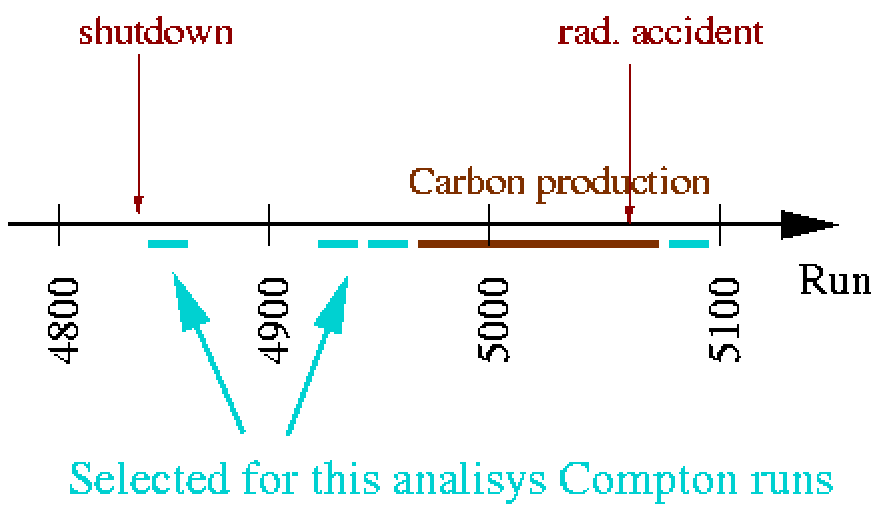
Compton data analysis:

Selection of data sample for analisys:

The purpose of this analisys is to check quality of the data (systematcis, resolution, etc.) and consistency of used Monte–Carlo (efficiency calculations, resolution VS data resolution)

Clean data have been selected:



Runs with very low statistics and bad beam conditions have been rejected

It is important to get maximum of resolution for a precision measurement

Kinematical constrains have been used to improve resolutions

Compton scattering has more kinematical constrains (4)

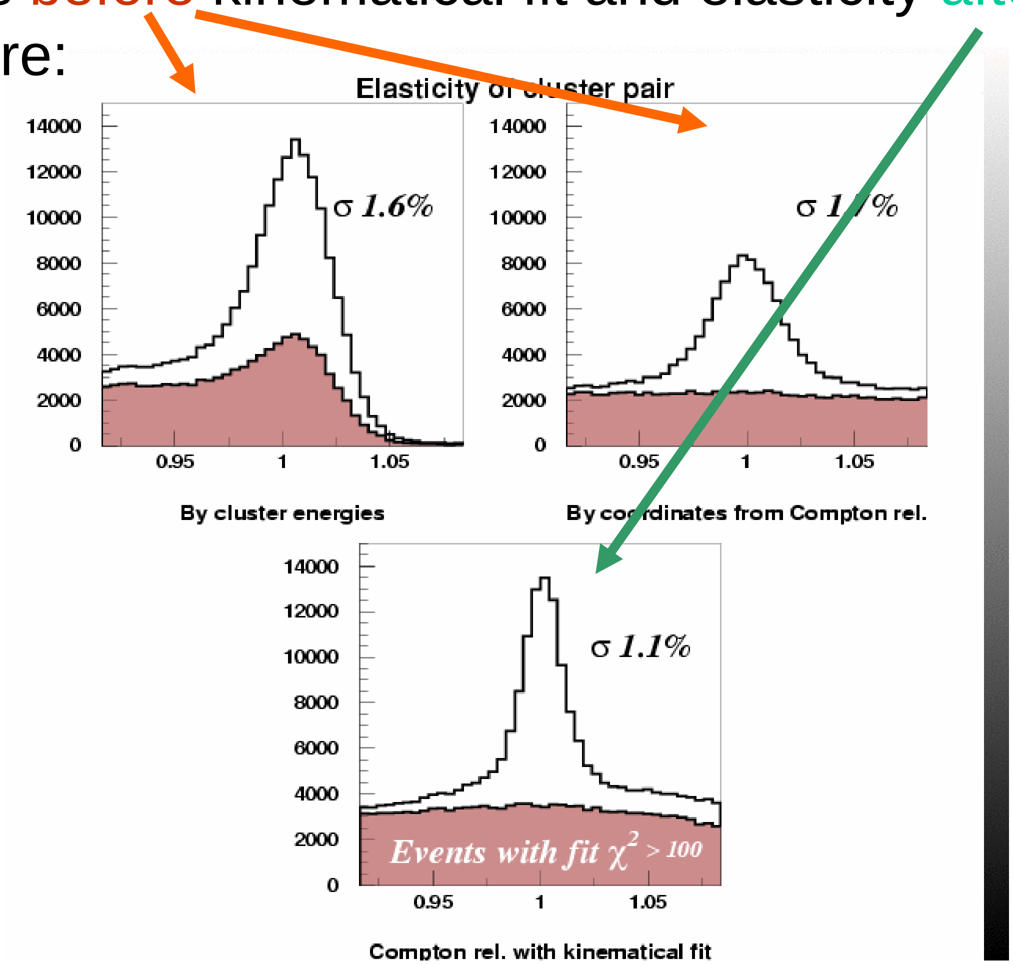
between measured variables than π^0 (2)

- ***elasticity: Epair = Ebeam***
- ***momentum conservation:*** $\vec{Pt} = \vec{0}$ ***or*** $(\Delta\phi = 180^0;\ \Delta\theta_{||} = 0)$
- ***Compton kinematical relations:*** $\theta_\gamma = f_\gamma(E_\gamma);\ \theta_e = f_e(E_e) \sim f_\gamma(E_e)$

for PrimEx geometrical acceptance with precision of 10urad or better

How much does kinematical fit improve resolution? - Elasticity

- Elasticity distribution by clusters energies and “compton” energies before kinematical fit and elasticity after applying fit procedure:

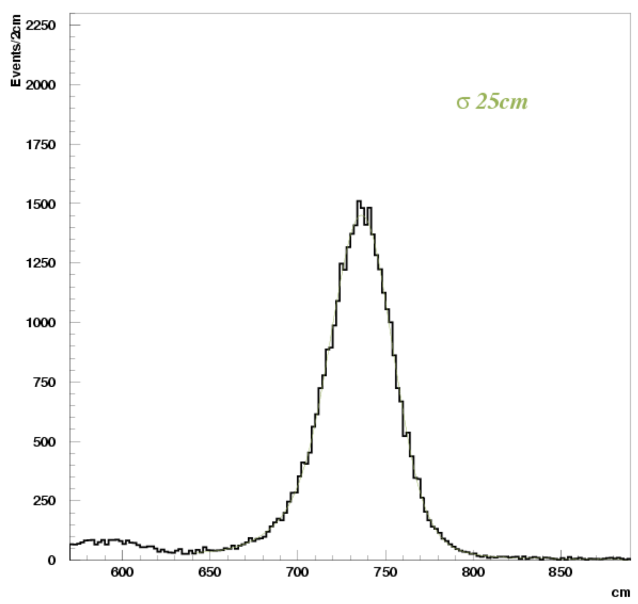


Constrains used for this distribution:

