

Hall A pi0 analysis (kin36_1) @ 12 GeV

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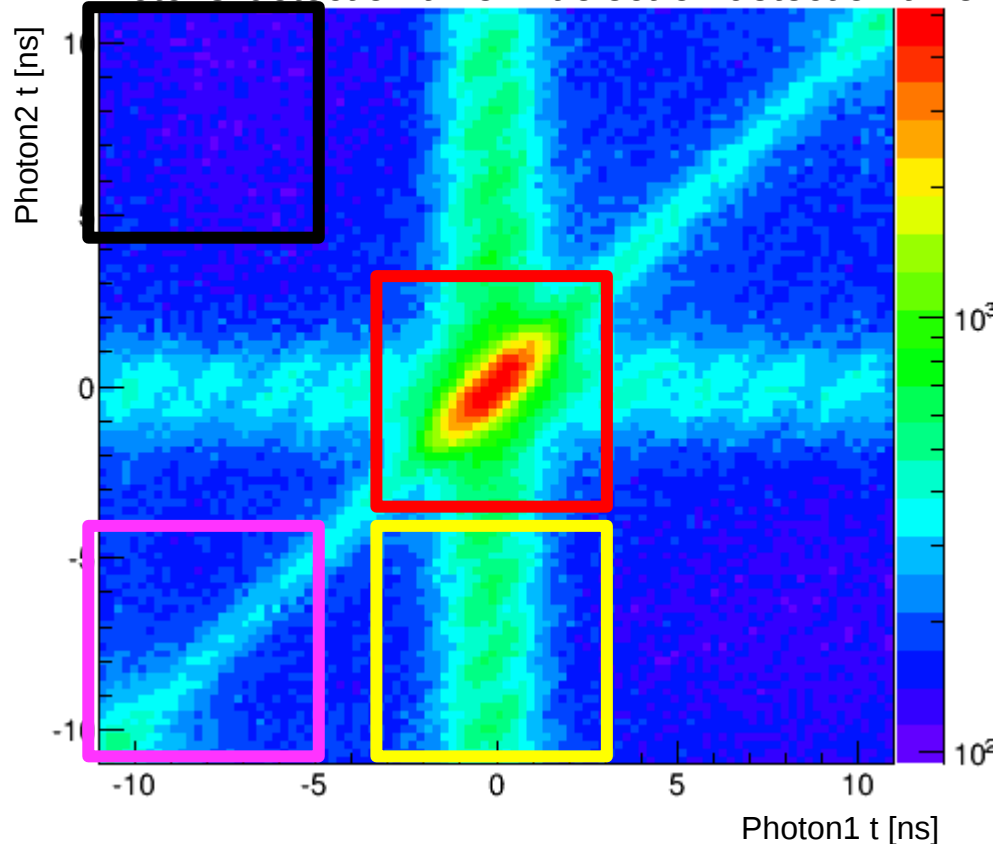
Hall A DVCS Meeting 2020

Outline

- Data accidentals subtraction
- Simulation smearing
- Binning, cuts and corrections
 - 3-clusters correction
- Cross-section extraction & comparison with Po-Ju
- Systematic errors calculation
 - Clustering systematic errors
 - Low statistics

Data accidentals subtraction

Photons' detection time wrt electron detection time



Pi0 candidates + accidentals : 2 photons in $[-3, 3]$ ns windows

Accidentals :

1. 1 photon in $[-3, 3]$ ns and 1 photon in $[-11, -5]$ ns
2. 1 photon in $[-11, -5]$ ns and 1 photon in $[-11, -5]$ ns
3. 1 photon in $[-11, -5]$ ns and 1 photon in $[5, 11]$ ns

Number of pi0 events :

$$\boxed{\text{red}} - \boxed{\text{yellow}} - \boxed{\text{magenta}} + \boxed{\text{black}}$$

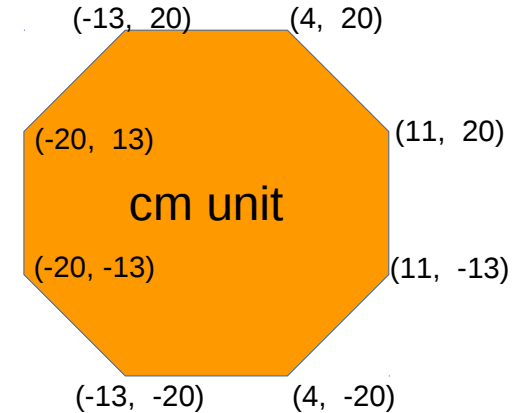
Smearing

- Cuts

- Vertex : [-6.9742, 6.6742] cm
- R-value : 0.003 (used Alexa's R-function)
- Photons' position(acceptance) cut : octagonal
- Clustering threshold : 1.10 GeV
 - (DAQ hardware threshold ~ 1.10 GeV)
- Photon energy threshold : 1.10 GeV
- Missing-mass²[Mx2] cut : [0.0, 1.2] GeV²
- Invariant-mass (pi0's)[Minv] cut : [0.11, 0.16] GeV

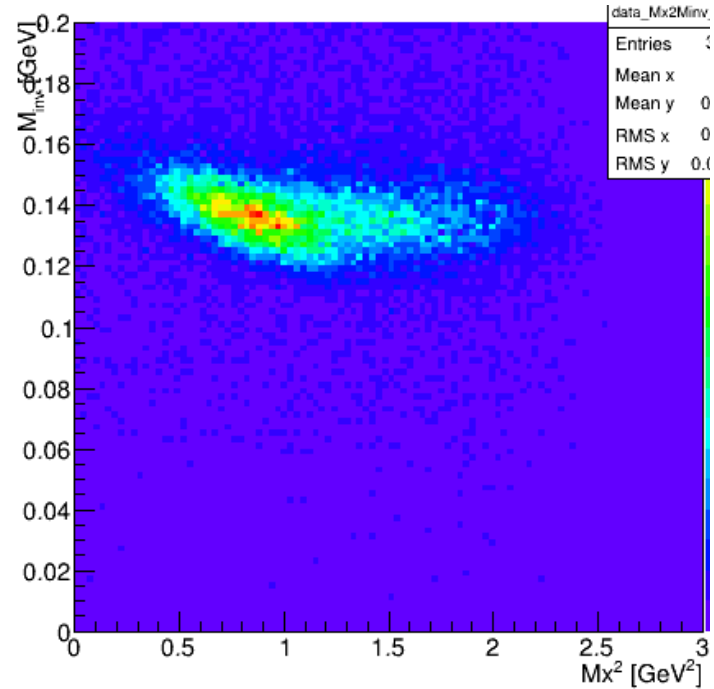
- Smearing division

- Divide octagon into 7X7 overlapped area.
- Smear photon energy in each area with gaussian random : smeared energy = Gaus(energy*mean, sqrt(energy)*sigma)
 - Find mean and sigma with smallest chi² comparing Mx2 and Minv of data and simulation.
- Interpolate mean and sigma.

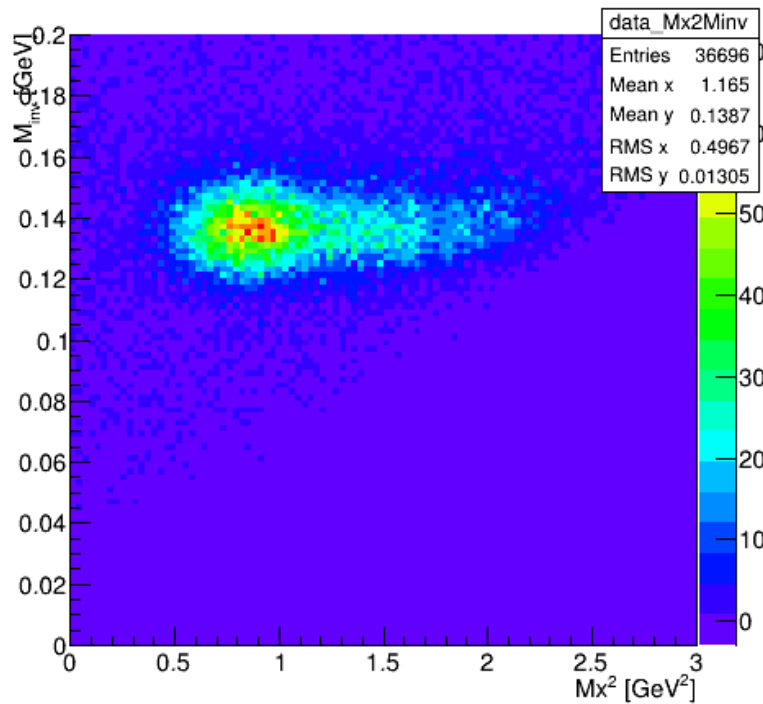


Mx2 rotation

Before rotation



After rotation



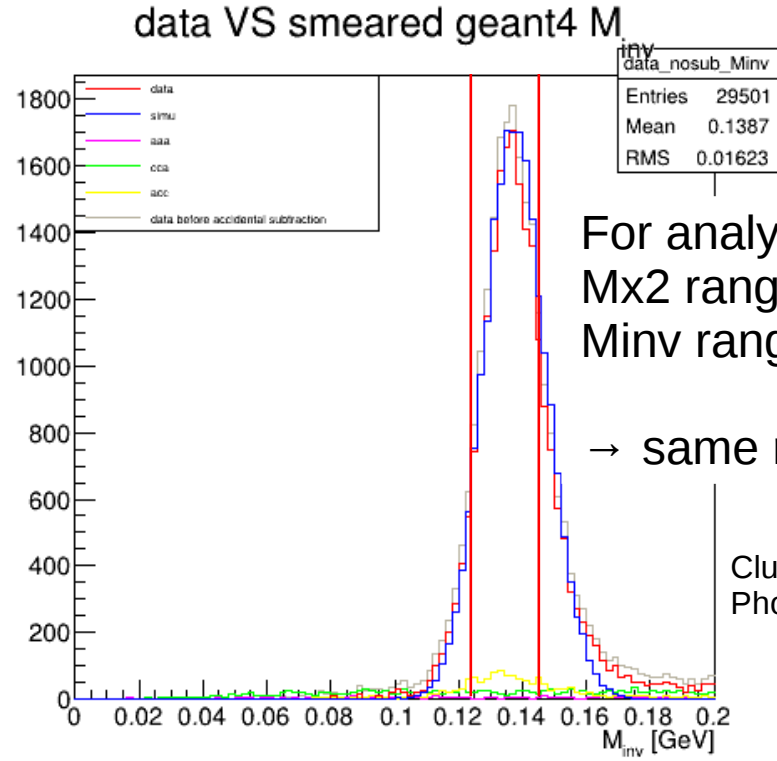
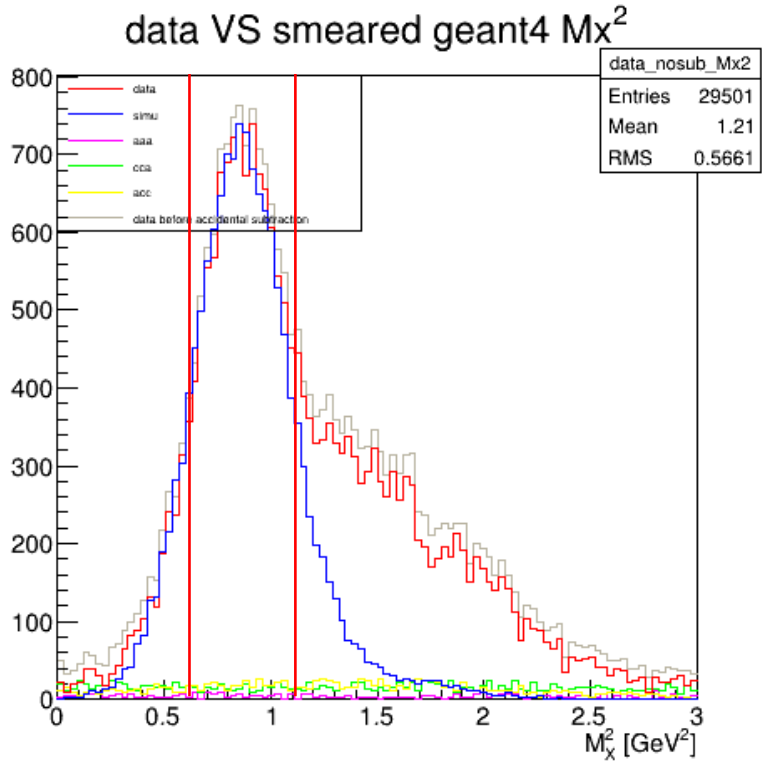
Mx2 and Minv should be independent variables

