{1}{2\pi} \Gamma_{\gamma^*}(Q^2, x_B, E_e) \left[ \frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt} + \sqrt{2\epsilon(1+\epsilon)} \frac{d\sigma_{TL}}{dt} \cos(\phi) + \epsilon \frac{d\sigma_{TT}}{dt} \cos(2\phi) \right],$$

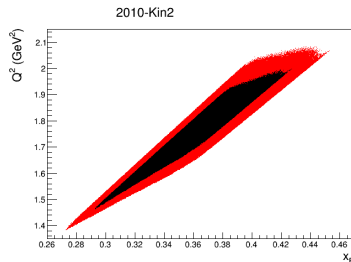
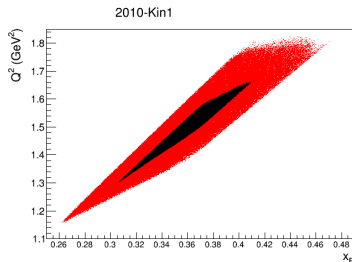
Setting	$E$ (GeV)	$Q^2$ (GeV <sup>2</sup> )	$x_B$	$\epsilon$
2010-Kin1	(3.355 ; 5.55)	1.5	0.36	(0.52 ; 0.84)
2010-Kin2	(4.455 ; 5.55)	1.75	0.36	(0.65 ; 0.79)
2010-Kin3	(4.455 ; 5.55)	2	0.36	(0.53 ; 0.72)

**Rosenbluth separation:** Measure  $\frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt}$  for two different  $\epsilon$ -values at same  $Q^2$ ,  $x_B$  and  $t'$ .

# Ensure the kinematics of the extraction

To limit the error induced by a slight mismatch between the averaged values of  $Q^2$  and  $x_B$  between the two beam energies:

- We apply a 2D-cut on  $Q^2$  and  $x_B$  to match the phase space of both beam energies.



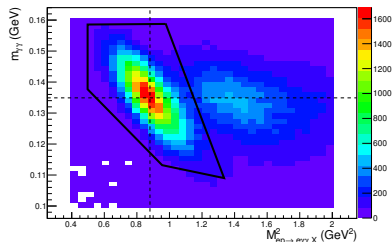
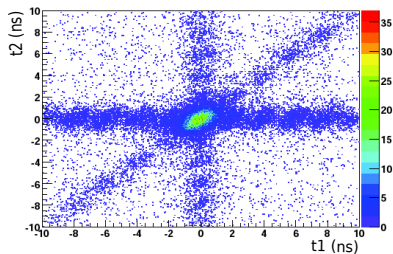
- Iteration in the extraction by fitting kinematical dependencies of  $\sigma_T$  and  $\sigma_{TT}$  with the following form:

$$\frac{t'^{\alpha}}{Q^{\beta}} \quad (1)$$

# Selection of exclusive $\pi^0$ events

Since  $M_{ep \rightarrow e\gamma\gamma X}^2$  and  $m_{\gamma\gamma}$  are correlated, we apply a 2D-cut to ensure exclusivity and particle identification.

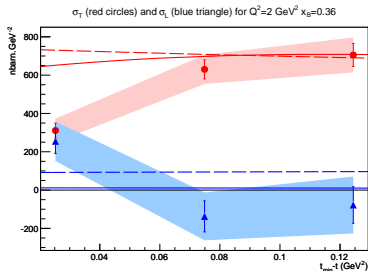
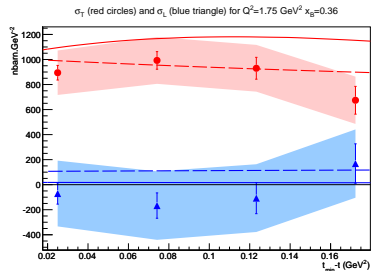
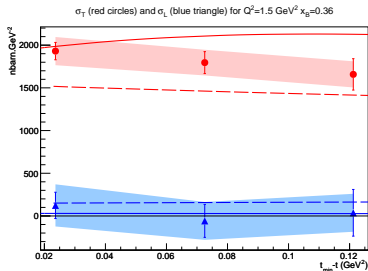
$$N_C = N_{ep \rightarrow ep\pi^0} + N_{acc} + N_{SIDIS} ,$$



Several accidental cases:

- $e\pi^0$  given by the diagonal.
- $e\gamma\gamma$  given by the horizontal or vertical line.
- $e\gamma\gamma$  everywhere.