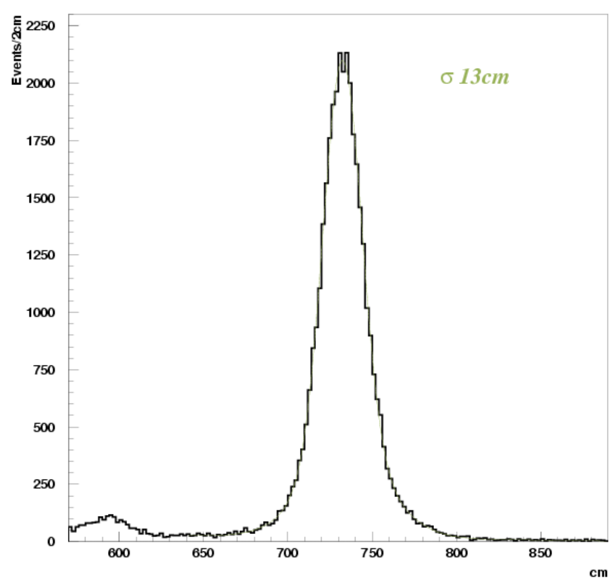
- ~~Elasticity~~
- Pt = 0
- Compton relations

How much does kinematical fit improve resolution? – distance production point

- Using Compton relations between clusters coordinates and energies (if we know beam energy), we can reconstruct Z of production point. Below are distributions for this Z coordinate before and after applying fit procedure:



Be: σ = 25 cm



Be: σ = 13 cm

Constrains used for this distribution:

- Elasticity
- Pt = 0
- ~~Compton relations~~

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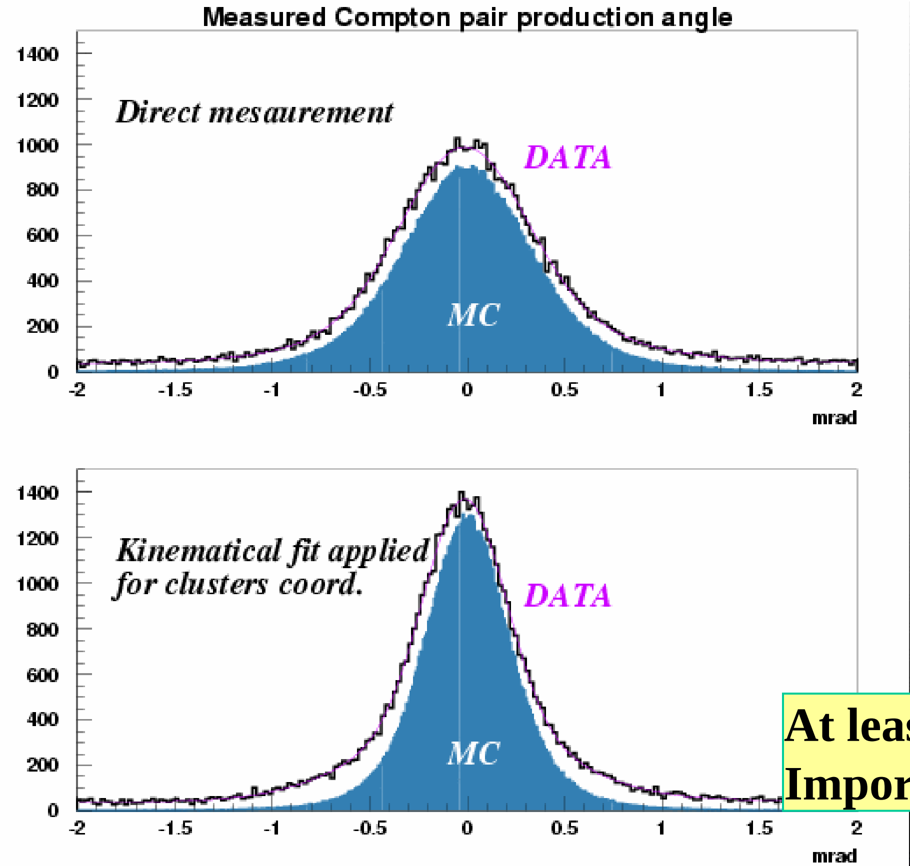
How much does kinematical fit improve resolution? – Compton production angle

- Compton production angle is very close to 0. All that we are measuring is our resolution. Below are distributions for measured production angle before and after applying fit:

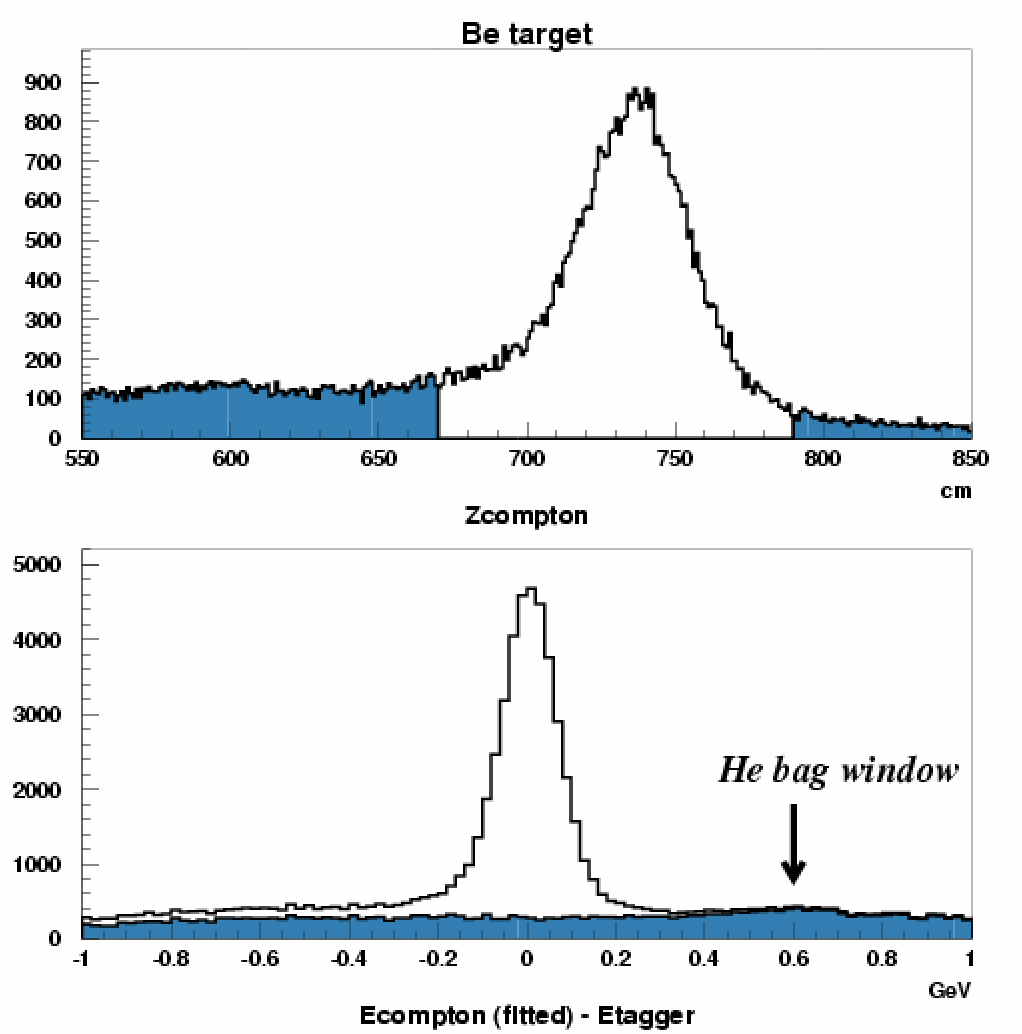


Constrains used for this distribution:

- Elasticity
- ~~Pt = 0~~
- Compton relations

At least 1.5 times improvement.
Important for π^0 measurement also.

