Status on in-beam angular distributions with AGATA

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Scientific context

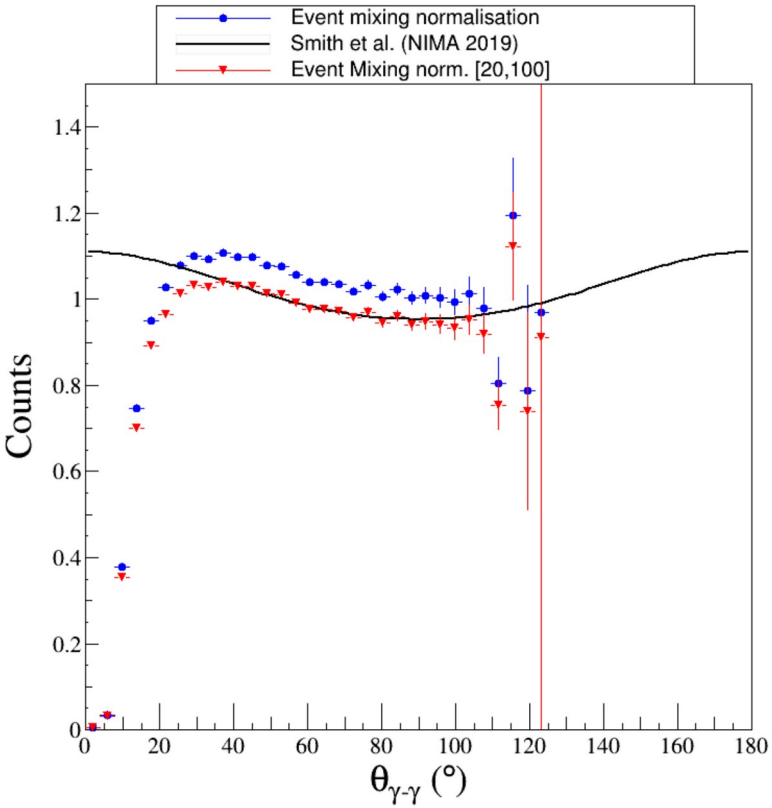
Searching for information on multipolarity

Study performed previously on ^{60}Co source

$$W(\theta) = \sum_{i=0,even}^{\infty} A_{ii} P_i(\cos(\theta))$$

$$W(\theta) \sim A_{00}(1 + a_2 P_2(\cos(\theta)) + a_4 P_4(\cos(\theta)))$$

- With and without tracking
- Normalization with event mixing
- Satisfactory results



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What about in beam data ?

Coulomb excitation experimental data

Experiment E667 overview (November 2017)

- **Beam : ^{124}Xe (~ 4 MeV/A)**
  - Run 230 → 234 E= 4.032 MeV/A
  - Run 235 → 239 E= 4.11 MeV/A
- **Target : ^{54}Fe (with W contamination)**
  - Thickness = 0.2 mg/cm^2
- **VAMOS to for particle identification**
  - VAMOS Angle = 29
- **AGATA for Gamma detection**
  - Nominal position
  - Around 30 crystals

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- **^{124}Xe coulomb excitation**
  - “Safe” coulex
  - Comparison with GOSIA calculations

→ Good case to investigate angular distributions

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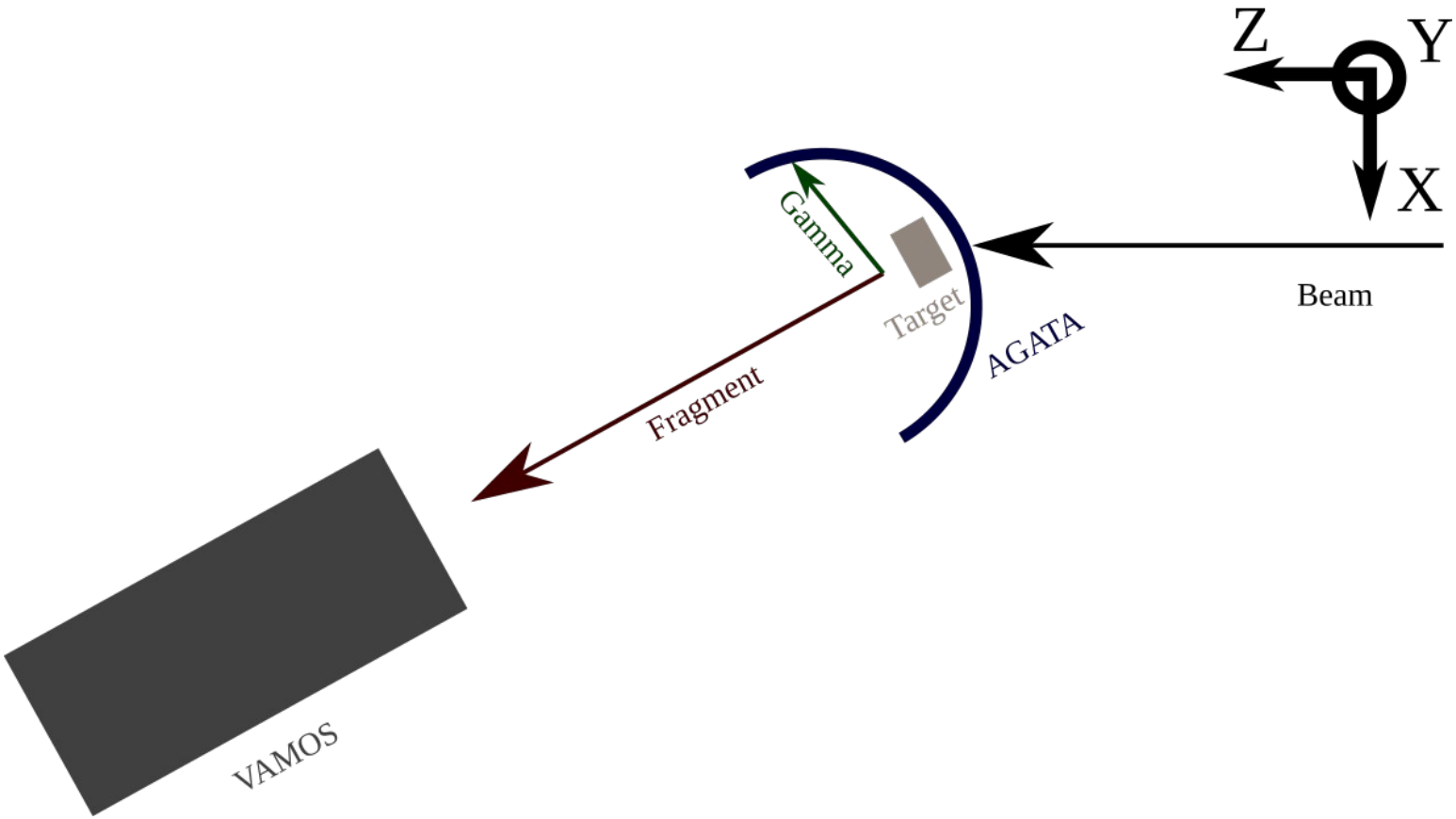
- **^{124}Xe transitions to observe**
  - 2+ → 0+ (E2)
  - 4+ → 2+ (E2)
  - 2+ → 2+ (M1+E2)