Rotate Mx2-Minv coordinate

$$Mx2_{rot} = Mx2 + C \cdot (Minv - M_{\pi 0})$$

$C = 20$
 $M_{\pi 0}$: $\pi 0$ invariant mass

Smearing result

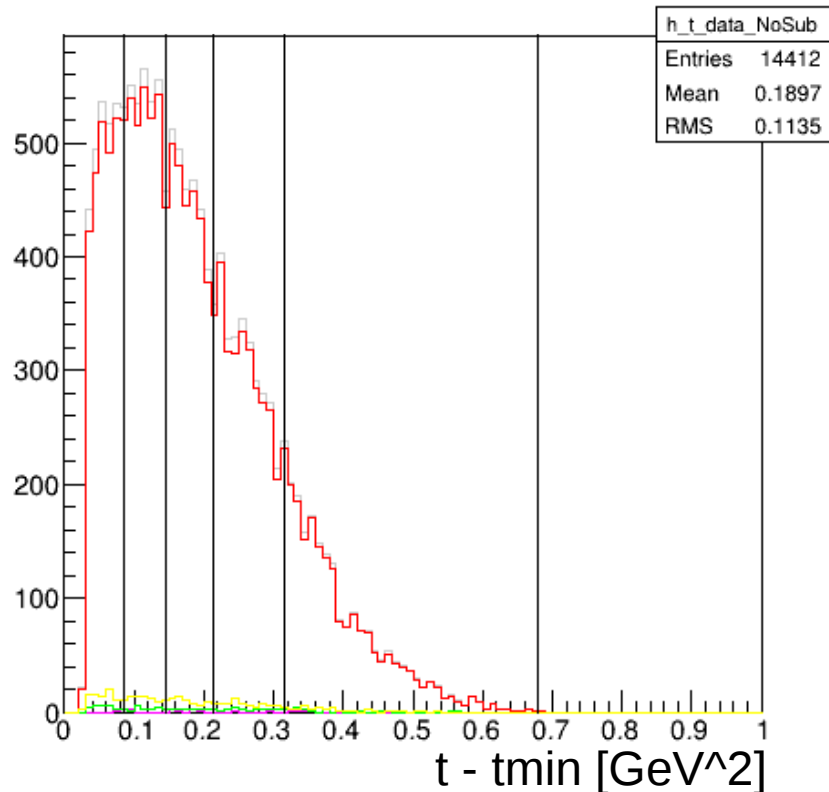


For analysis
 M_x^2 range : [0.6, 1.1] GeV^2
 M_{inv} range : [0.124, 0.144] GeV

→ same range as Po-Ju's

Clustering threshold : 1.10 GeV
 Photon energy threshold : 1.70 GeV

t-Binning (t - tmin)



t-binning with similar number of entries (events)

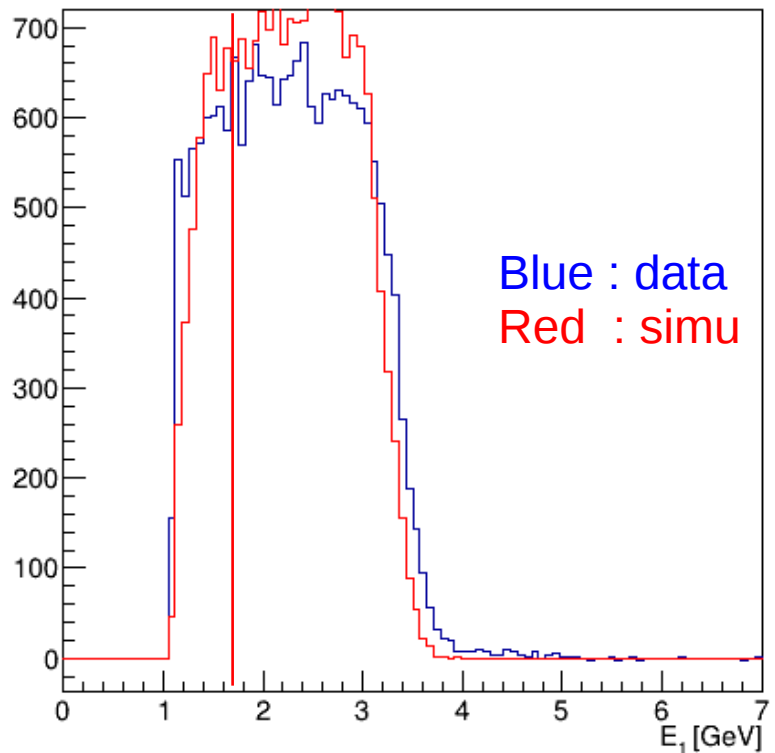
t0 : [0, 0.085] GeV²
t1 : [0.085, 0.145] GeV²
t2 : [0.145, 0.215] GeV²
t3 : [0.215, 0.315] GeV²
t4 : [0.315, 0.680] GeV²

However, to compare cross-section with Po-Ju's, used same t-binning.

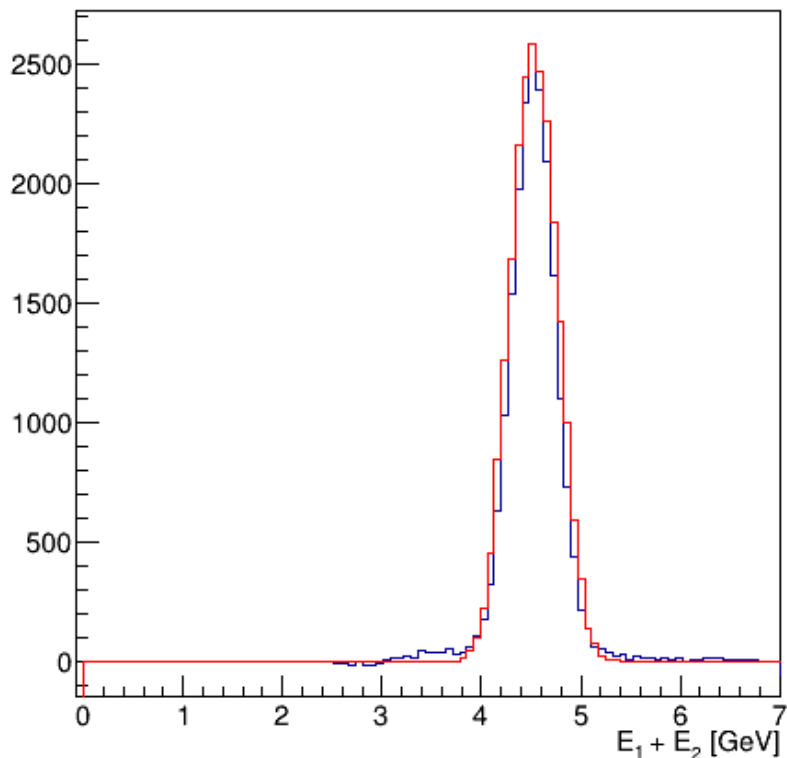
t0 : [0, 0.097] GeV²
t1 : [0.097, 0.167] GeV²
t2 : [0.167, 0.258] GeV²
t3 : [0.258, 0.480] GeV²
t4 : [0.480, 0.900] GeV²

Photon energy distribution

photon1 energy. M_x^2 rage : [0.6, 1.1] [GeV²]. Clustering threshold : 1.10 GeV



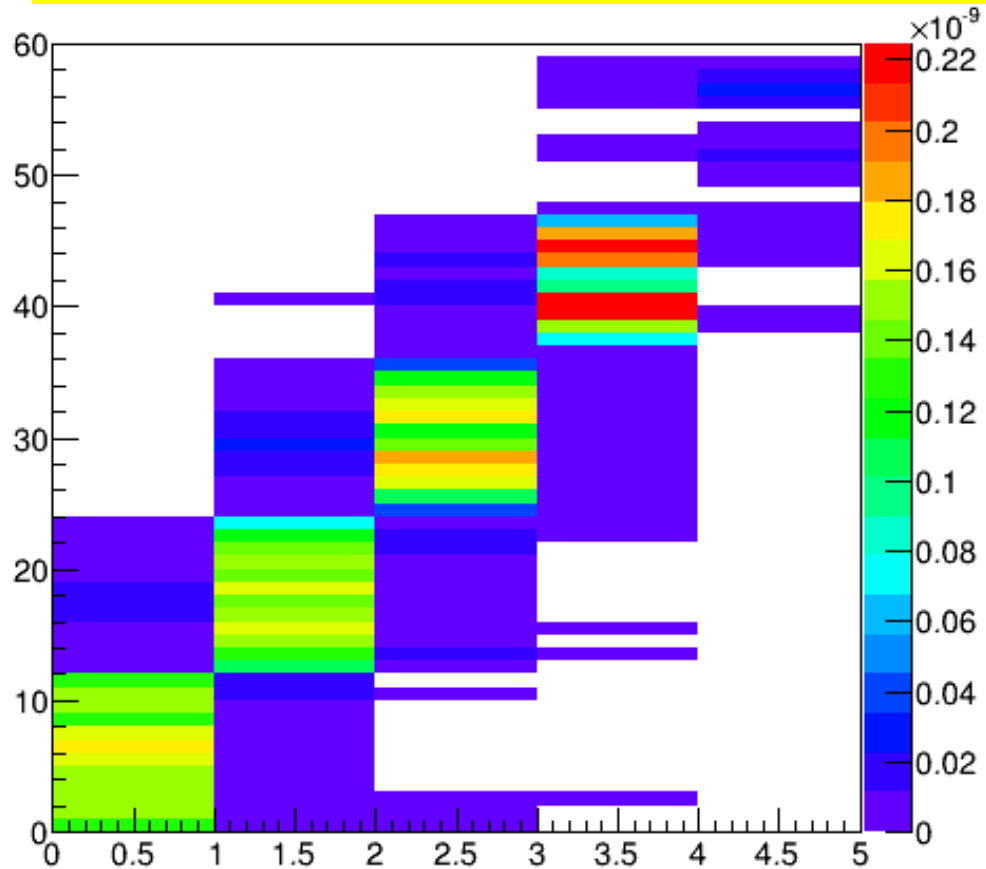
two photon energy. M_x^2 rage : [0.6, 1.1] [GeV²]. Clustering threshold : 1.10 GeV



Photon energy
threshold : 1.70 GeV

Seems high, but still
lower than the
average of half of π^0
energy.