The kinematical fit procedure with elasticity and transverse momentum constrains is picking up only elastic events (no need of extra cut on it). To get the number of signal events we used fit of production Z distribution



Distribution for distance to Compton production point (no fit applied, selected sideband is shown solid)

Distribution for "$E_{compton}$" and E_{tagger} difference (with fit applied, solid distribution is for sidebands from the top plot). Sideband regions show no elasticity peak.

Simulation features important for precision analysis (1)

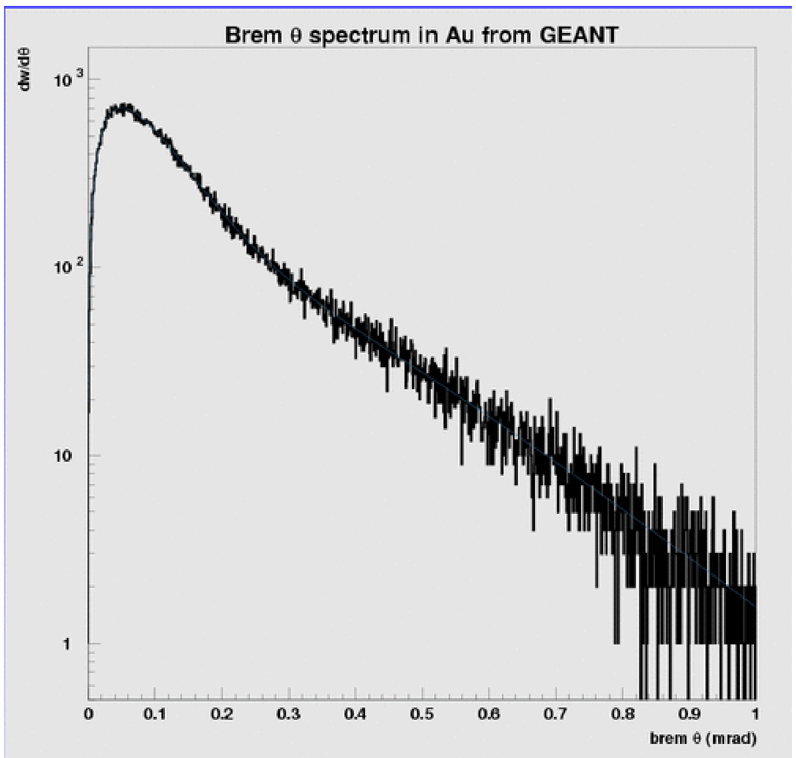
- **Beam coordinate** and angular divergence are included (needs further tuning). Beam alignment VS Hycal is taken from PrimEx database
- **Target absorption** is generated automatically since beam is traveling from the target upstream surface to uniformly pre-generated interaction point
- **HYCAL gains** are taken from the database and smeared by 0.5%-0.7% to get reasonable energy resolution. May be we have to create a special database entry for smeared gains
- **Photon flux** is generated proportionally to the measured flux for each given run
- **Embed technique:** Result of MC-generation is mixed with a clock-trigger skim-file corresponding to the given run, simulating randomly picked up background.
- **Beam trips** are to be switched off both for the clock-skims and for data.
- **Sparsification** level of 5 counts is applied for MC-data
- **Electronics noise** is simulated according to the ped_sigma from the database

Simulation features important for precision analysis(2)

- **Light-collection non-uniformity along the PWO-crystal axis is to be inserted into MC in the nearest future (not done yet). Real Cherenkov light for lead glass with absorption due to reflections and attenuation length is included now.**
- **Small hardware details far from the beam line are not included to make the code more transparent.**
- **TAGM bank pattern from the data (Eugene advice) is to be picked up to make simulation more realistic (to be done in the nearest future)**
- **Generator for contamination by downstream Compton and e+e- pairs is to be included and used to simulate background on the proportional to observed level**
- **Output is to be converted to the raw-data format (with maybe some unused trigger bit assigned to MC events)**

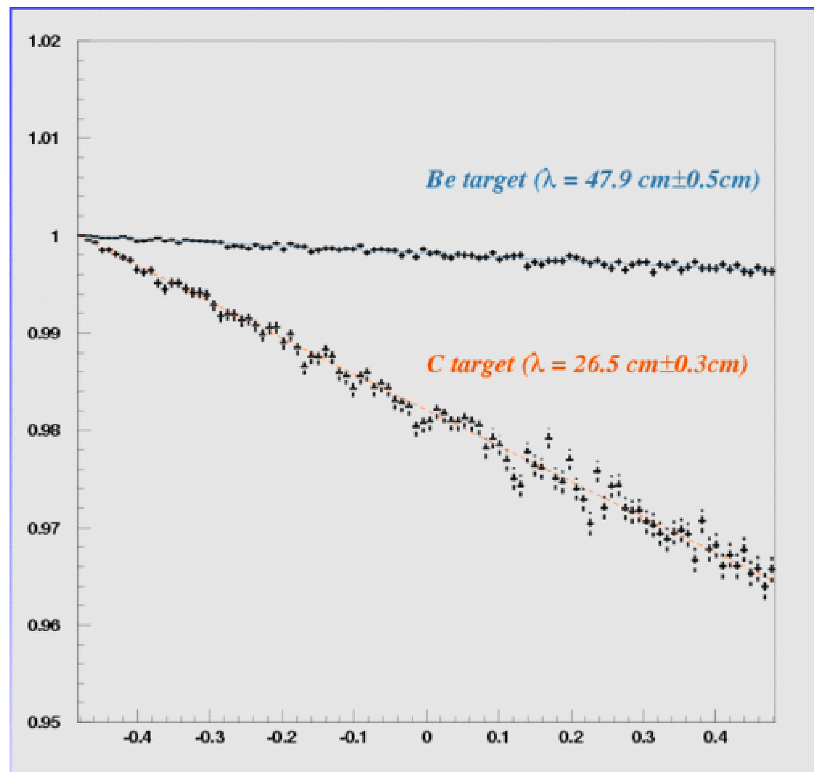
Overview of some simulation details:

Bremsstrahlung beam divergence in the gold PrimEx radiator is convoluted with e-beam parameters (σx, σy = 0.01cm; σθx, σθy = 0.1mrad, to be verified)



- **Beam absorption will automatically give exponential shape of generated point distribution along the target thickness with λ ~ 9/7 X0**