Experimental setup

VAMOS in 29 degree configuration



Data analysis overview

Overall analysis

- **VAMOS spectrometer**
  - Particle identification
  - Particle angle
  - Particle Beta
  - Interaction position on target
- **AGATA tracking**
  - Gamma energy
  - Gamma angle (with PSA)

Overall analysis

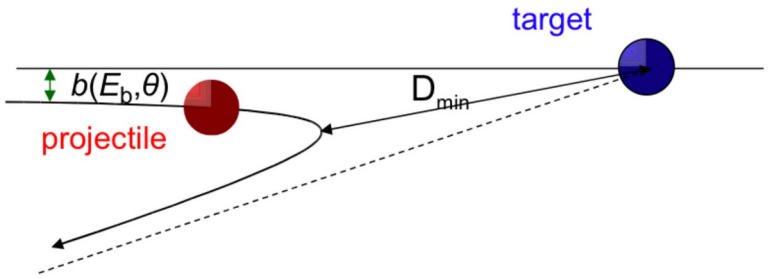
- **VAMOS spectrometer**
  - Particle identification
  - Particle angle
  - Particle Beta
  - Interaction position on target
- **Analysis gate**
  - Reaction
  - Time stamp
  - Target position

- **AGATA tracking**
  - Gamma energy
  - Gamma angle (with PSA)
- **Analysis gate**
  - Transition Doppler energy ± 4keV
  - Gamma prompt

Safe coulex : cline's criteria

- To avoid influence of strong interaction
- Limit on the Fragment angle based on the following :

$$d = 1.25 \cdot (A_p^{1/3} + A_t^{1/3}) + 5.0 \quad [\mathrm{fm}]$$



Results :

$\theta_{max}^{CM} = 23.78°$

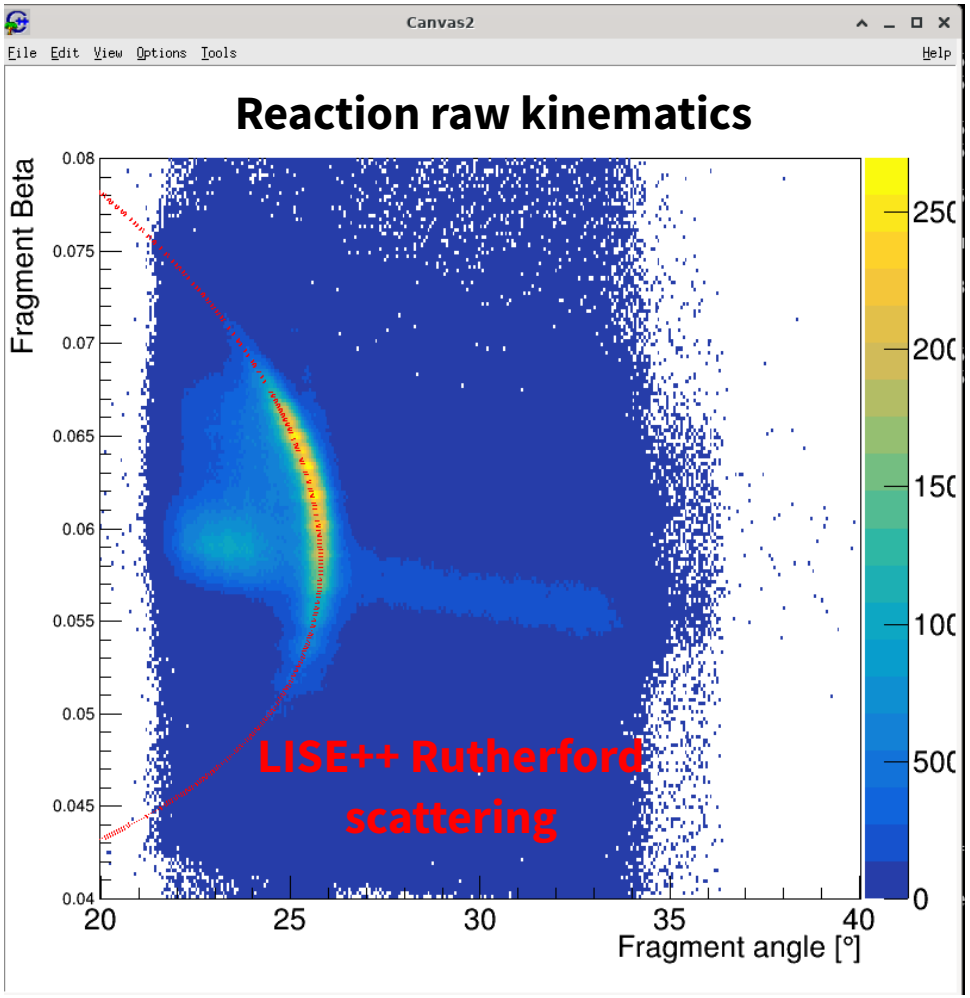
$\theta_{max}^{Lab} = 91.64°$

$$E_b(\theta_{cm}) = 0.72 \cdot \frac{Z_P Z_T}{D_{min}} \cdot \frac{A_p + A_t}{A_t} \cdot \left[1 + \frac{1}{\sin\left(\frac{\theta_{cm}}{2}\right)}\right] [\mathrm{MeV}]$$

Cline criteria applied to data

Reaction kinematics

- Mainly scattering of Xe on Fe
- Reproduce LISE++ calculations
- Require little tuning of MWDC angle