# Results at my defense (with DIS normalization)



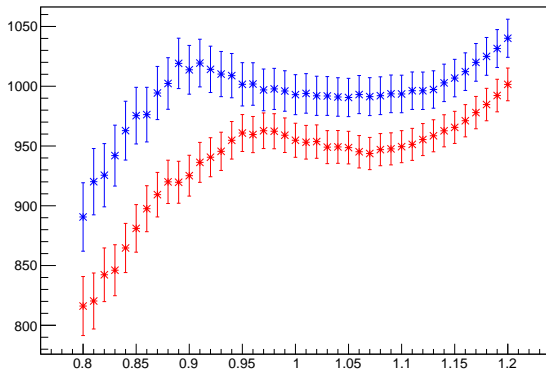
Kroll-Goloskokov (solid line)  
 Goloskokov S. and Kroll  
 P., *Eur.Phys.Jour.A* 47:112 (2011)  
 Goldstein-Liuti (dashed line)

Goldstein *et al.*, hep-ph 1311.0483  
 (2013)

# But problems were...

- Disappointing  $\chi^2$  (about 2 or 3).
- $\sigma_L$  mostly negative, even by applying a normalization correction using the DIS results.
- When evaluating the exclusivity uncertainty, we obtained it large.

$\sigma_T \pm \sigma_L$  Kin2  $t'=0.07$



Improve the smearing!

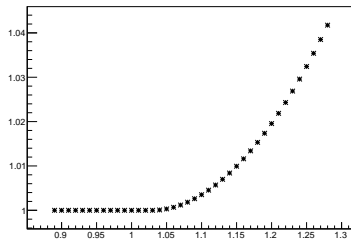
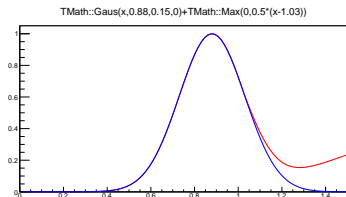
# Why smearing is so important:

You cut on the missing mass to ensure exclusivity. But you remove approximately 30% of events.

It is corrected by cutting in the Monte Carlo simulation...

**ONLY IF...** MC reproduces perfectly the experimental distribution.

Graph



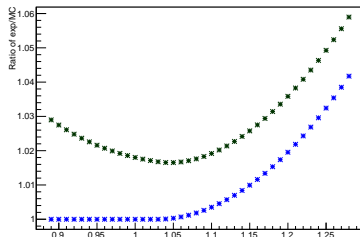
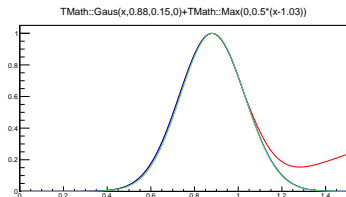
$\mu = 0.88$  and  $\sigma = 0.15$  for the exclusivity peak.

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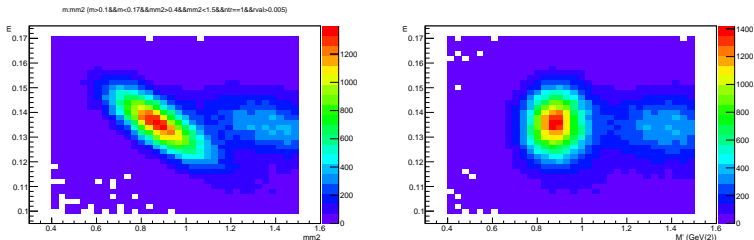
MC mismatch:  $\mu = 0.8825$  and  $\sigma = 0.1475$  for the exclusivity peak.



# Smearing part 1

As mentioned previously, there is a correlation between  $m_{\gamma\gamma}$  and  $M_{ep \rightarrow e' \pi^0 X}^2$ . To compensate it and make things easier:

$$M_{ep \rightarrow e' \pi^0 X}^2 \rightarrow M' = M_{ep \rightarrow e' \pi^0 X}^2 + 12 \times (m_{\gamma\gamma} - m_{\pi}) \quad (2)$$



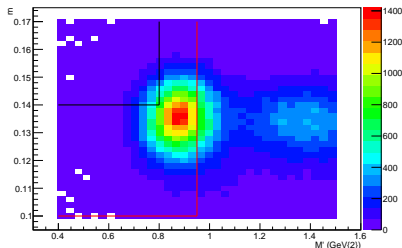
We need to find three parameters to match missing mass and invariant mass distributions (and a stable cross section):

- Calibration coefficient.
- Energy resolution. (control the width of  $M'$  and  $m_{\gamma\gamma}$ )
- Angular resolution. (control the width of  $M'$  and  $m_{\gamma\gamma}$ ) Very difficult to disentangle from energy resolution.