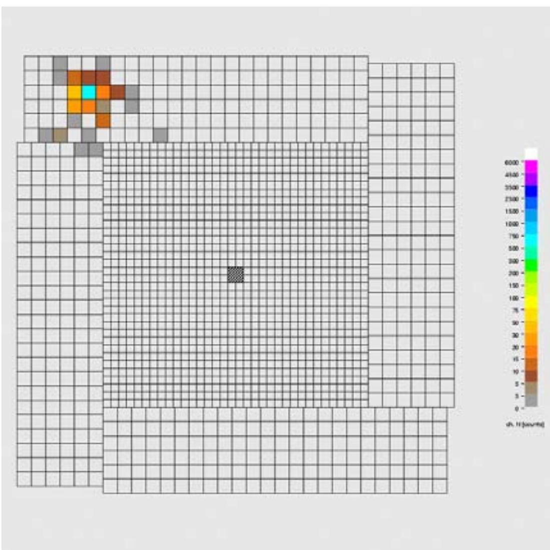
Probability to generate event on the given Z the rest of events is counted absorbed



Z coord. of generated interaction inside the target (in "target thickness = 1 units", Be ~1.8mm; C ~9.7mm)

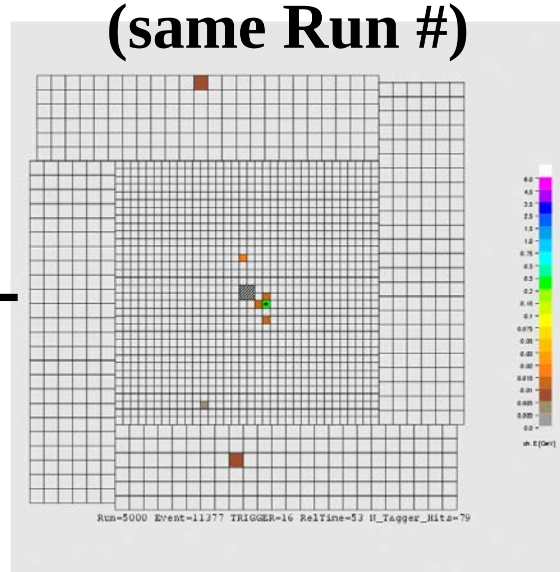
Mixing MC events

MC event



+

Clock-trig.
(same Run #)



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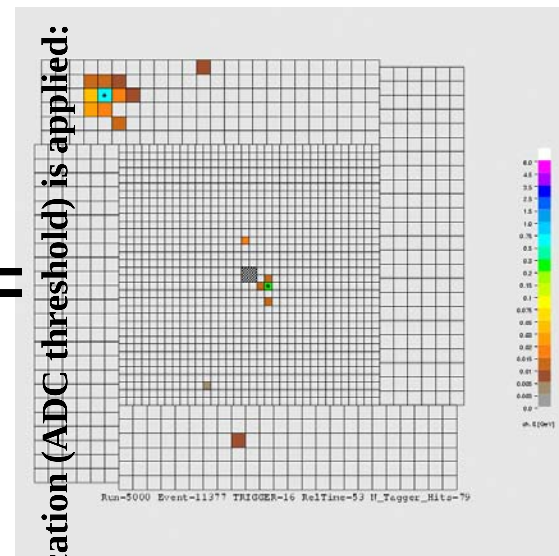
Final product

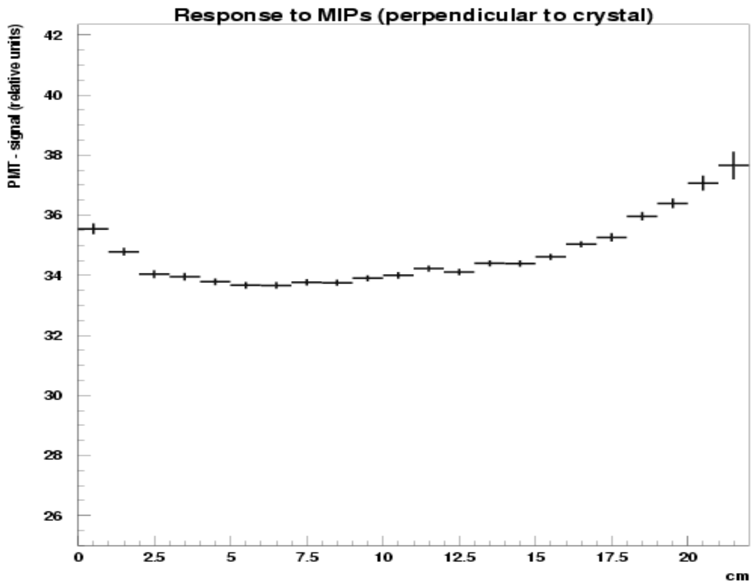
Sparsification (ADC threshold) is applied:



Experimental non-uniformity of the light collection has to be included to make coordinate resolution more close to the data

- **Experimental data of PWO study (IHEP, Protvino, data are kindly given by V.Kravtsov)**

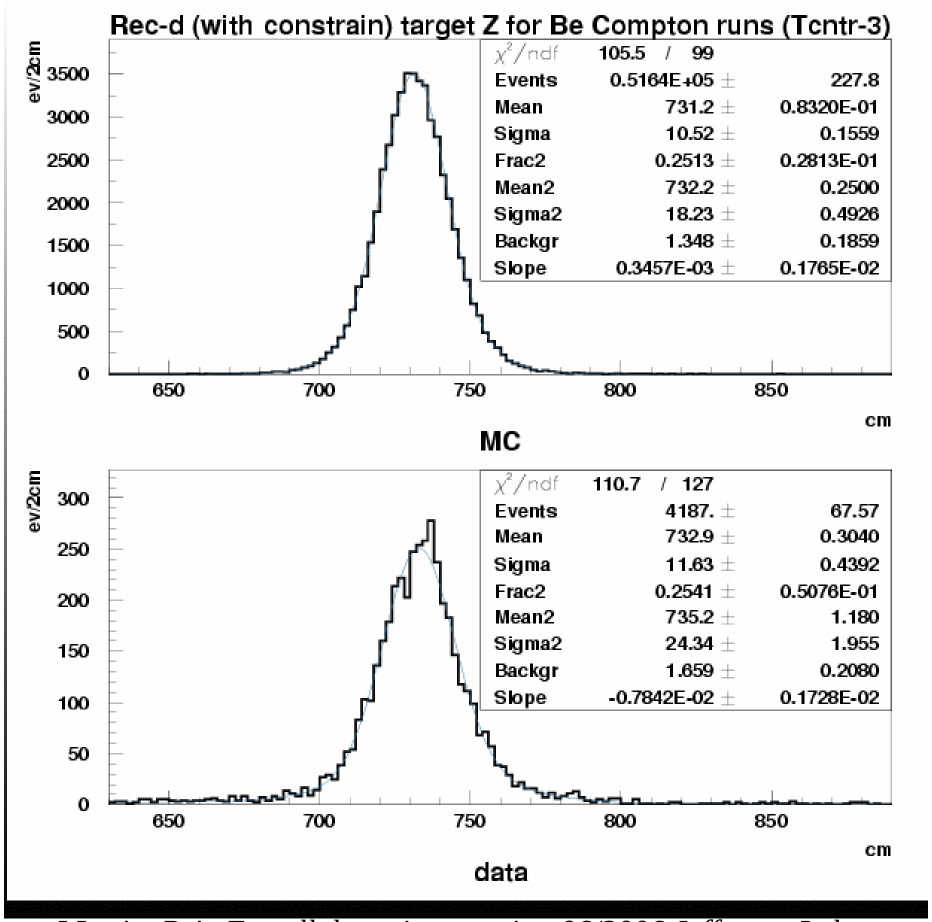
Example of the response to transverse MIPs exposition along the crystal