Cline criteria applied to data

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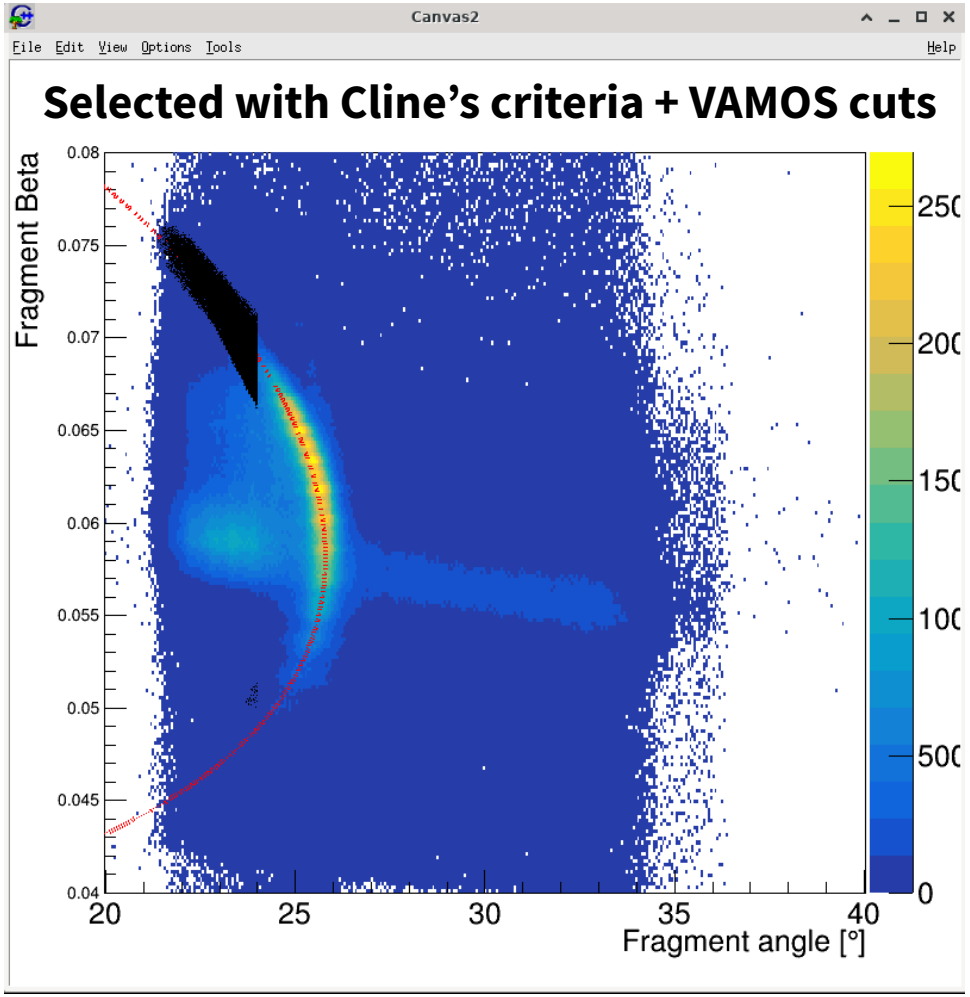
Safe coulex

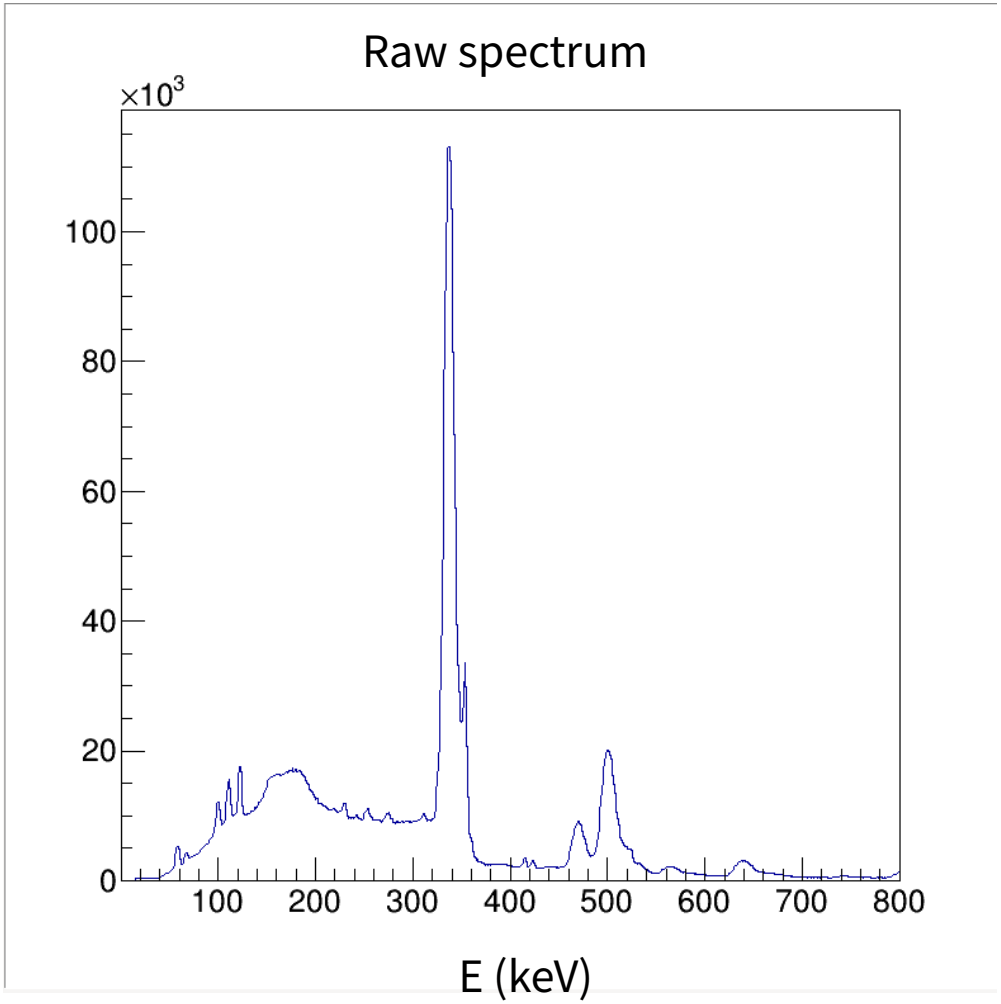
- Less than 5 % of the total data
- Highly sensitive to θ_{max}



Doppler correction

Using

- Angle of gamma
- Angle of Charge particle
- Charged particle velocity (from VAMOS)
- Position of interaction on target