# Smearing part 2

Idea: With a perfect smearing, the cross section should not change when changing the cut on  $M'$  and  $m_{\gamma\gamma}$ .

Let's try to find the parameters by requiring the cross section to not change when changing the cuts. We are going to try it bin-by-bin.



We define  $\sigma_{xy}$  such as  $m_{\gamma\gamma}$  in  $[y; 0.17]$  and  $M'$  in  $[0.4; x]$ .

## Smearing part 2: For a specific experimental bin...

- We try a set of parameters and smear the MC. We fill the histograms of missing mass and invariant mass with  $\frac{psf}{N_{event}}$ .
- With this smearing, we can also extract a cross section  $\sigma_0$  with  $m_{\gamma\gamma}$  in  $[0.1;0.17]$  and  $M'$  in  $[0.4;0.95]$ .
- We multiply the missing mass and invariant mass histograms with  $\sigma_0$  and the luminosity. We should recover the experimental histograms.
- We also look at the ratio  $R$ :

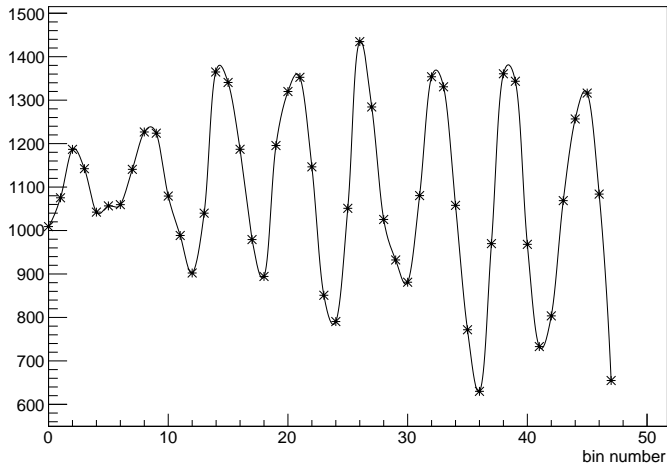
$$R = \frac{\sigma_{xy} \text{ with } m_{\gamma\gamma} \text{ in } [y;0.17] \text{ and } M' \text{ in } [0.4;x]}{\sigma_0} \quad (3)$$

We minimize the  $\chi^2$ 's of the missing mass and invariant mass, on top of minimizing the variations of  $R$ .

# Smearing part 3: Check $\sigma_0$

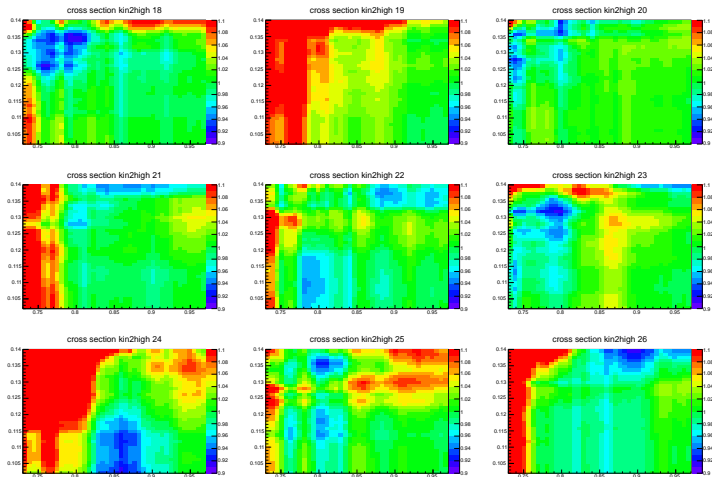
Be careful: Bin migration not corrected!