PMT side

Comparing shape of the important distributions: Be target, MC VS data

- **Distribution for reconstructed Z (after kinematical fit), used for counting of Compton events**



- **MC plot, double gaussian fit:**

σ**1 (75%events) ~10.5cm**

σ2 **(25%events) ~18…19cm**

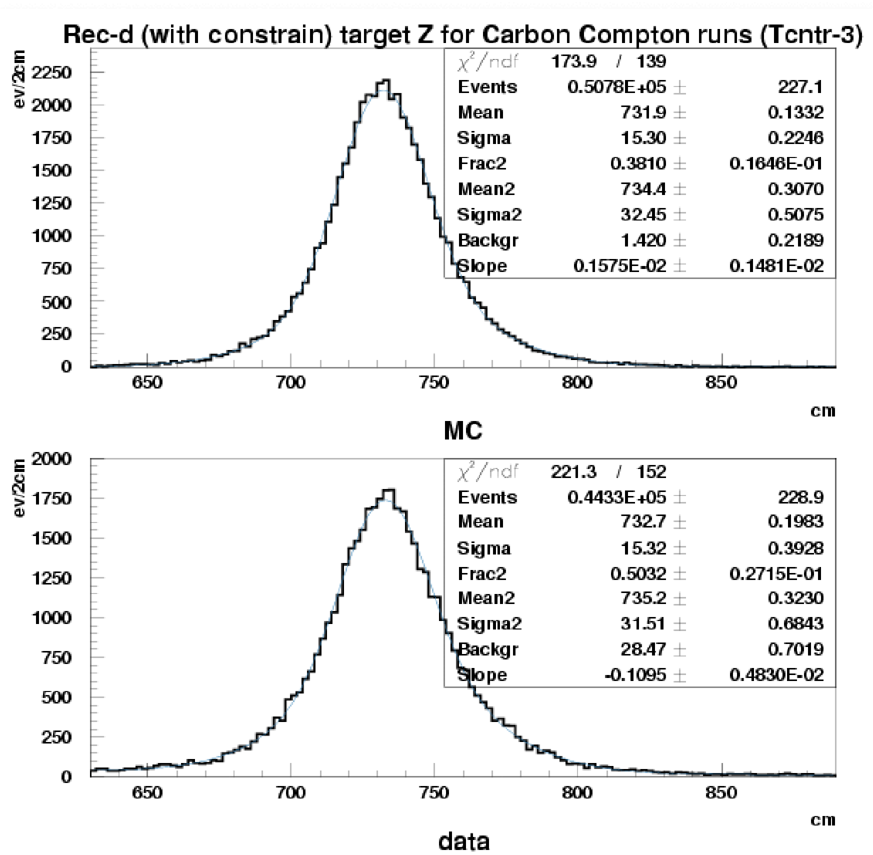
- **Data plot, double gaussian fit:**

σ**1 (75%events) ~11.6cm**

σ**2 (25%events) ~22…26cm**

Comparing shapes of important distributions: Carbon target: MC vs DATA

- **Distribution for reconstructed Z (after kinematical fit), used for counting of Compton events**



- **MC plot, double gaussian fit:**

σ**1 (62%events) ~15.3cm**

σ2 **(38%events) ~32…33cm**

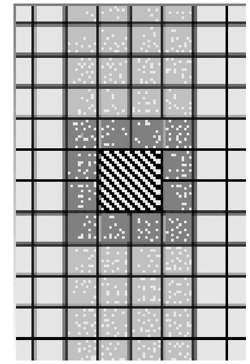
- **Data plot, double gaussian fit:**

σ**1 (50%events) ~15.3cm**

σ**2 (50%events) ~31…32cm**

Cuts used in this analysis:

- **Energy:**
  - **one cluster: greater than 0.5 GeV**
  - **cluster pair: greater than 3.8 GeV (from skim)**
- **Geometry:**
  - **Absorber region is excluded (4x4 modules)**
  - **Crystal part of Hycal only**
  - **Optionally 4 central vertical rows were excluded (e+e- background suppression, got this idea from Kelly's analysis)**

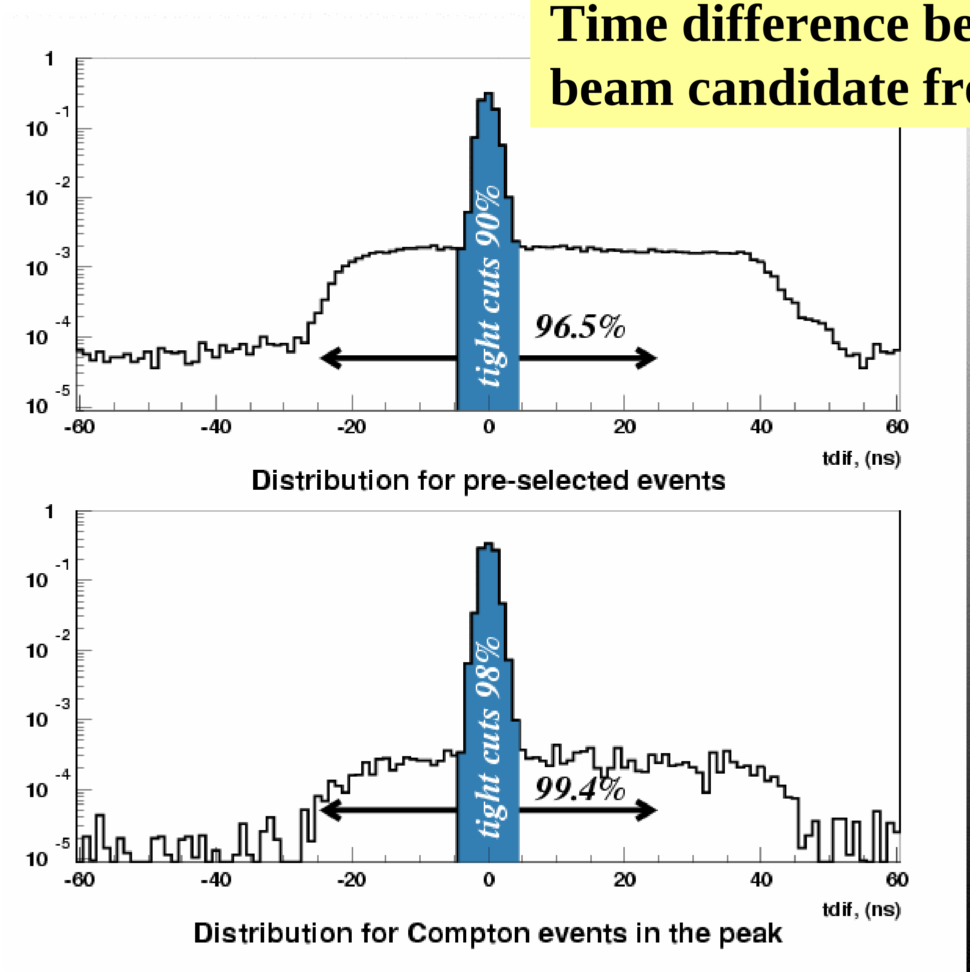


- **Timing:**
  - **Very loose tdiff cut (+/-25ns ~ TDC dead time).**
  - **Only closest in time beam candidate was selected (no double counting).**
  - **Optionally narrow tdiff cut +/-4ns was used to check systematics**