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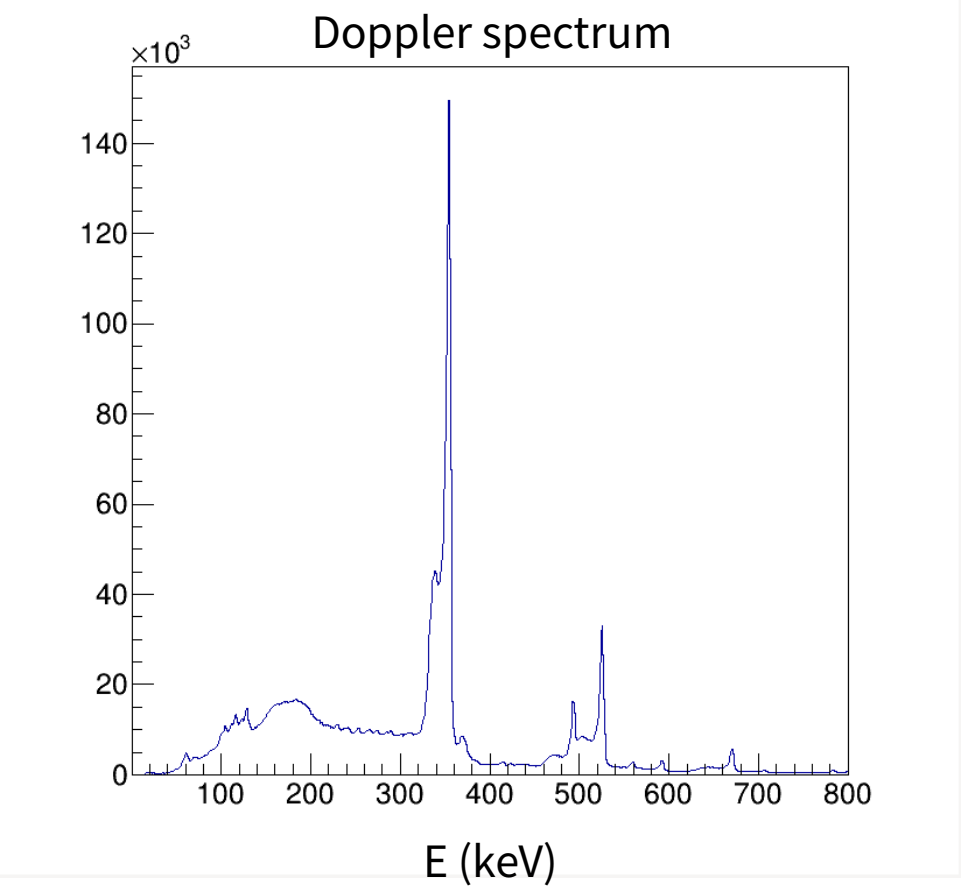

Doppler correction

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- Angle of gamma
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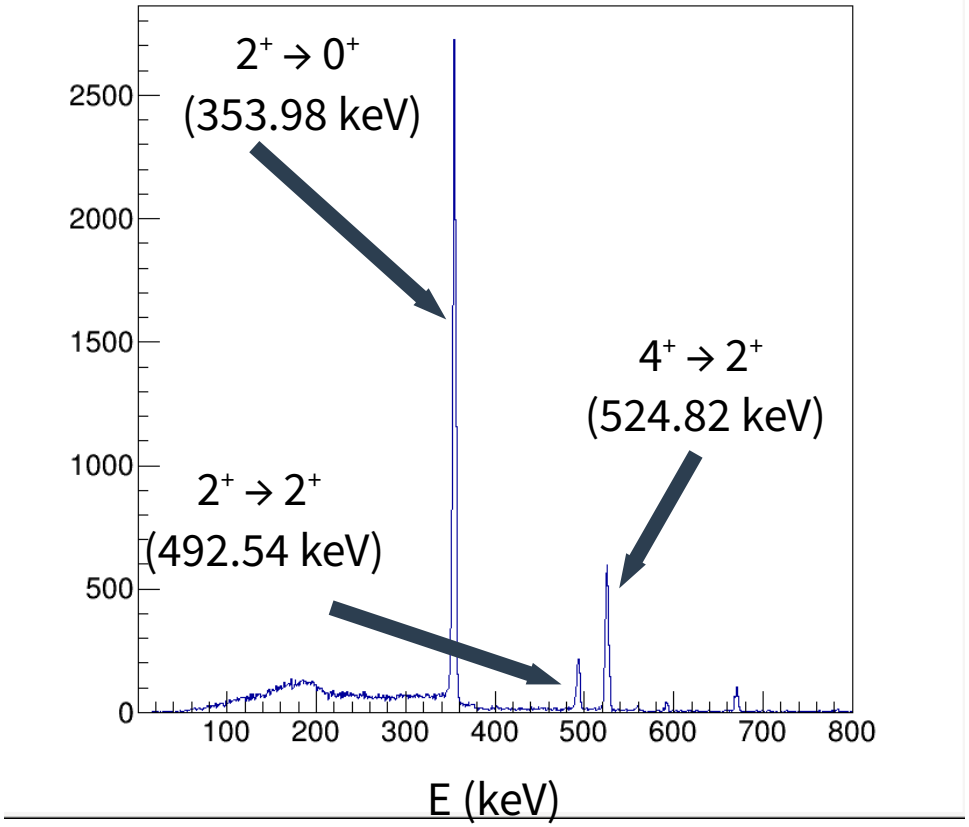
Results

- Resolution achieved @ 353 keV
  - σ ~ 1.7 kev
  - FWHM ~ 4 keV

Doppler spectrum + analysis cuts



Statistics for ^{124}Xe safe coulex

Estimation with gamma energy gate ± 4 keV

	$2^+ \rightarrow 0^+$	$4^+ \rightarrow 2^+$	$2^+ \rightarrow 2^+$	$4^+ \rightarrow 2^+ \rightarrow 0^+$
Run 230 to 234	10416	2280	867	105
Run 235 to 239	17434	4150	1800	166

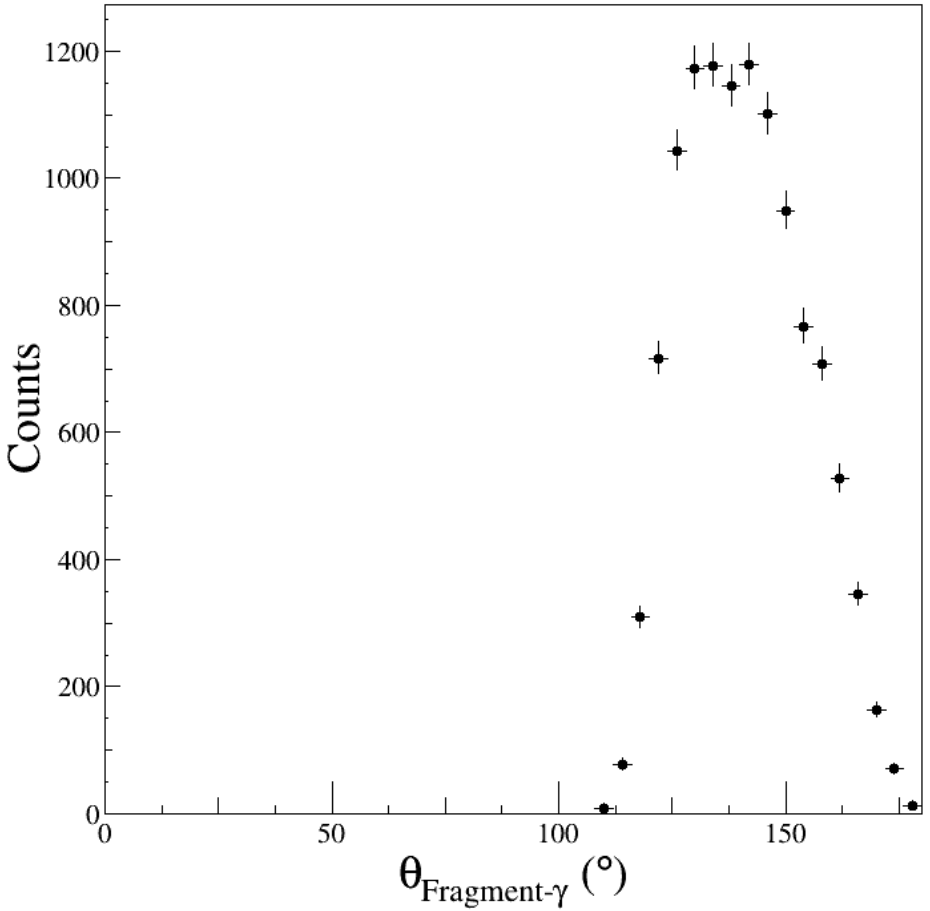
Very sensitive Cline's criteria.
e.g. Variation of 25% for θ_{max}^{Lab} from 23.77° to 24°