Bin migration matrix



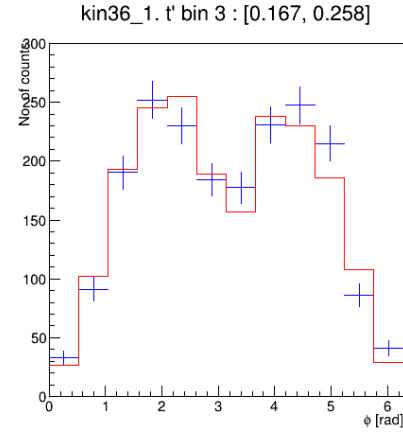
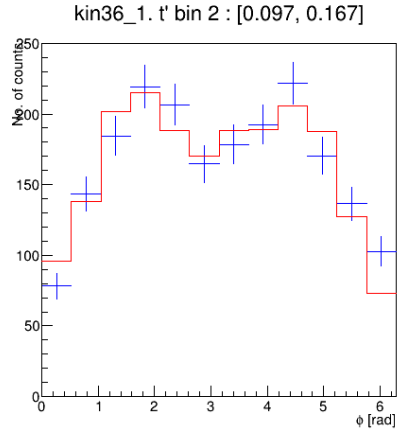
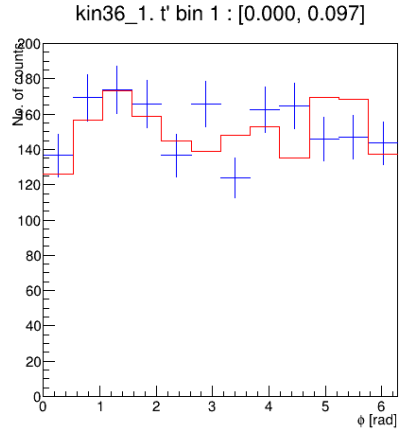
Bin migration matrix of constant term of the cross section (T + L)

5 tbins, 12 phi bins

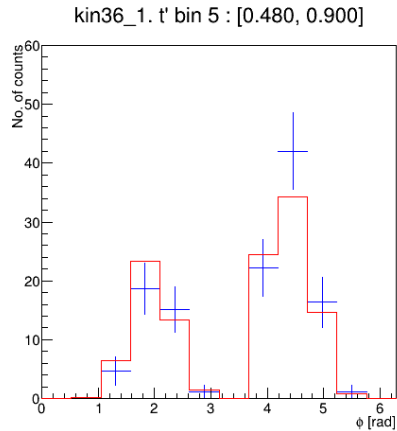
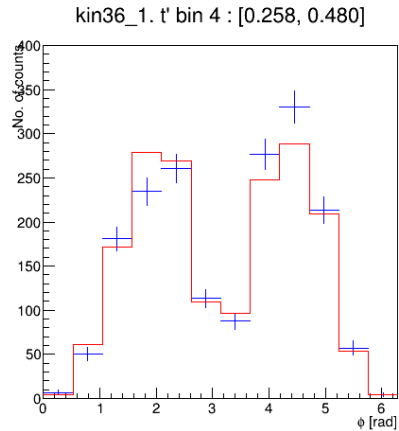
Corrections :

- Multi-track correction : 1.060
 - Cerenkov efficiency correction : 0.9984
 - scintillator(S2) efficiency correction : 0.9974
 - Pi0 branching ratio : 0.98823
 - 3-cluster correction at photon energy threshold of 1.70 GeV : 8%
- Corrected No. events
= No. Events X (multi-track) X (3-cluster)/(cerenkov)/(S2)/(Branch)
- Radiative correction not applied, yet.

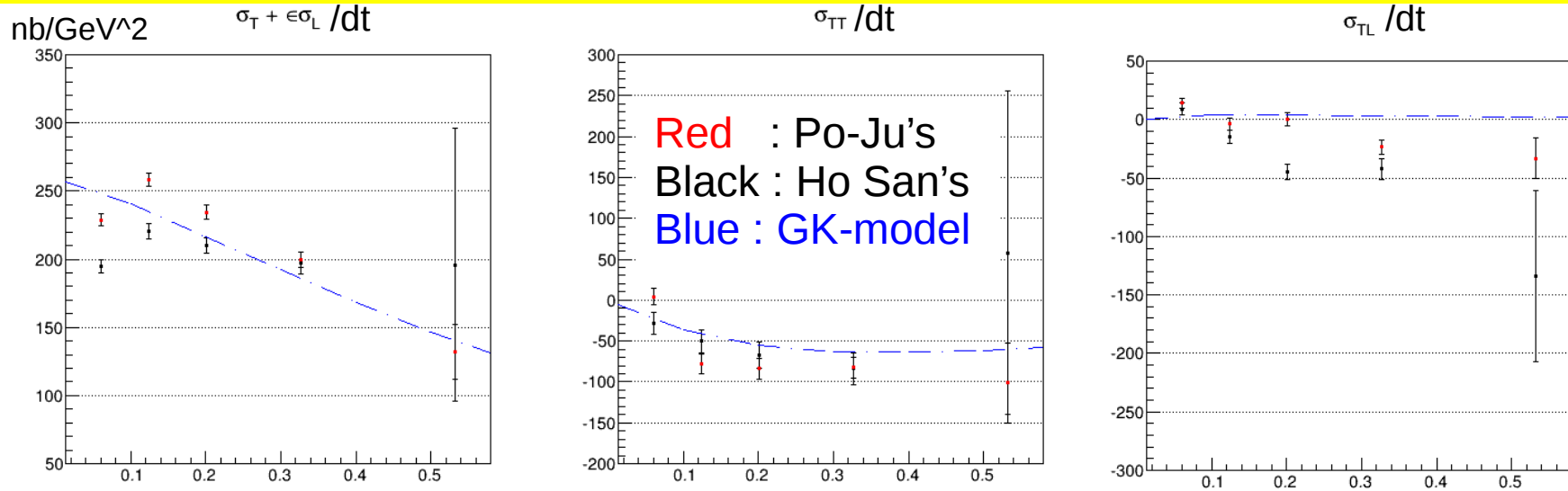
No. of events : data vs simu



- Blue : data
- Red : simu



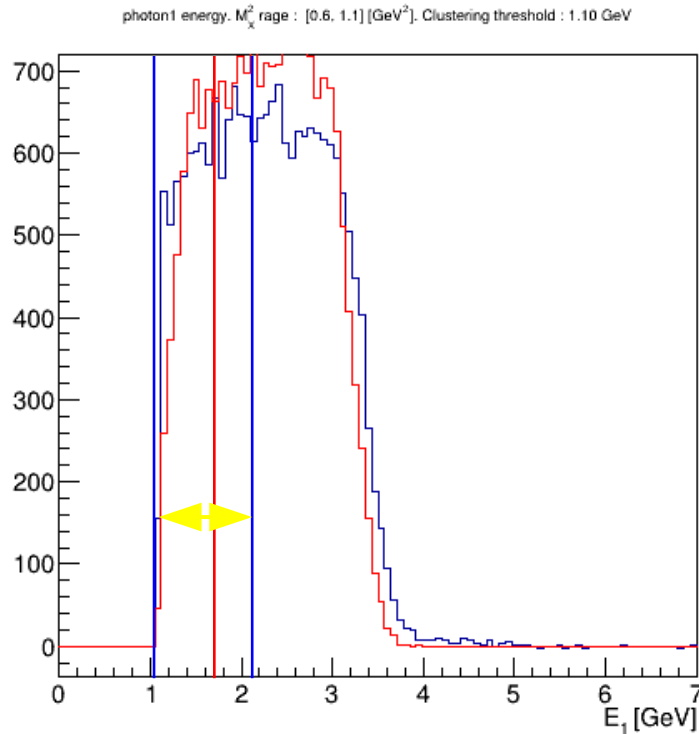
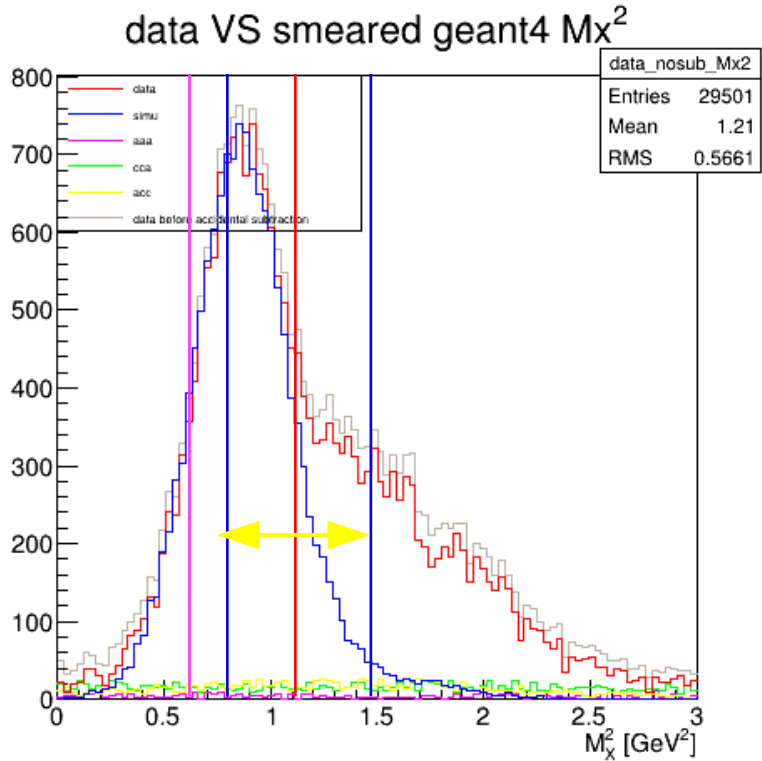
Cross-section extraction