- **Events with very high χ^2 (>100) of the kinematical fit were rejected to suppress background, which is important for separation of more wider part of the signal from the background. Systematics of this cut is controlled.**

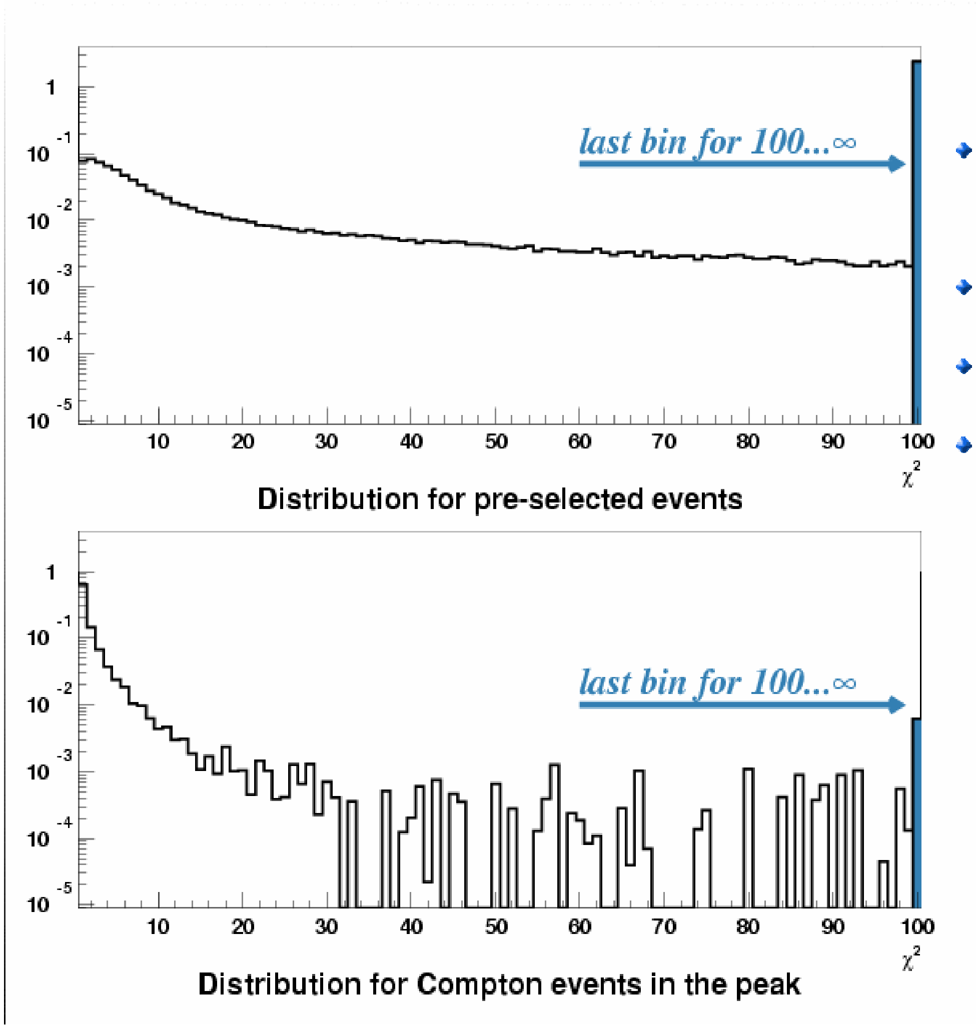
Some sources of systematics:
timing window selection

Time difference between Hycal trigger and beam candidate from TAGM bank



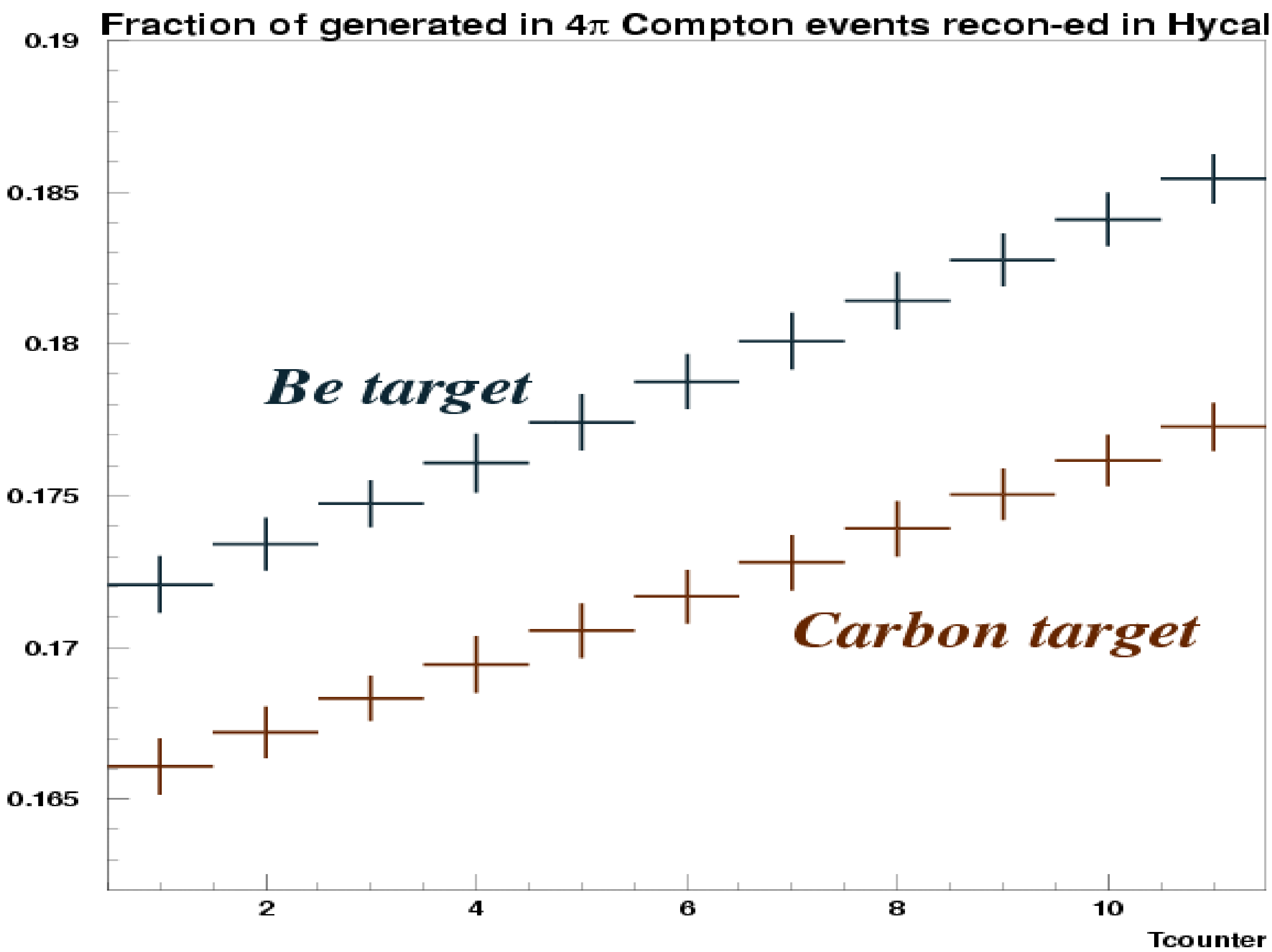
- **Selecting reasonably narrow timing window may decrease number of events at 1.5-2% level**
- **Selecting only "the best in time" beam candidate may reject up to 0.5% events for these Compton runs**

Some sources of systematics:
χ^2 of kinematical fit



- Fraction of rejected events by $\chi 2<100$ cut:
- Be: data 0.6%; MC 0.25%
- Carbon: data 1.9%; MC 1.1%
- This correction has not been applied to the calculated efficiency and has opposite sign in comparison with possible "tdif correction" (if we will select narrow timing window).