Angular distributions

Angular distributions for $2^+ \rightarrow 0^+$ run 230-234

Standard algorithm:

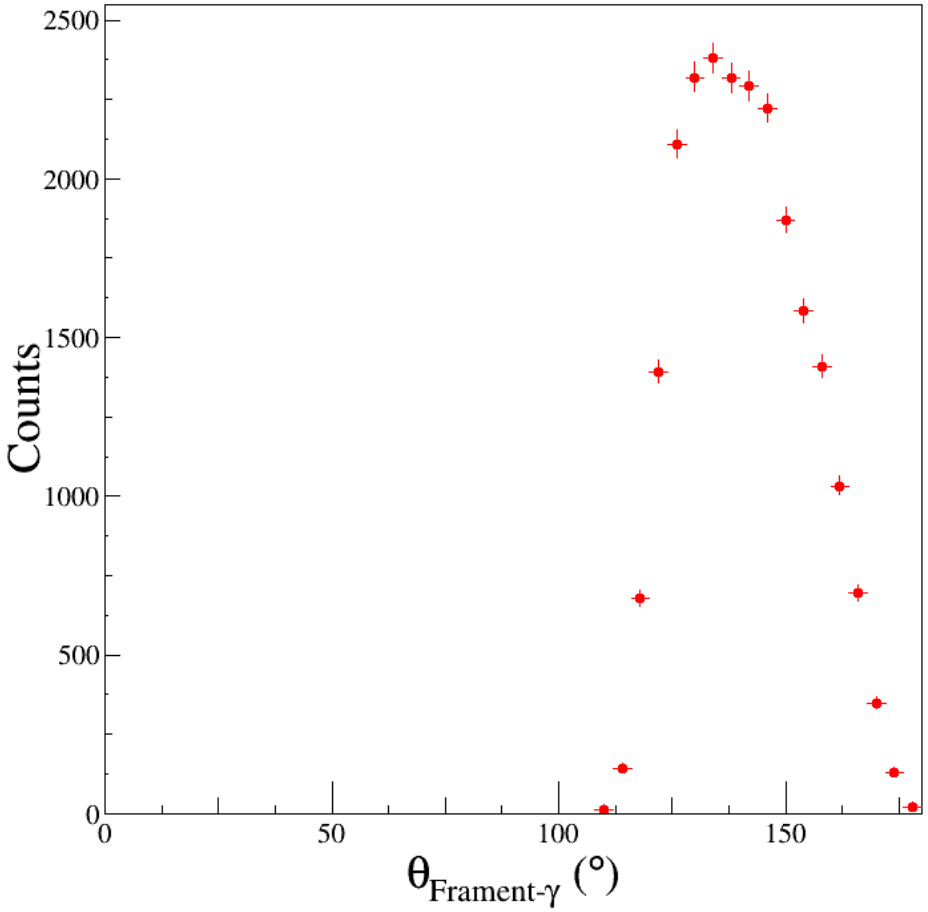
- Get ^{124}Xe angle from VAMOS
- Get target position
- Calculate gamma angle from target
- Deduce angle bewteen charged particle and gamma



Normalisation for $2^+ \rightarrow 0^+$ run 230-234

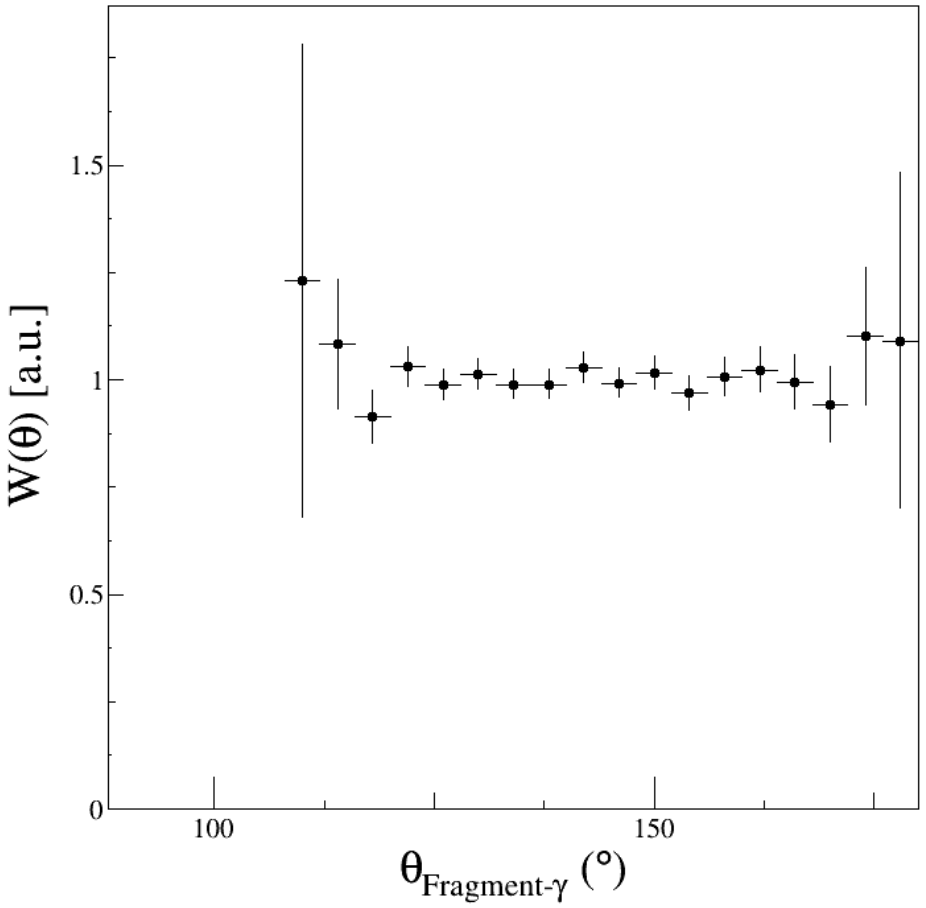
Event mixing algorithm:

- For each event
  - Store charged particle angle θ_{Fevent}
  - Store gamma angle $\theta_{\gamma event}$
- Get previous event
  - Store charged particle angle $\theta_{Fprevious}$
  - Store gamma angle $\theta_{\gamma previous}$
- Calculate mixed distribution
  - between θ_{Fevent} and $\theta_{\gamma previous}$
  - between $\theta_{Fprevious}$ and $\theta_{\gamma event}$

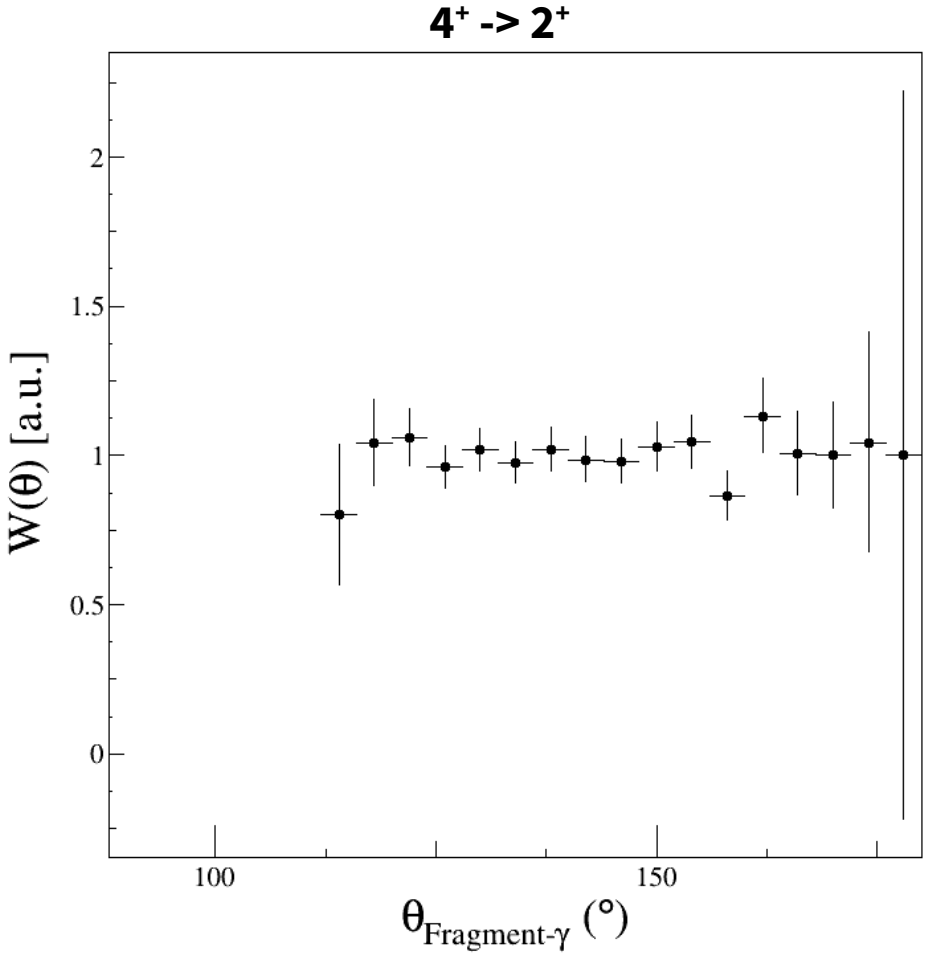


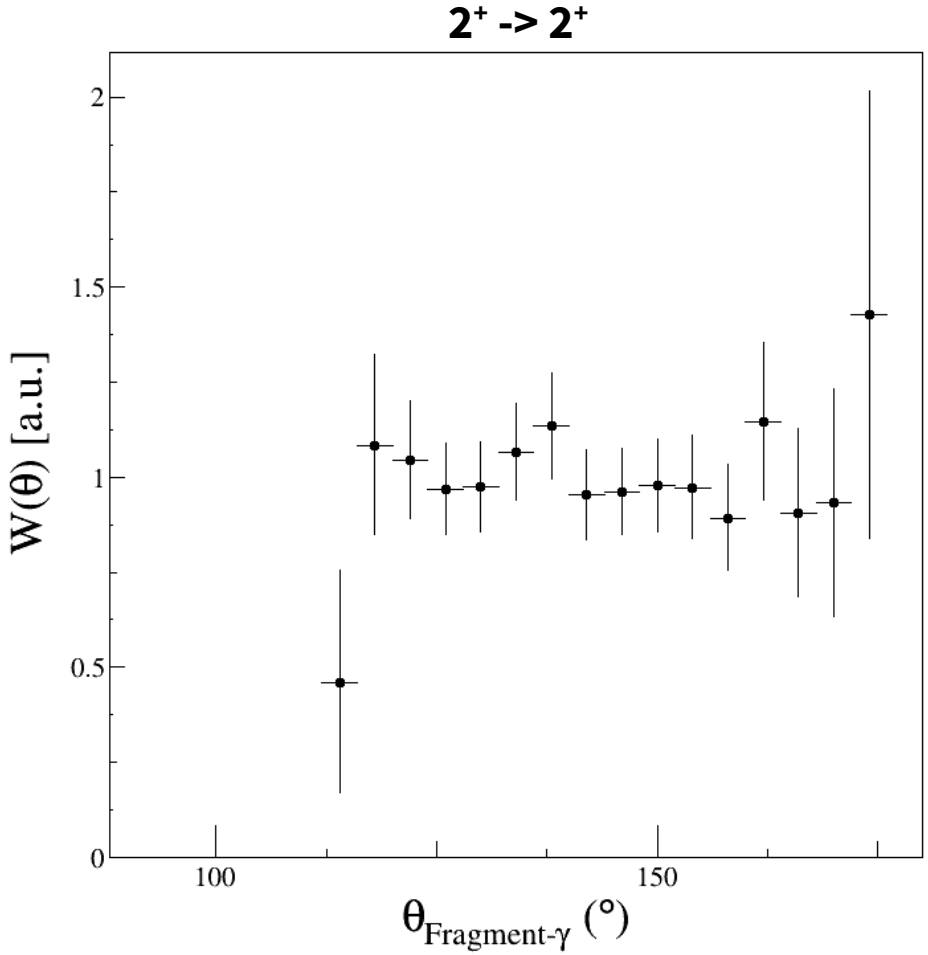
Deduce angular distribution for $2^+ \rightarrow 0^+$ run 230-234