Same cuts applied : vertex, rval, octagonal, Mx2, Minv

Next step : systematic error studies

Variables for systematic error calculation

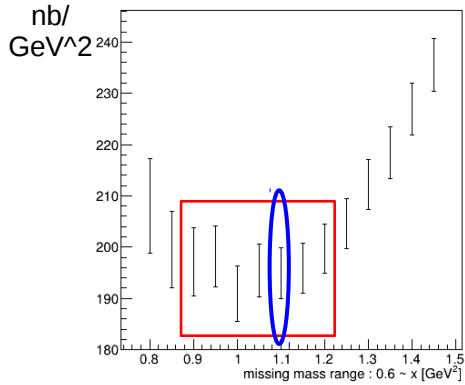


Variables

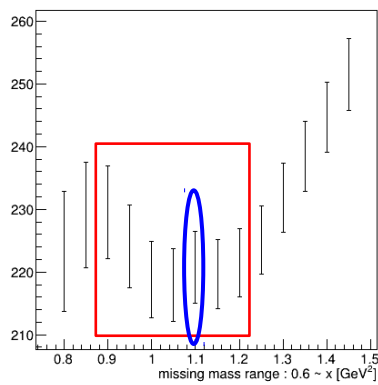
- M_x^2 max cut :
[0.8, 1.45] GeV²
- M_x^2 min cut : fixed
- Photon energy threshold :
[1.10, 2.10] GeV
- Clustering threshold :
[1.10, 1.40] GeV
- Red : nominal cut
- Blue : cut range for sys. err.

Cross sections with different Mx2 max cut

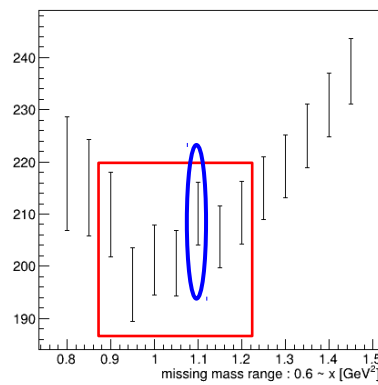
$\sigma_T + \epsilon\sigma_L$ t1 /dt



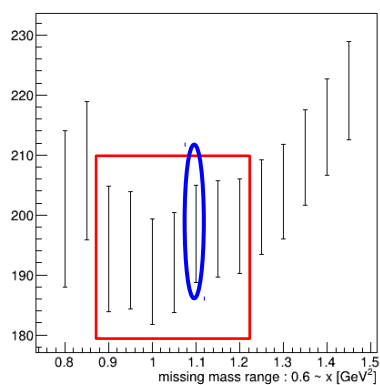
$\sigma_T + \epsilon\sigma_L$ t2



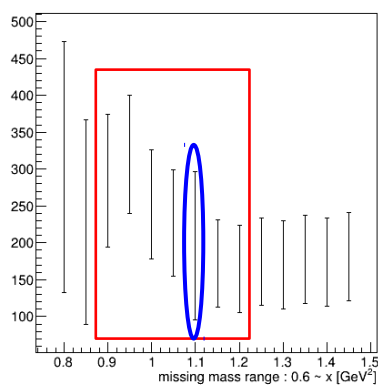
$\sigma_T + \epsilon\sigma_L$ t3



$\sigma_T + \epsilon\sigma_L$ t4



$\sigma_T + \epsilon\sigma_L$ t5

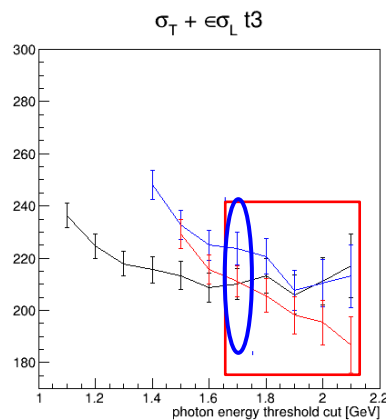
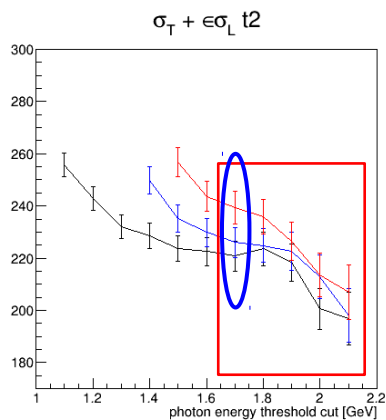
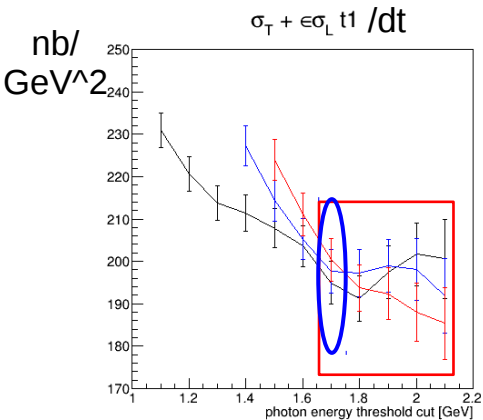


- **Blue** : nominal cross-section (@ 1.10 GeV²)
 - **Red** : Mx2 max cut range for systematic error : [0.9, 1.2] GeV²
- @clus_thresh : 1.10 GeV
@phot_thresh : 1.70 GeV

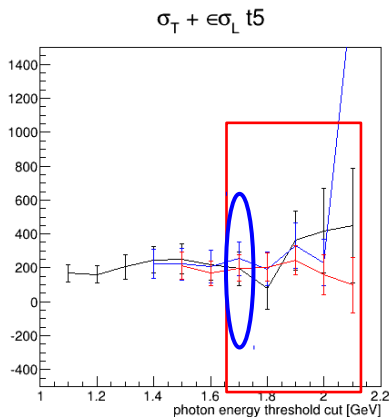
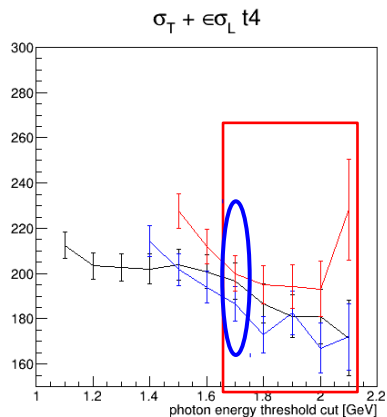
T+L	t1	t2	t3	t4
Mx2max	+2.4% -2.1%	+4.0% -1.3%	+0.10% -6.4%	+0.68% -3.2%

Cross sections with different clustering threshold and photon energy threshold

@ Mx2 max : 1.10 GeV²

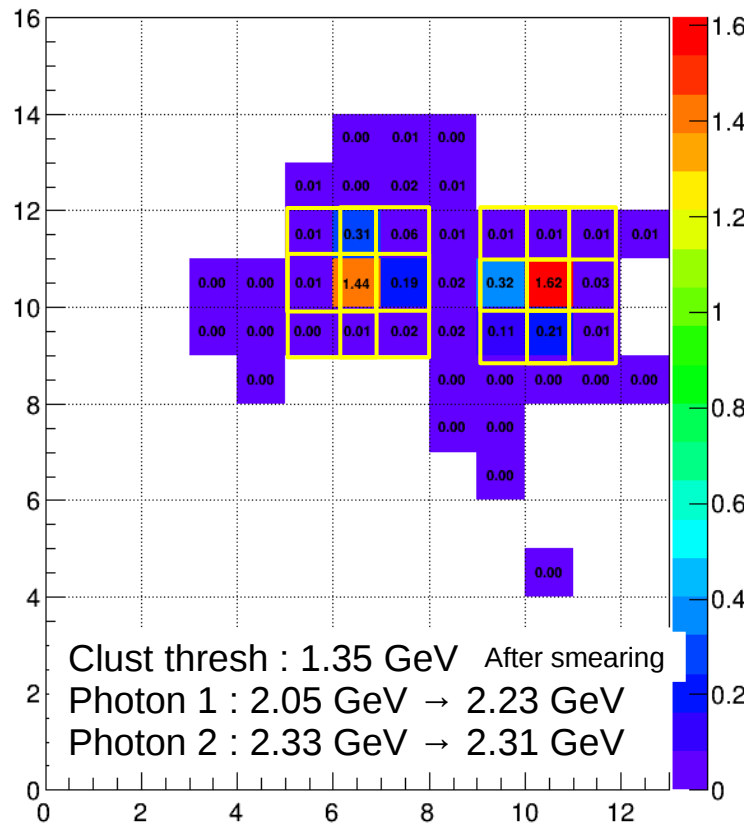
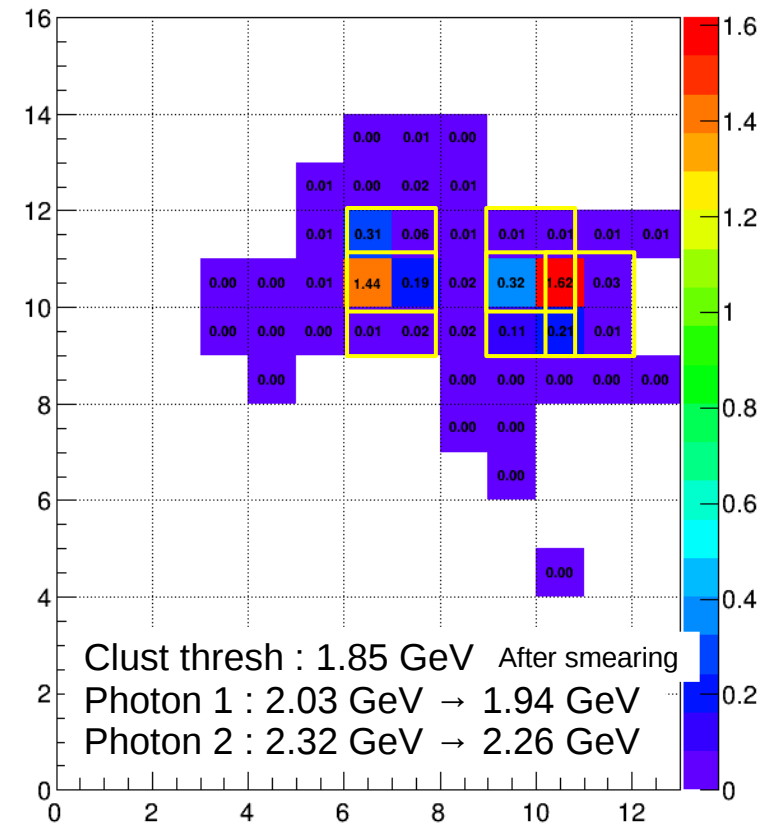