Results of efficiency simulations:



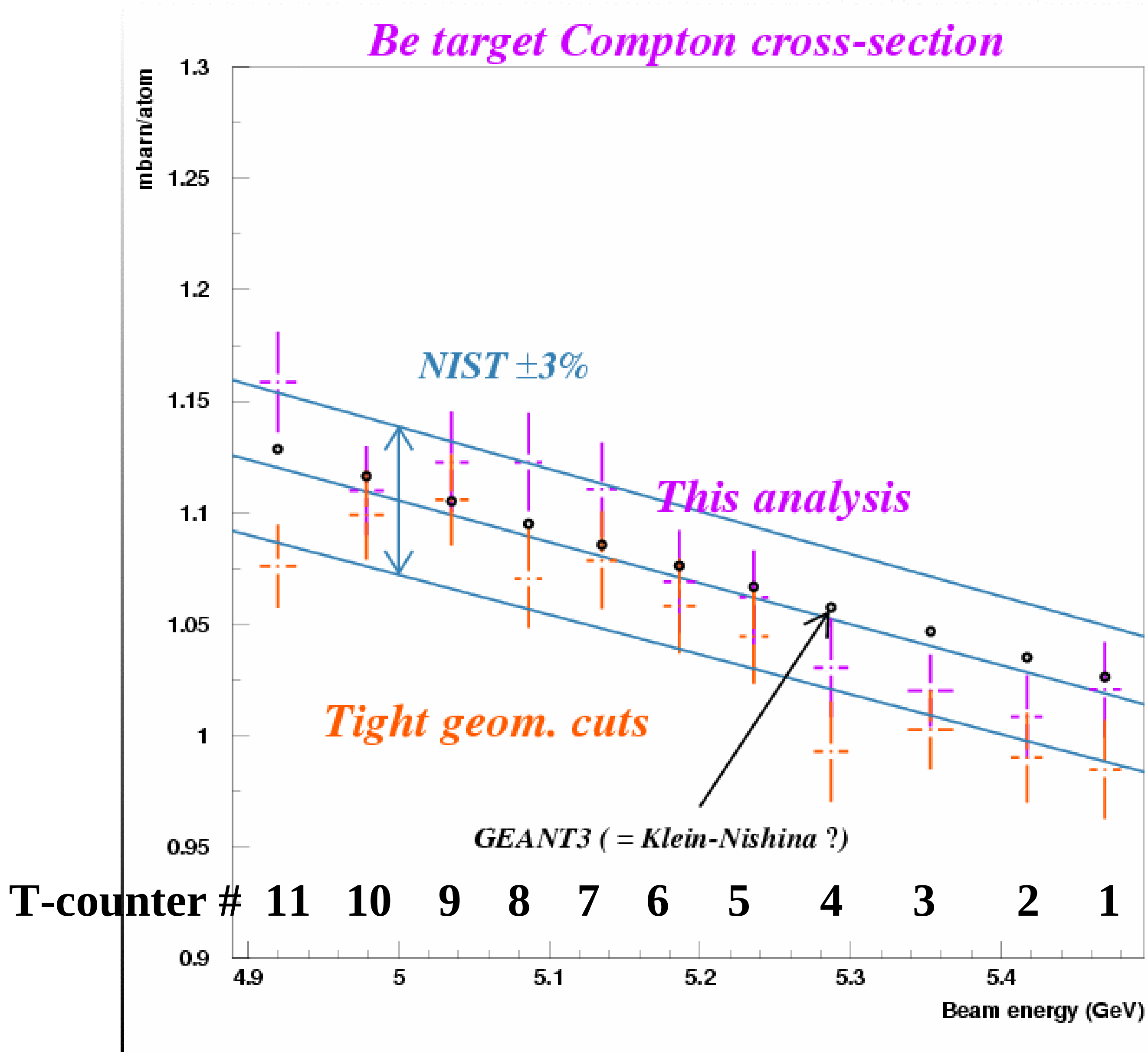
Error budget of this Compton analysis:

- **General systematics of beam, flux, tagging ratio, etc.**

are not considered in this study

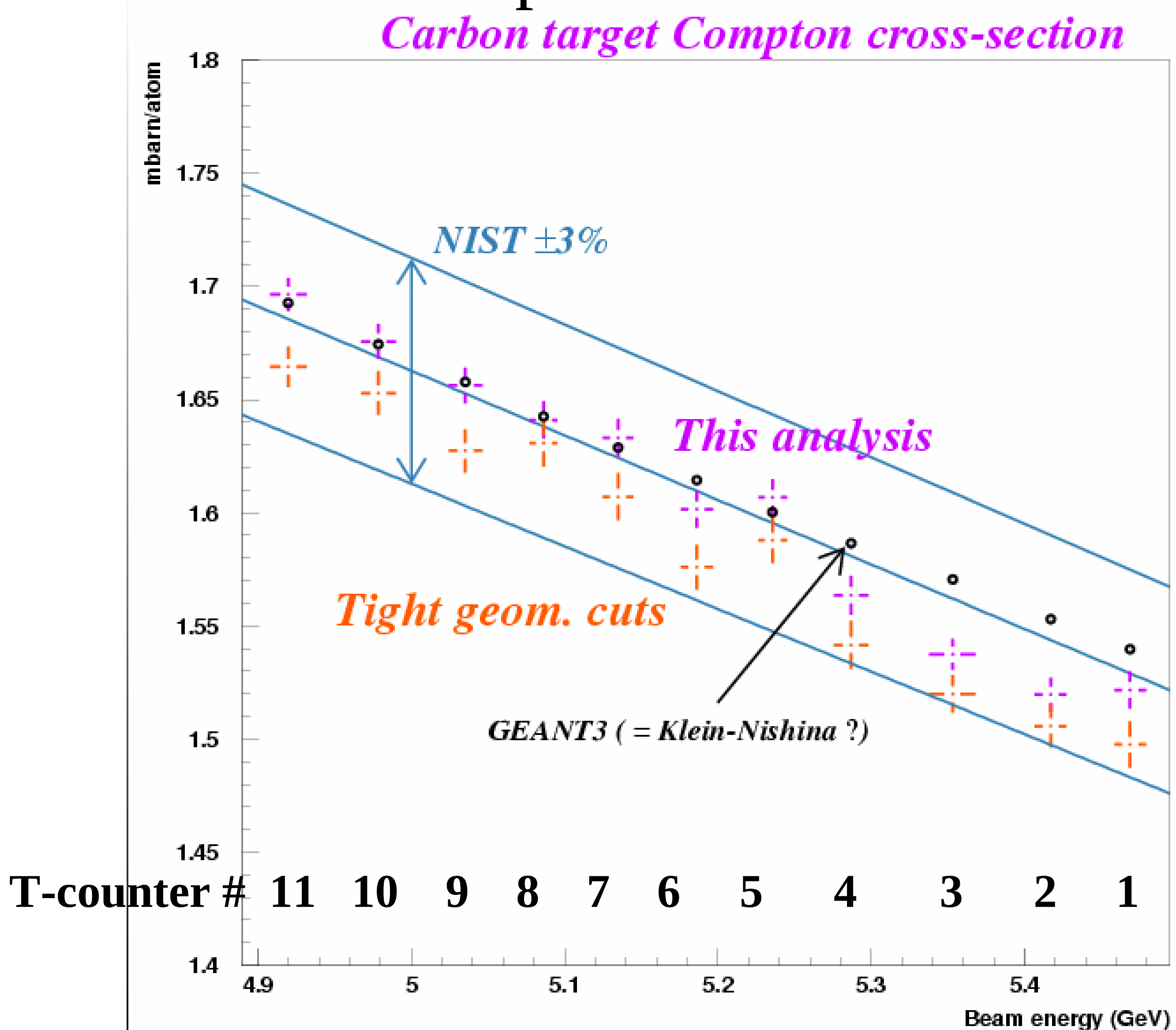
- **Geometry cuts variations (rejecting e+e- background) shift all data points down (decreasing cross-section) by -1...-1.5%**
- **Narrow timing window of 4ns shifts final result down (all data points together) by ~ -2%**
- **"The best in time beam candidate" correction expected to be 0…+0.5%**
- **kinematical fit $\chi 2$ <100 cut: correction is estimated as +0.3% for Be target and +0.8% for Carbon target**
- **Signal / Background separation uncertainties are estimated to be on 2% level by variation of applied cuts**
- **Simulation (GEANT3) systematics need further investigation and their level have to be verified (hopefully within 3% for current stage).**