- **Normalization**
  - Normalize mixing distribution to number of events of data
  - Divide experimental data by normalized mixing distribution
- **Overall result:**
  - Angular distribution appears flat
  - Slight curvature but due to point with higher uncertainty



Angular distribution for $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 2^+$ run 230-234





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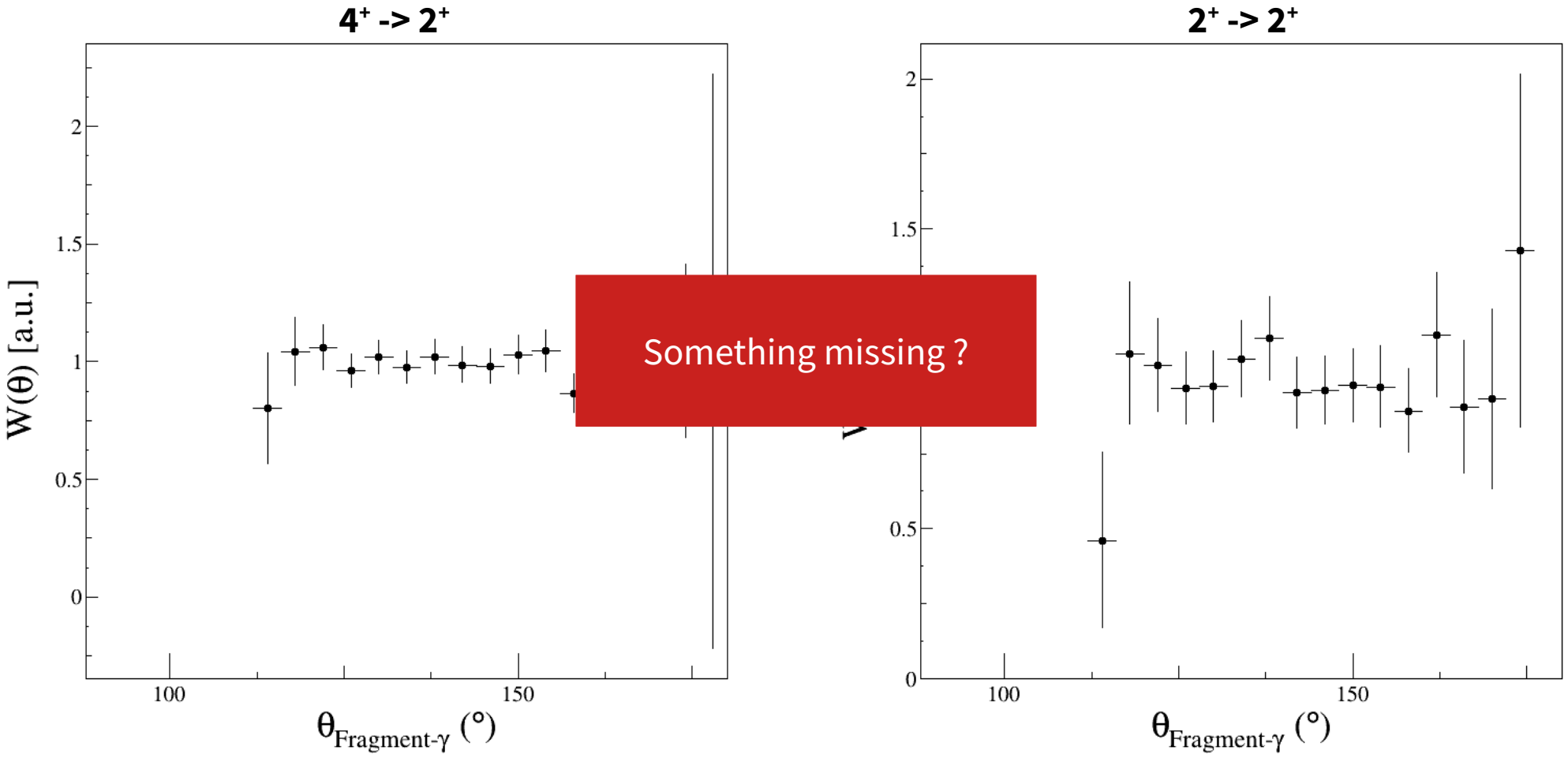


Comments on reliminary results

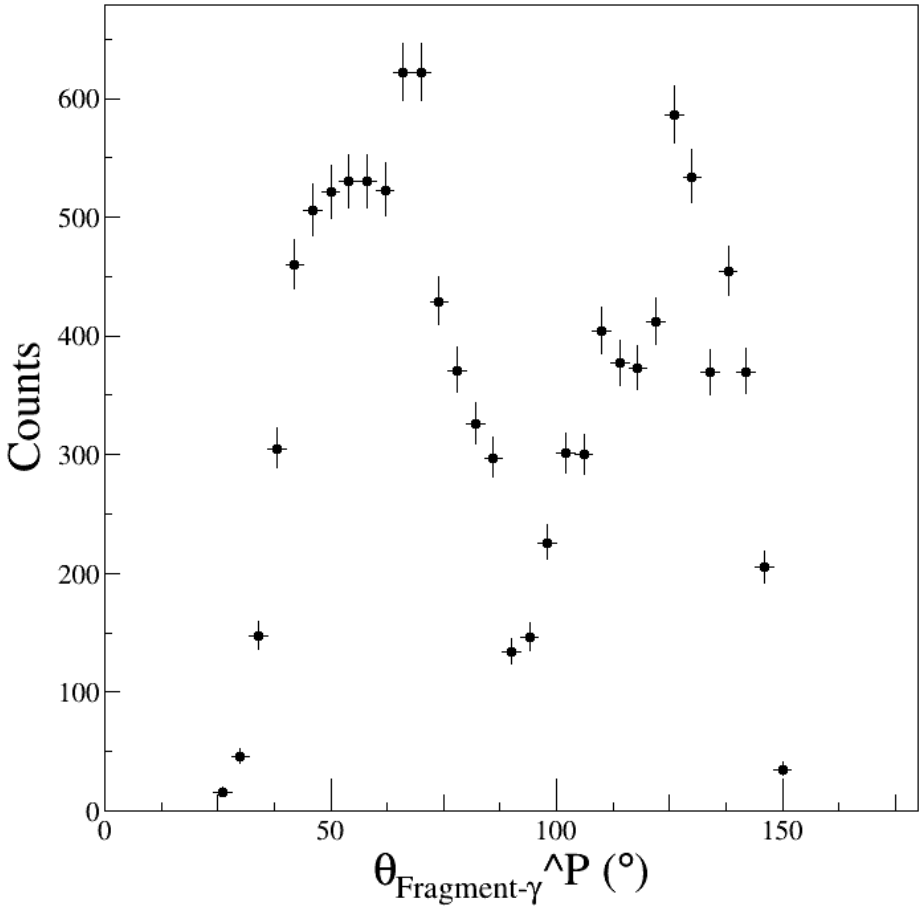
- **Obtained distributions are flat. The expected angular distribution seems to be washed out by some effect**
  - 2+→ 0+ , 4+→ 2+ and, 2+ → 2+ show similar angular trend…
- **Hypothesis to explain the effect**
  - Effect of the reaction plan ?
  - Issue in the event mixing algorithm ?
  - Problem in the geometry ?
  - Else ?