- Clustering threshold
 - Black : 1.10 GeV (nominal)
 - Blue : 1.35 GeV
 - Red : 1.40 GeV
- Photon energy threshold range : [1.70, 2.10] GeV
- Nominal cross-section (@ 1.70 GeV)



T+L	t1	t2	t3	t4
clus_thresh	+2.8%	+8.4%	+6.5%	+1.6%
	-0.0%	-0.0%	-0.0%	-5.1%
Phot enemim	+3.4%	+1.3%	+3.4%	+0.0%
	-1.9%	-11.0%	-1.9%	-13.0%

Events lost due to smearing after clustering

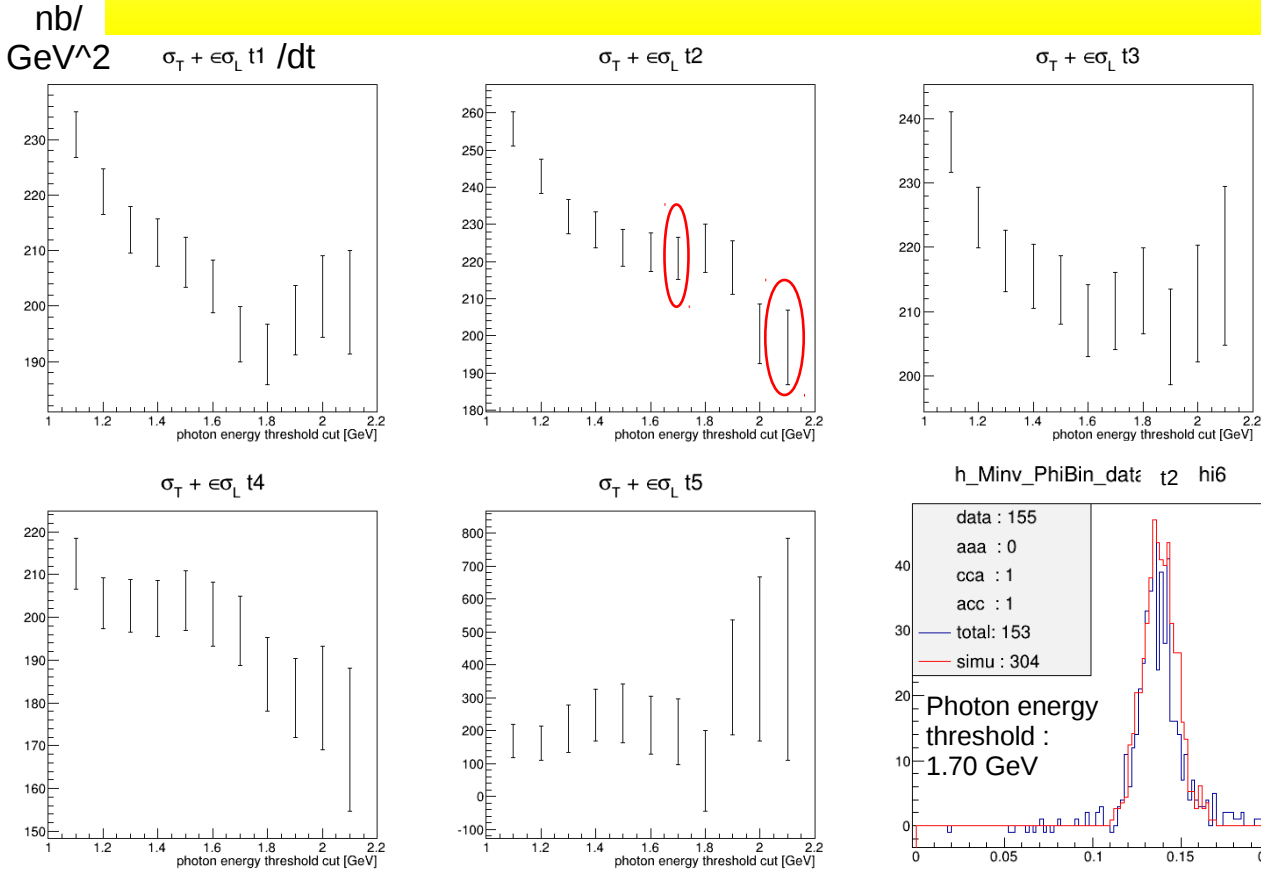


Event that passed 2-cluster, octagonalcut, vertexcut, rvalcut, mass cut.

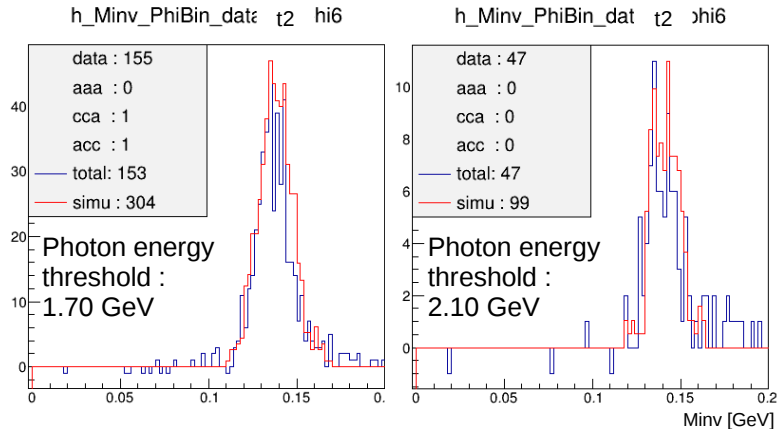
But detected with clus_thresh 1.35 GeV not with 1.85 GeV
Photon energy threshold : 2.0 GeV

\rightarrow Photon energy threshold should be far away from clustering threshold

Low statistics in systematic error studies



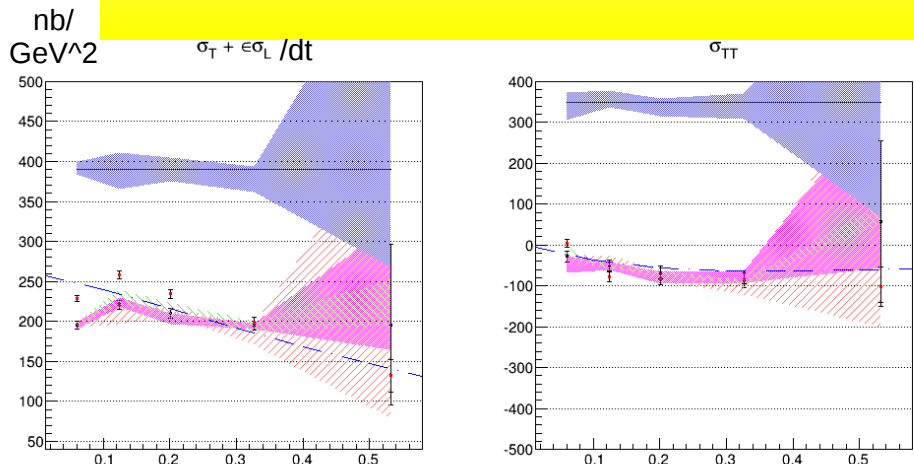
- @ fixed clustering threshold 1.10 GeV
- When changing photon energy threshold, the **statistical error increases**



Minv of simulation and data matches in each 5 t-bins and 12 phi-bins.

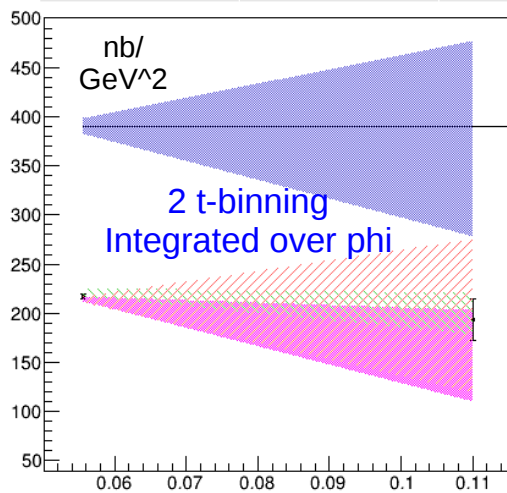
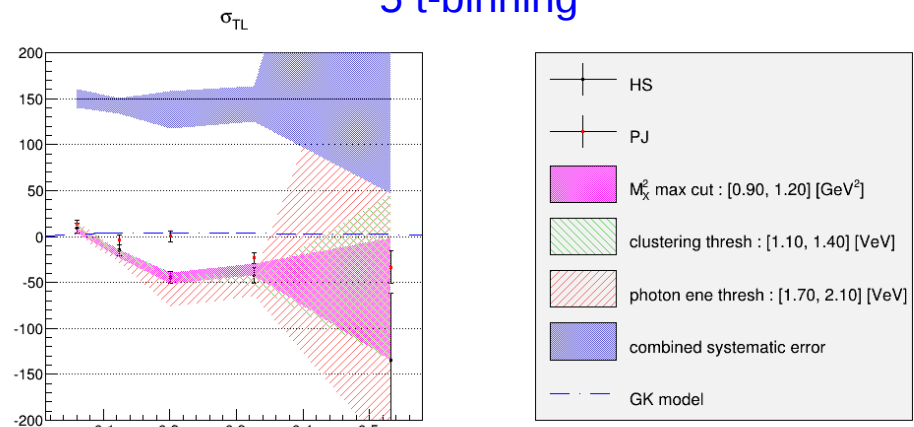
Statistics decreases.

Cross-section with systematic errors



	T+L	t1	t2	t3	t4
Mx2 max cut		+2.4% -2.1%	+4.0% -1.3%	+0.10% -6.4%	+0.68% -3.2%
clus_thresh		+2.8% -0.0%	+8.4% -0.0%	+6.5% -0.0%	+1.6% -5.1%
Photon enemim		+3.4% -1.9%	+1.3% -11.1%	+3.4% -1.9%	+0.0% -13.1%
total		+5.0% -2.8%	+9.4% -11.1%	+7.3% -6.7%	+7.8% -14.1%

5 t-binning



	T+L	t1 : [0, 0.48] GeV ²
Mx2 max cut		+0.0% -2.3%
clus_thresh		+3.8% -0.0%
Photon enemim		+0.0% -2.9%
total		+3.8% -3.7%

Conclusion

- Photon energy threshold should be far away from the clustering threshold.
 - Due to simulation photon energy smearing after the clustering.
- Low statistics give effects to systematic error.