cross-section for each production T-counter: Be



NIST (National Institute of Standards)

cross-section for each production T-counter: C



Normalized yield for all 11 T-counters together for each of used runs:

Normalized yield for each run is defined as:

$$y = \frac{N_{events}(run)}{F_L \Sigma w_i \sigma_i(table) L(tgt)}$$

Where: F_L – total flux for run;

w_i – fraction of total flux for i^{th} Tcounter

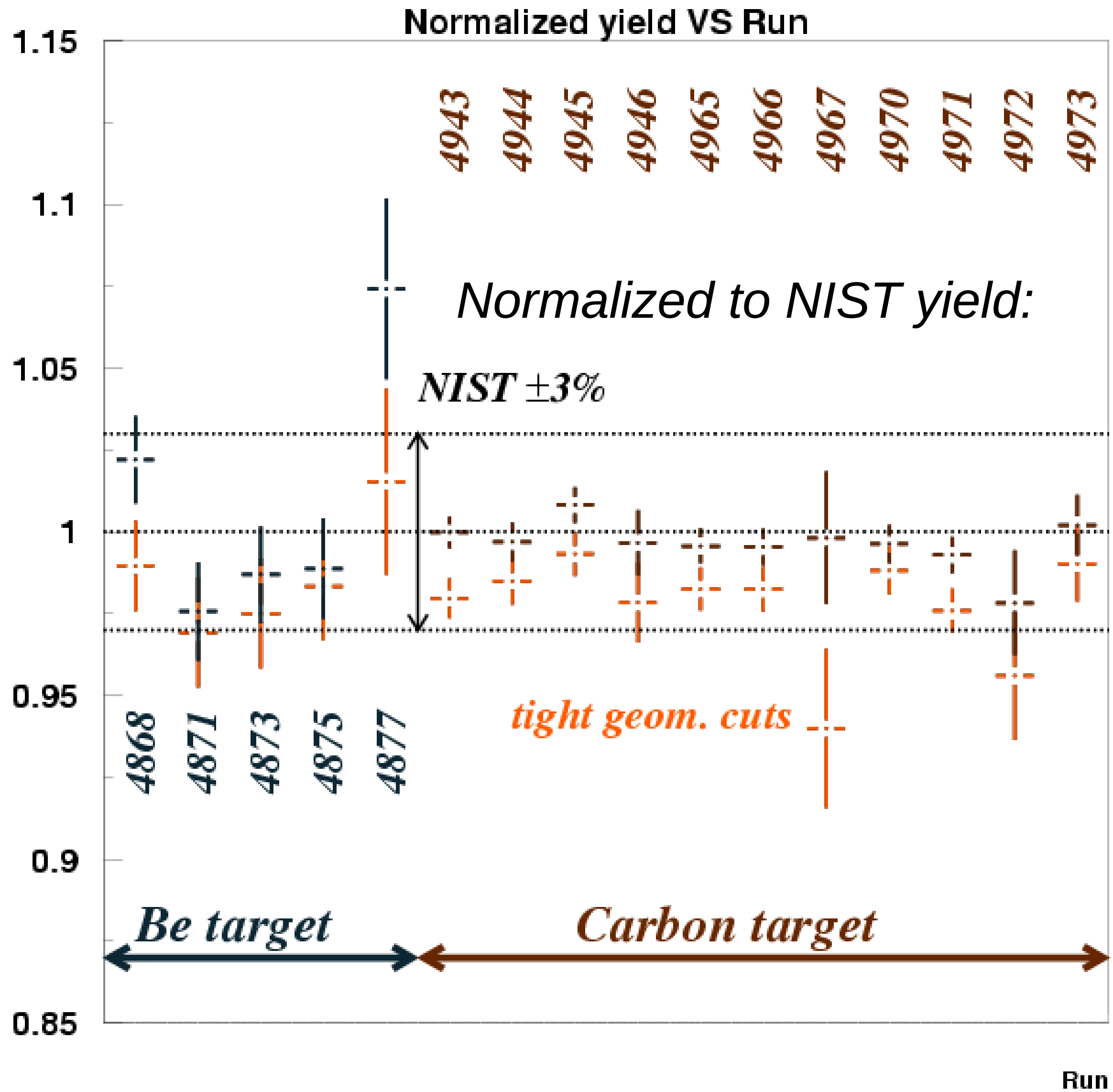
L(tgt) so called target luminosity;

$L = \rho\, l\, N_A / \mu$

(ρ – density; l – thickness;

μ - atomic weight)

σ_i = cross-section from the Table for the given T-counter energy



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Summary

- **There is agreement at ~3% level (statistical error) between cross-section for all production T-counters and for normalized run by run yield and Klein-Nishina formula**
- **Systematics of ~2-3% mostly comes from “timing”. This item might give different contribution into production data with 10 times higher beam current**
- **Signal / Background separation is at ~2% level of accuracy. Background generator and false beam candidate simulation are necessary.**
- **Monte-Carlo systematics is to be confirmed by further comparison with data.**
- **Alternative MC (like used one) is developed to confirm present simulations of our precision measurements**
- **Further extended study of the systematics required**