Kin2high cross section



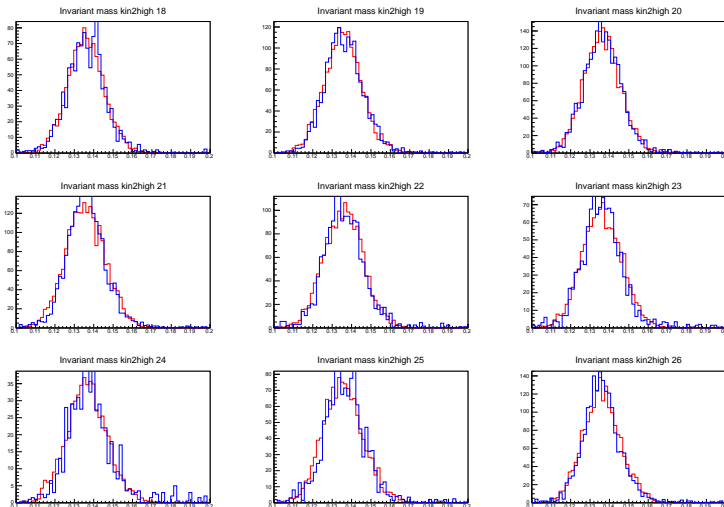
# Smearing part 4: Check the stability

$R$  as a function of  $x$  and  $y$  ( $m_{\gamma\gamma}$  in  $[y;0.17]$  and  $M'$  in  $[0.4;x]$ ) .



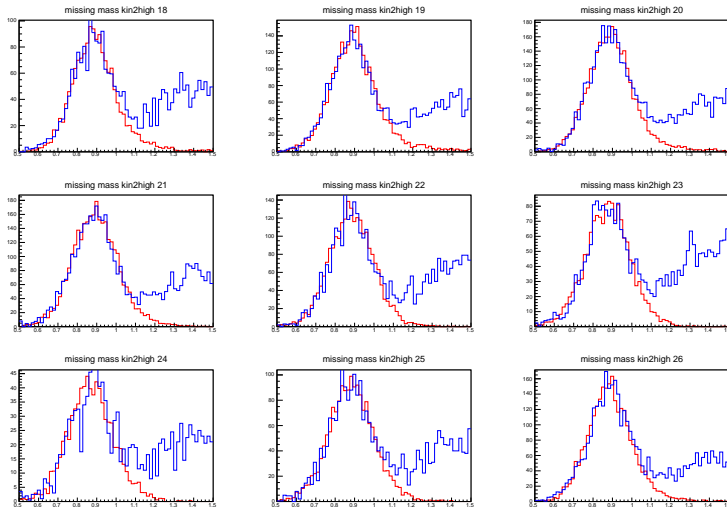
# Smearing part 5: Check $m_{\gamma\gamma}$ and $M'$

You can also check that  $m_{\gamma\gamma}$  and  $M'$  are well reproduced. (red is MC and blue experimental).



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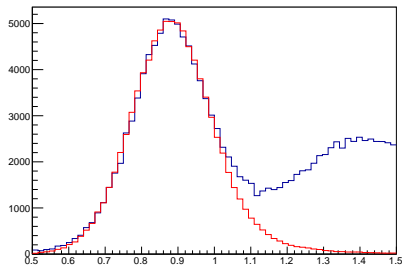
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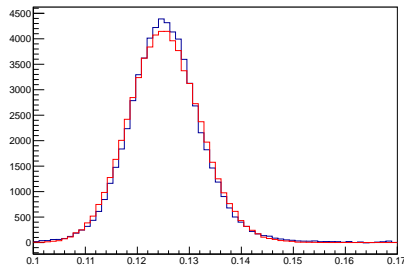
# Smearing part 6: However...

Summing over all the bins... Great but could be better!

Kin2high M' (missing mass)



Invariant mass kin2high



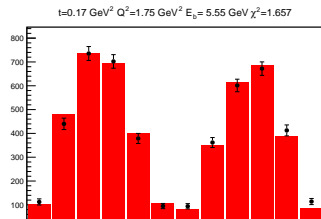
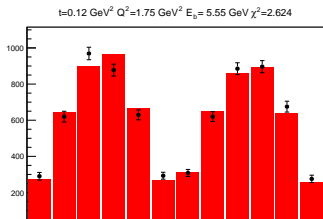
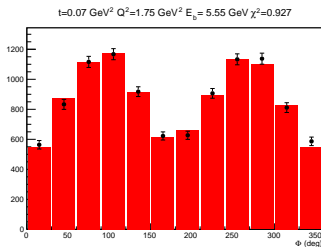
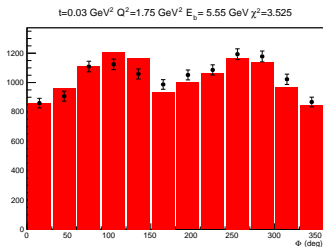
Need to take into account bin migration (10%) since I normalize with the cross section!

And need to tune the missing mass fit range for a few bins by hand.