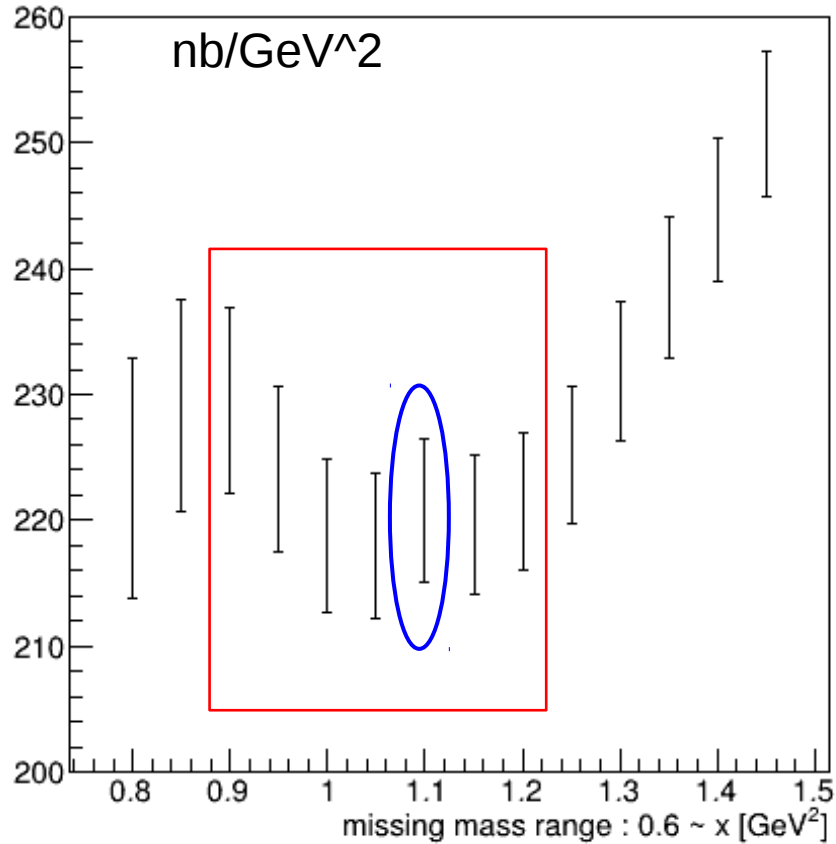
Outlook

- Future plans
 - Change cuts & t-binnings.
 - Loosen the Minv cuts.
 - Sys. err. calculation on Mx2 min., max, Minv min. and max..
 - Higher clustering threshold.
 - Thesis writing.
 - Helicity dependent term.

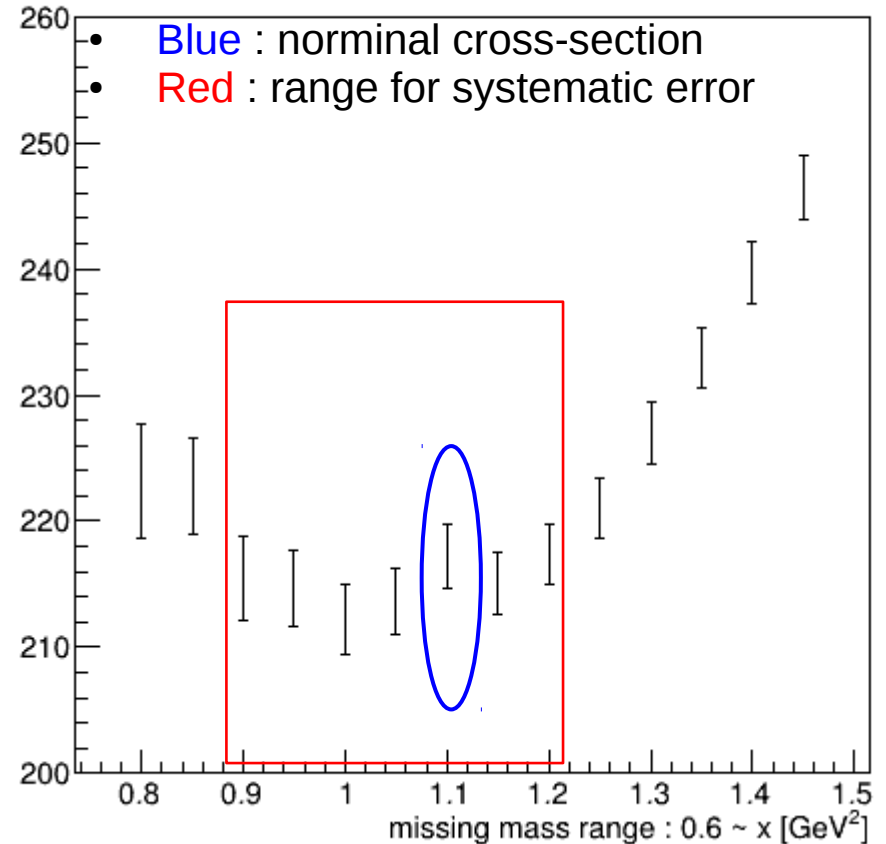
Backups

Statistical errors

$$\sigma_T + \epsilon\sigma_L t^2$$

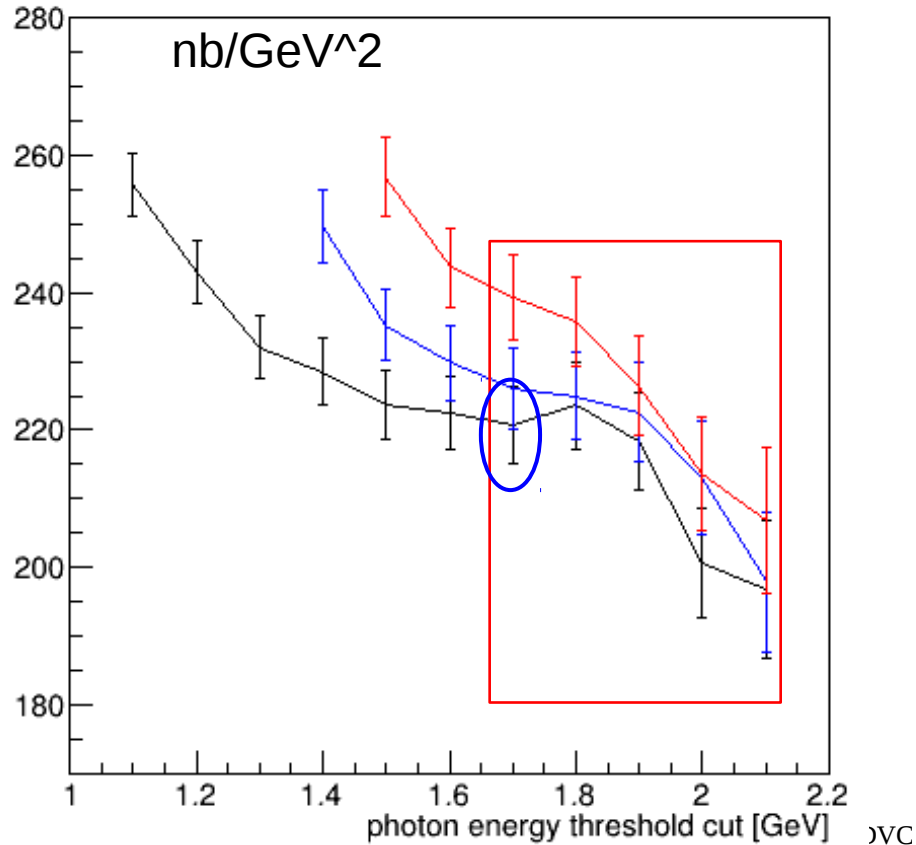


$$\sigma_T + \epsilon\sigma_L \text{ Integrated over } t \text{ \& } \phi$$

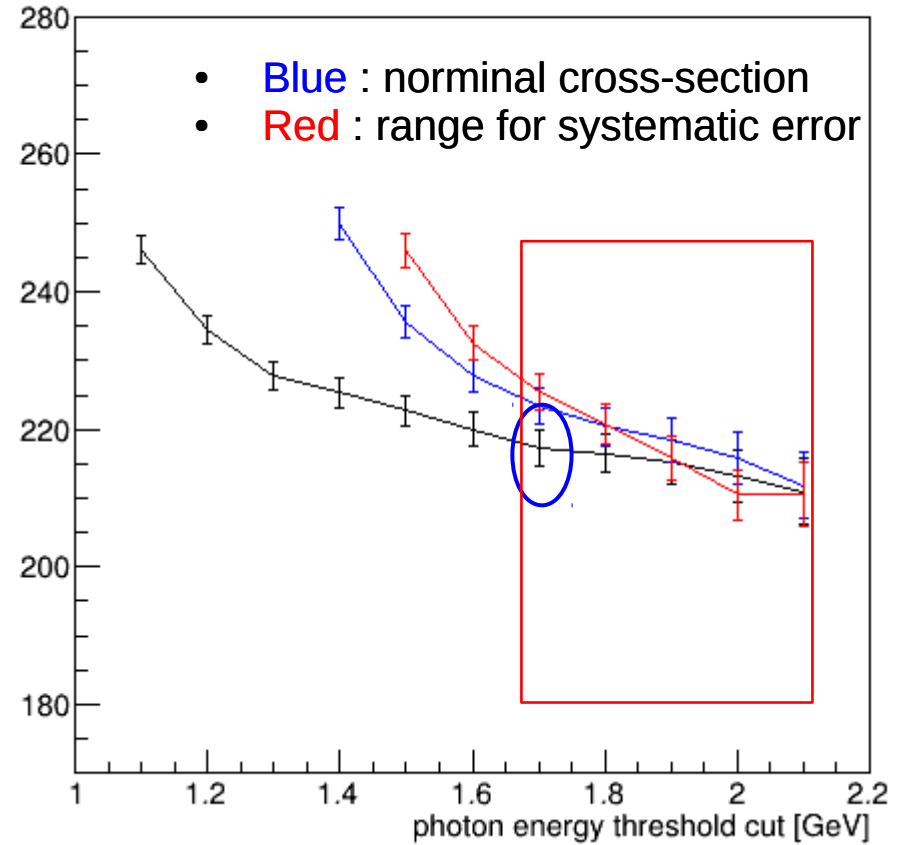


Statistical errors

$$\sigma_T + \epsilon \sigma_L t^2$$

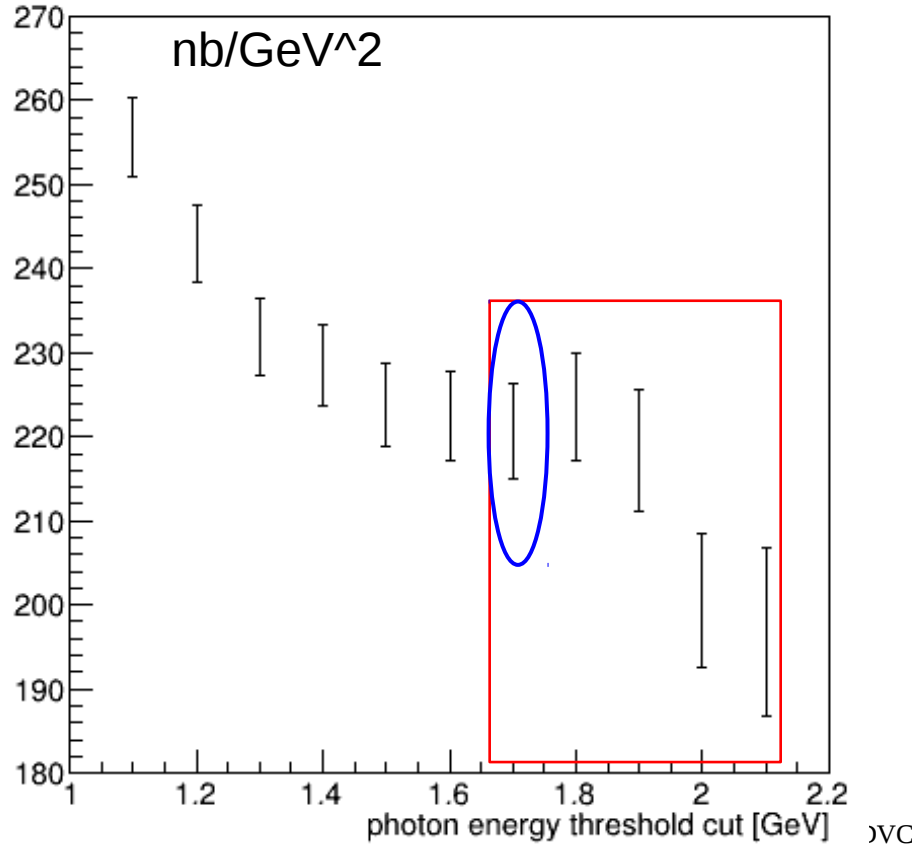


$$\sigma_T + \epsilon \sigma \text{ Integrated over } t \text{ \& } \phi$$

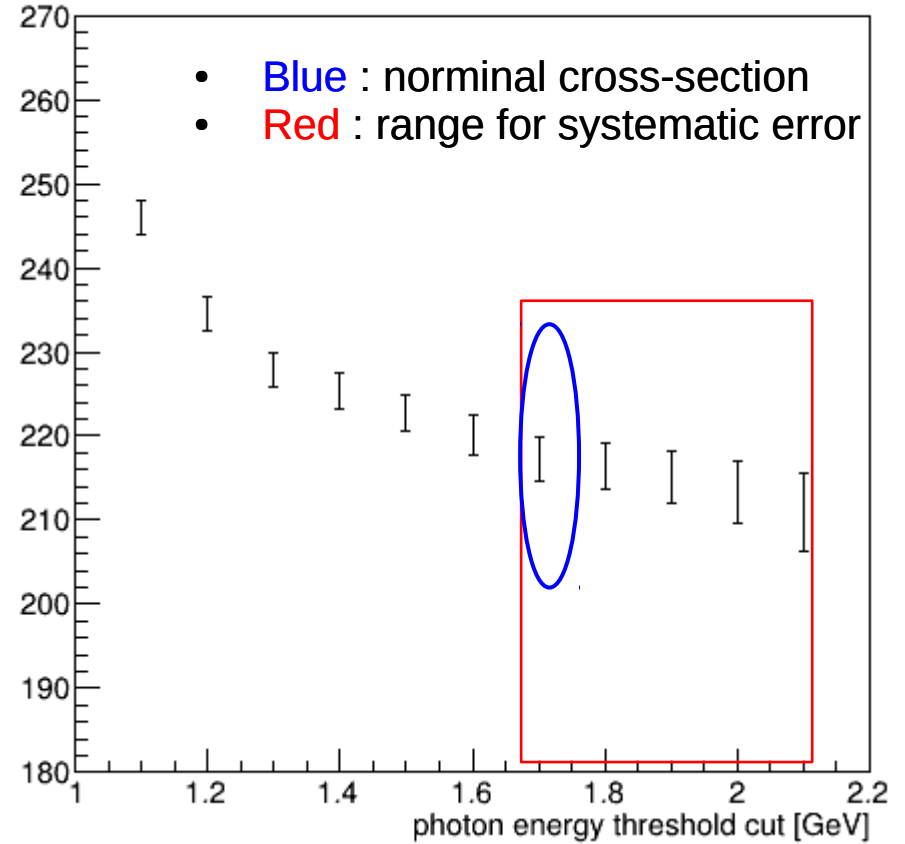


Statistical errors

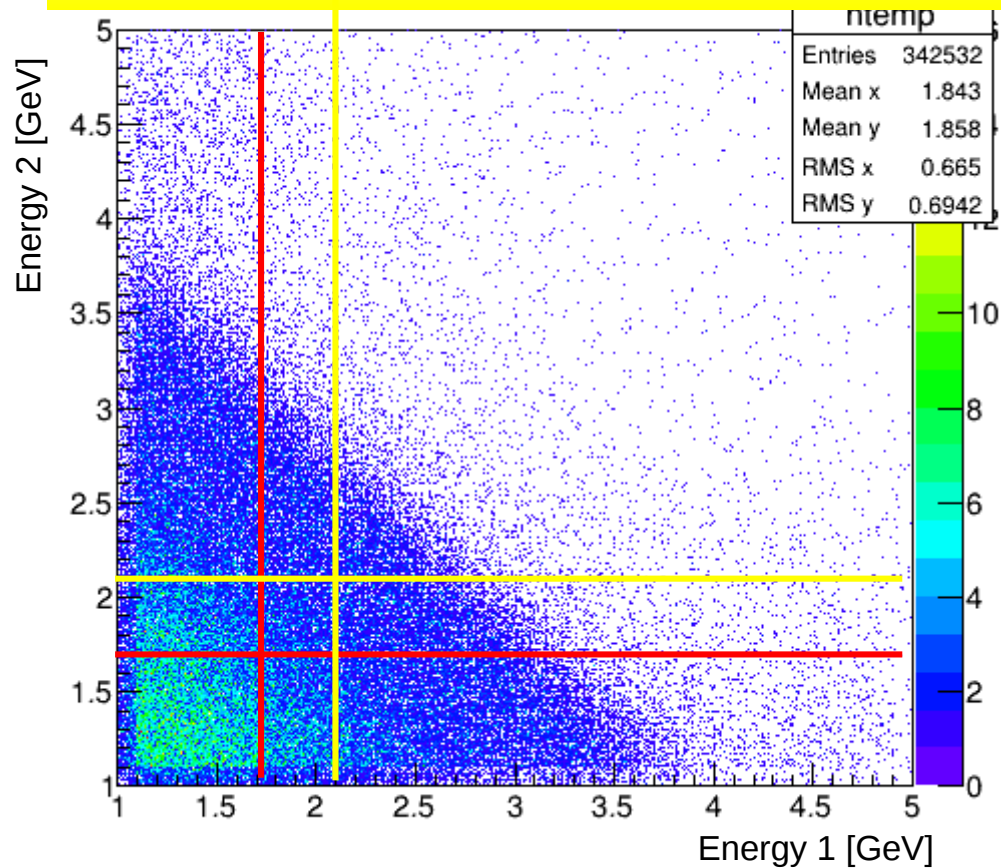
$$\sigma_T + \epsilon\sigma_L t^2$$



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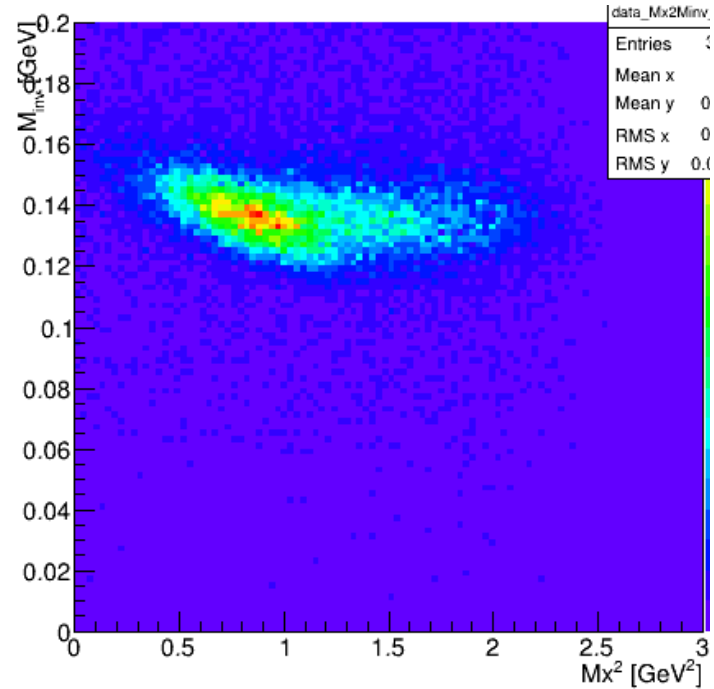