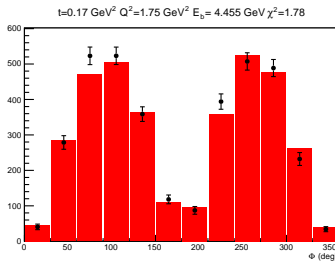
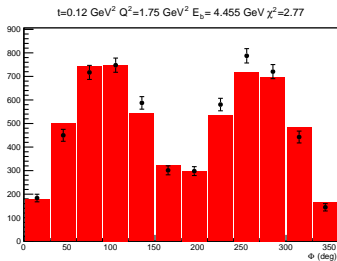
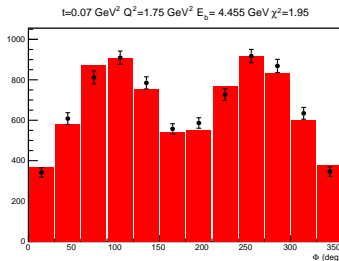
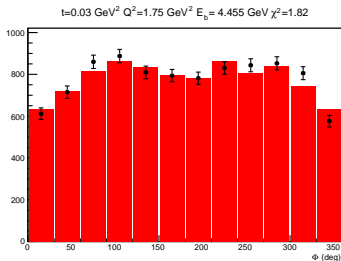
# The fit of experimental number of counts: Kin2high

We fit low and high beam energy number of counts to extract  $\frac{d\sigma_T}{dt}$ ,  $\frac{d\sigma_L}{dt}$ ,  $\frac{d\sigma_{TL}}{dt}$  and  $\frac{d\sigma_{TT}}{dt}$  For the worst case: (MC in red, experimental counts in black)



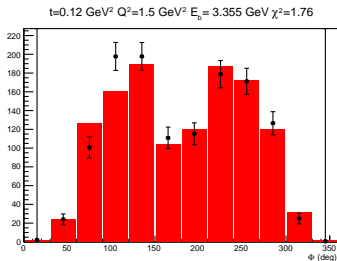
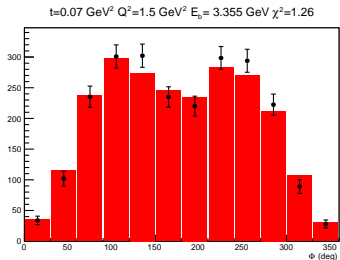
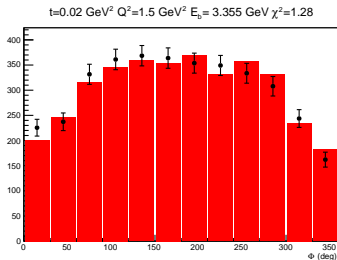
# The fit of experimental number of counts: Kin2low

Better for kin2low,

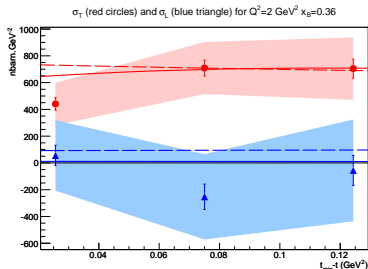
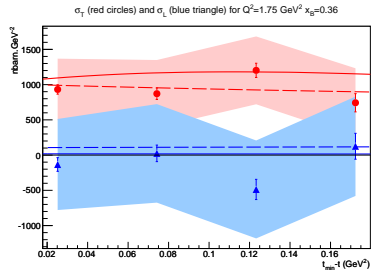
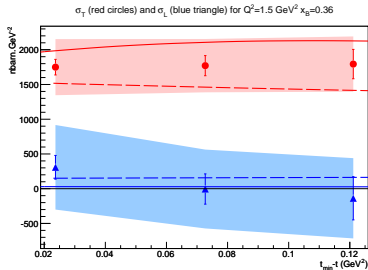


# The fit of experimental number of counts: Kin1low

Other kinematics have  $\chi^2/Ndf$  of about 1.5,



# Results today (with **NO** DIS normalization... still PRELIMINARY)

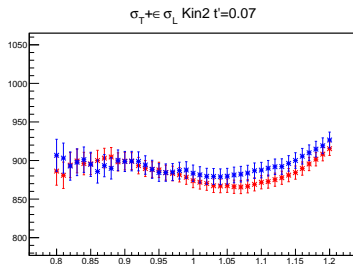
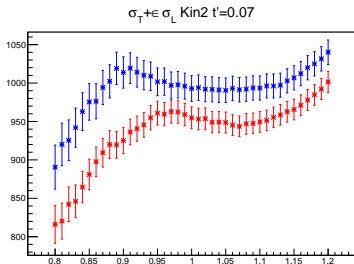