Photon energies

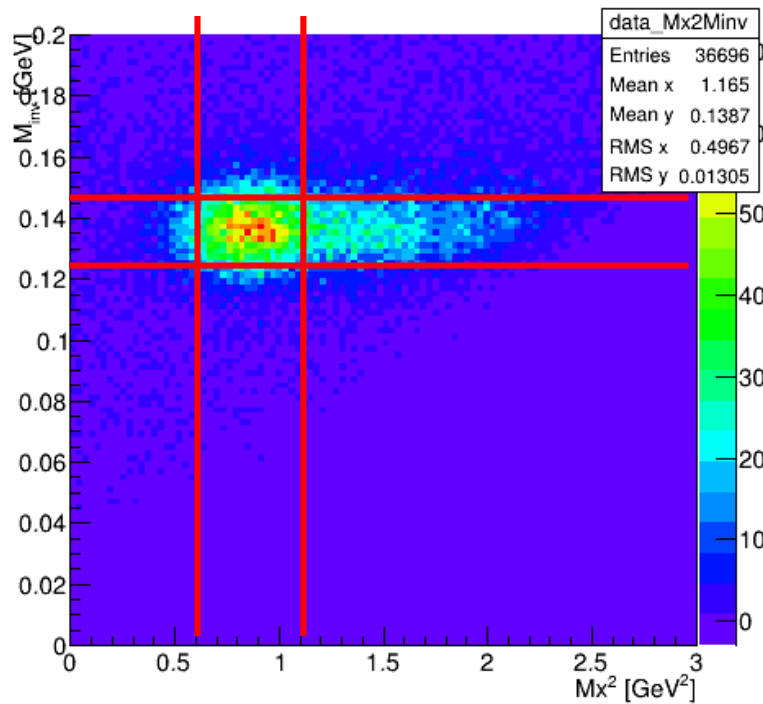


Mx2 rotation

Before rotation



After rotation



Mx2 and Minv should be independent variables

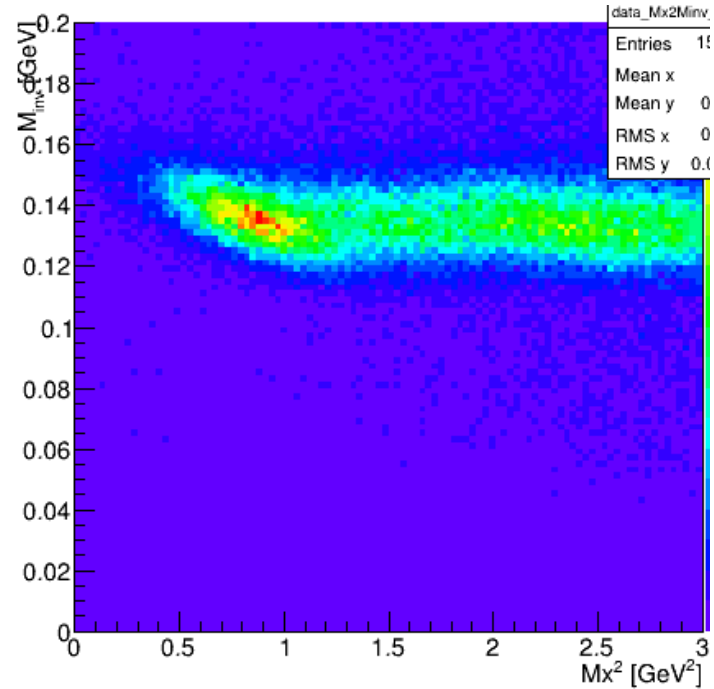
Rotate Mx2-Minv coordinate

$$Mx2_{\text{rot}} = Mx2 + C \cdot (Minv - M_{\pi 0})$$

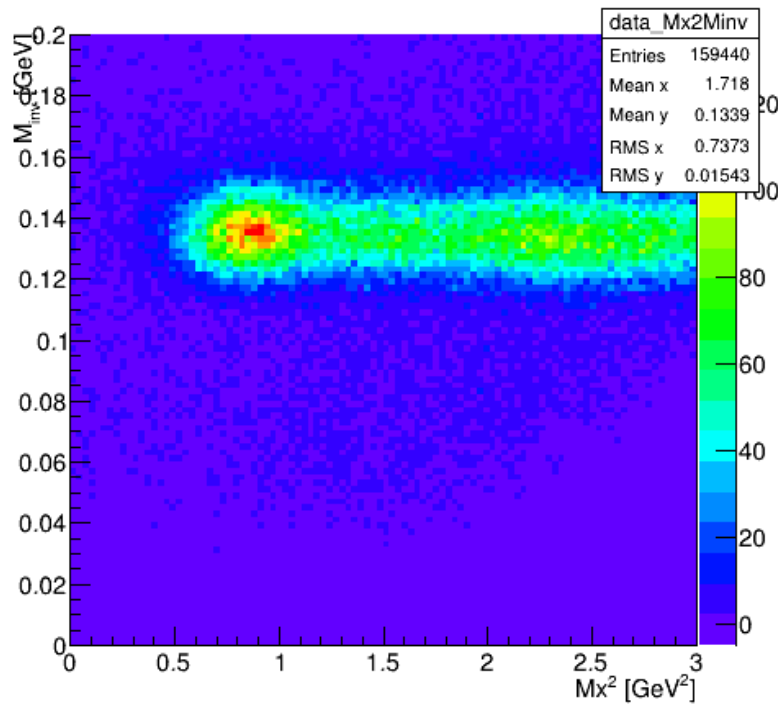
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Before rotation



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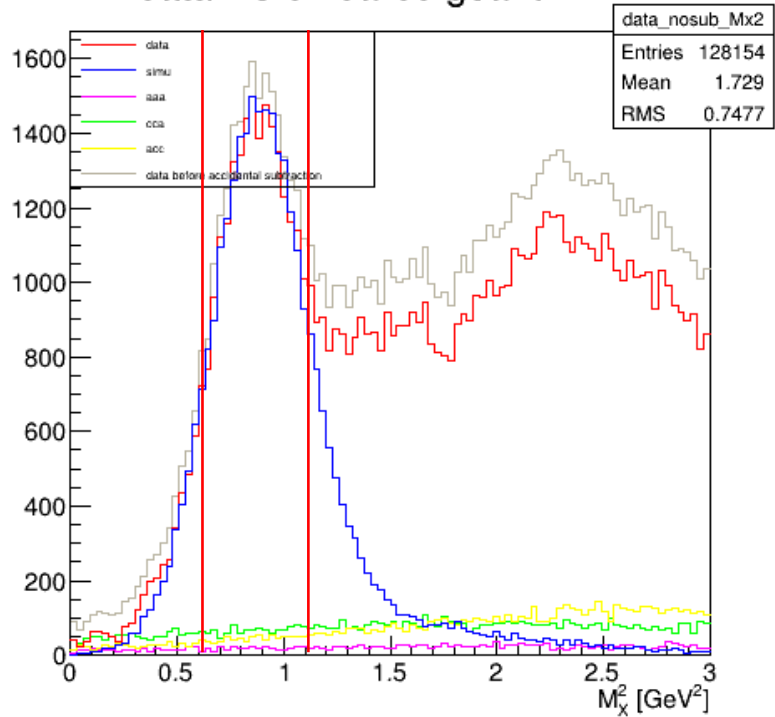
Rotate Mx2-Minv coordinate

$$M_{x^2_rot} = M_{x^2} + C \cdot (M_{\text{inv}} - M_{\pi^0})$$

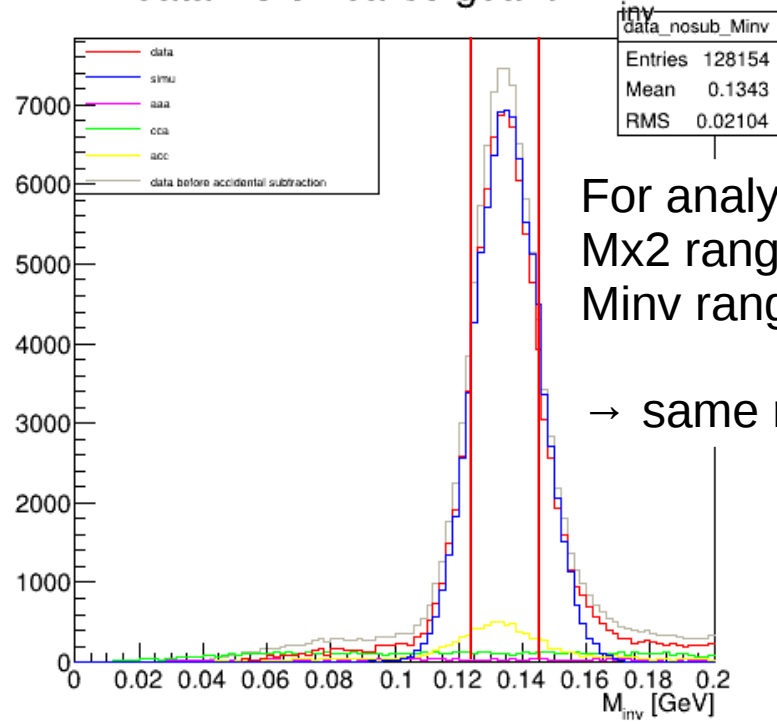
$C = 20$
 M_{π^0} : π^0 invariant mass

Smearing result

data VS smeared geant4 M_x^2



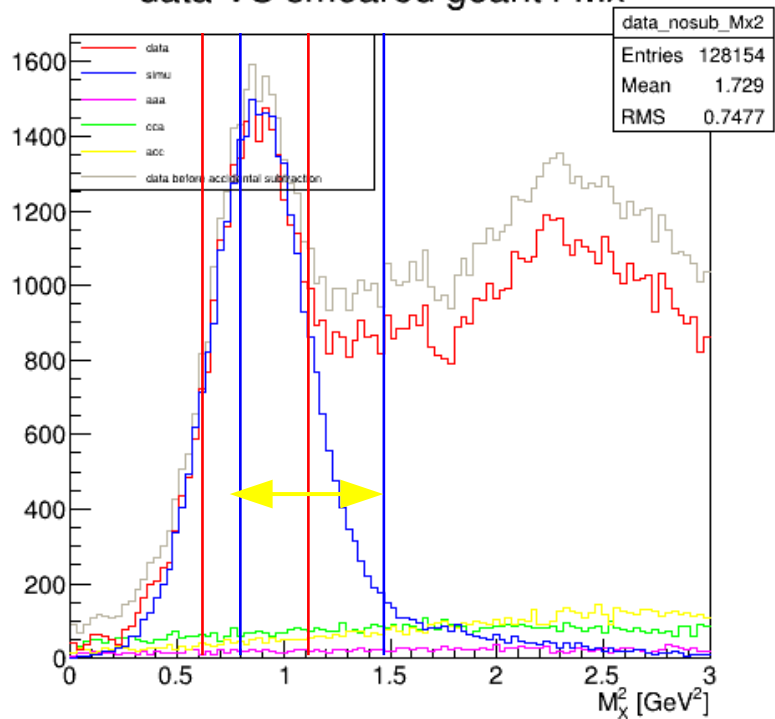
data VS smeared geant4 M_{inv}



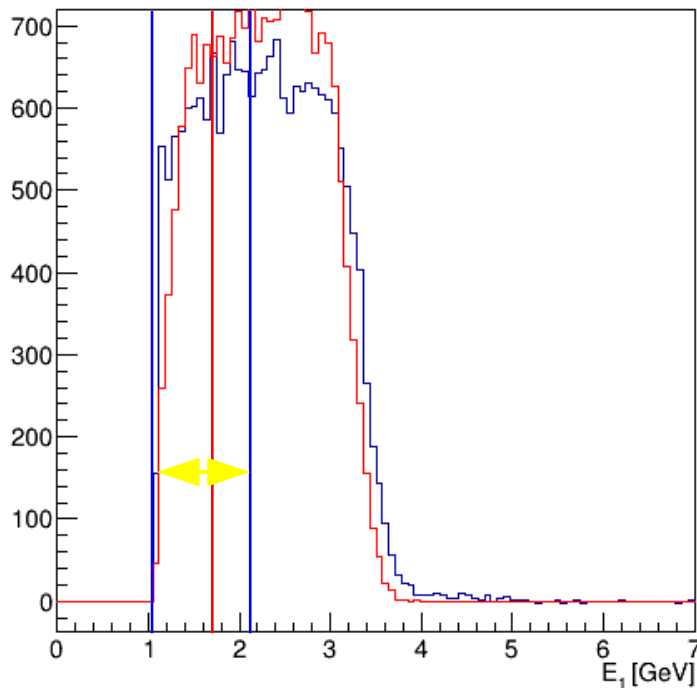
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Variables for systematic error calculation

data VS smeared geant4 M_x^2



photon1 energy. M_x^2 rage : [0.6, 1.1] [GeV²]. Clustering threshold : 1.10 GeV



Variables

- M_x^2 max cut : [0.8, 1.45] GeV²
- Photon energy threshold : [1.10, 2.10] GeV
- Clustering threshold : [1.10, 1.40] GeV