Kroll-Goloskokov (solid line)  
 Goloskokov S. and Kroll  
 P., Eur.Phys.Jour.A 47:112 (2011)  
 Goldstein-Liuti (dashed line)

Goldstein *et al.*, hep-ph 1311.0483  
 (2013)

# The exclusivity cut uncertainty

If we look at the stability of the unseparated cross section:  
(left at my defense, right today!: Same scale for a better comparison)

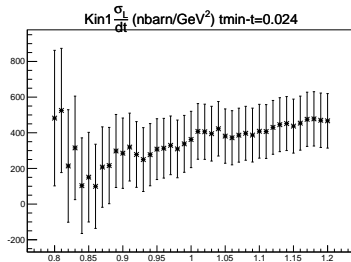
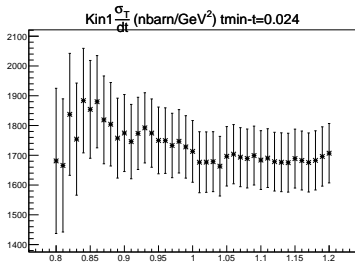
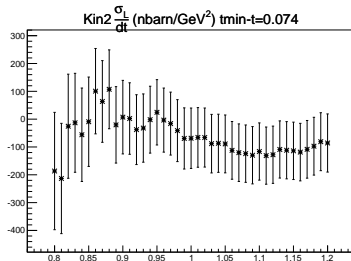
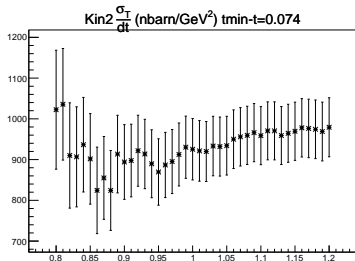


- It is much more stable than a few months ago!
- Compared to the flat part of the cross section in June, we have lost 5 to 10%. (I was off by 5 to 10%).

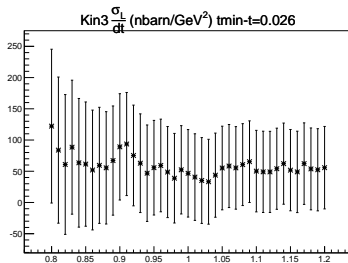
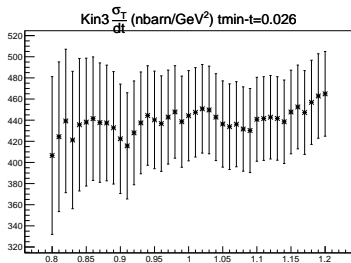
Not all of them are that beautiful!

It is not because it is flat at some point that there is no systematic shift.  
The low missing mass behaviour is a hint of how big you this shift is.

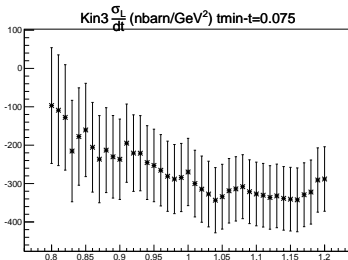
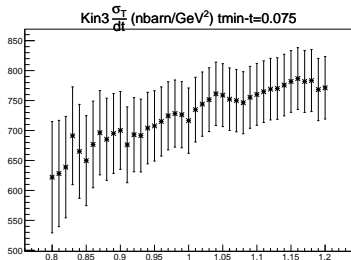
# Exclusivity cut: Separated cross sections



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But still some work maybe... difficult acceptance for Kin3low at  $\phi = 0^\circ$



# Conclusions

## Positive outputs:

- Robust method to smear the Monte-Carlo simulation (Finally! sorry for the wait).
- $\sigma_L$  is closer from 0 than ever, and thus without DIS normalization! (but it might be a coincidence)
- Significant decrease of the systematic uncertainties and better  $\chi^2$ .  
**Very important!**
- Disagreement of 10-20% with Malek may be explained by smearing procedure.

## Perspective:

- Can try to improve the smearing by gathering bins 2-by-2. Or include bin migration for normalization (running now!).

## Suggestions:

- In any case, I would like to drop the last bin since we do not correct for bin migration ( $\sim 10\%+$  terrible acceptance effect).
- Since we have some troubles with the luminosity, I would like to give asymmetries instead of polarized cross sections.