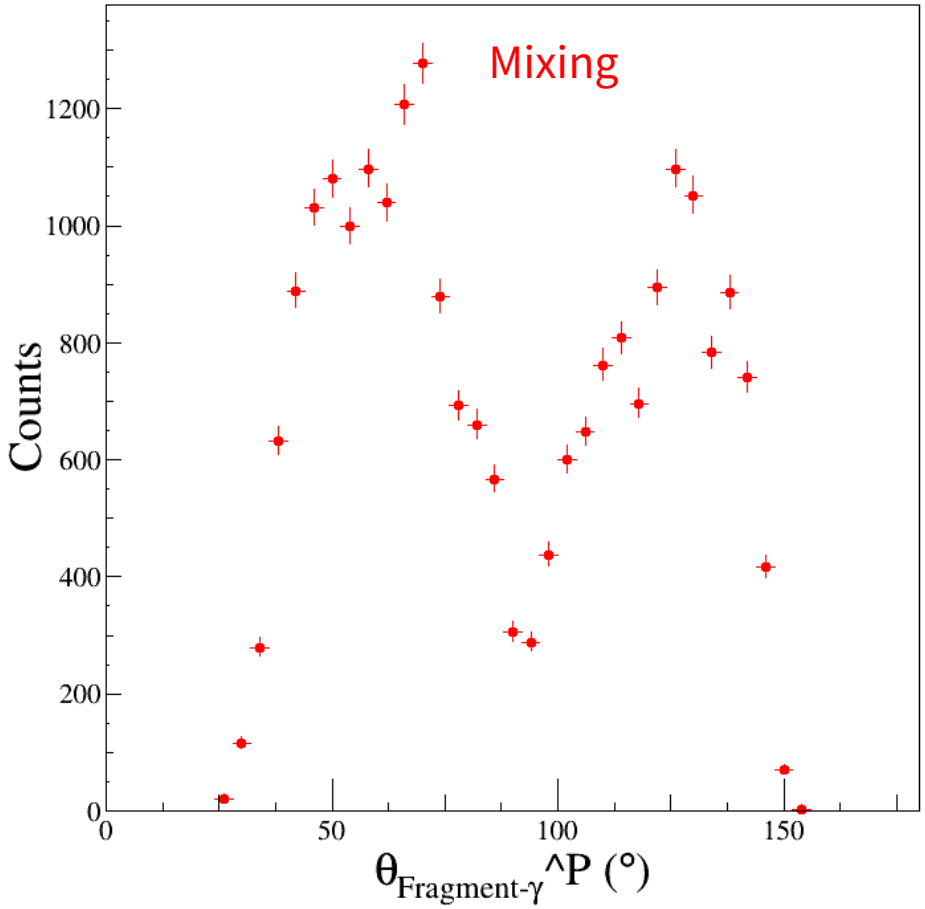
Further investigation

Using reaction plan angle

Calculating now reaction plan angle : $\vec{B} \times \vec{F}$

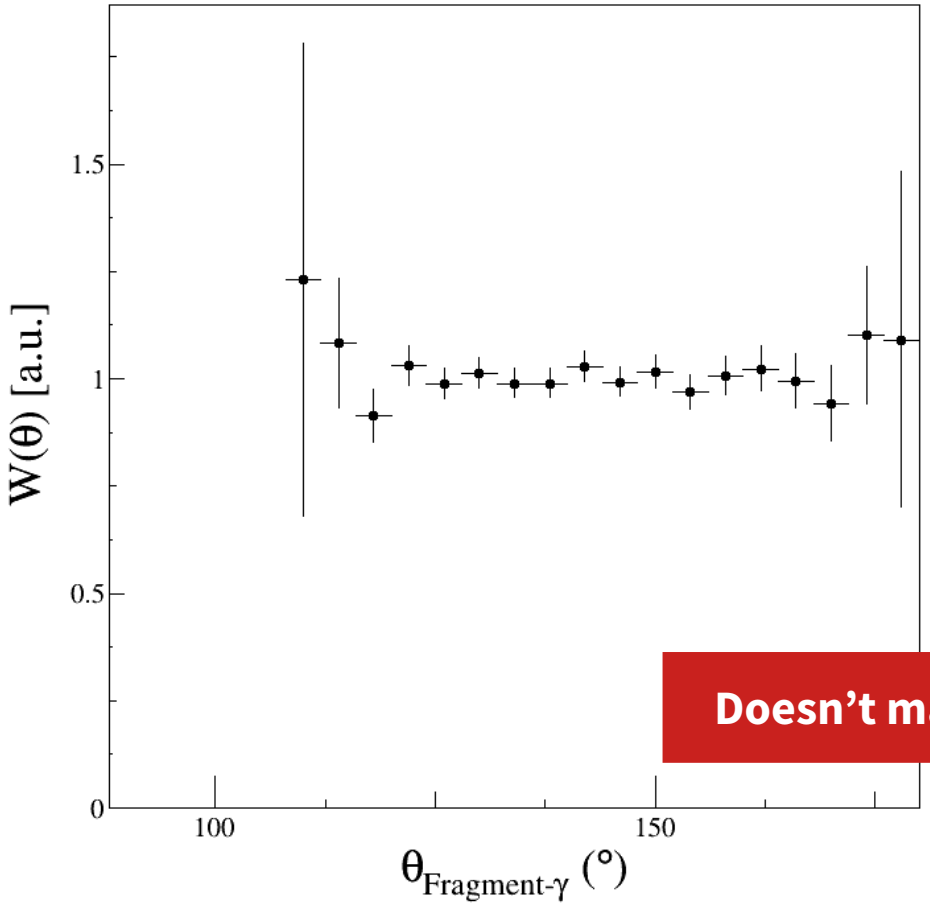
Gamma angular distribution is calculated relative to this angle



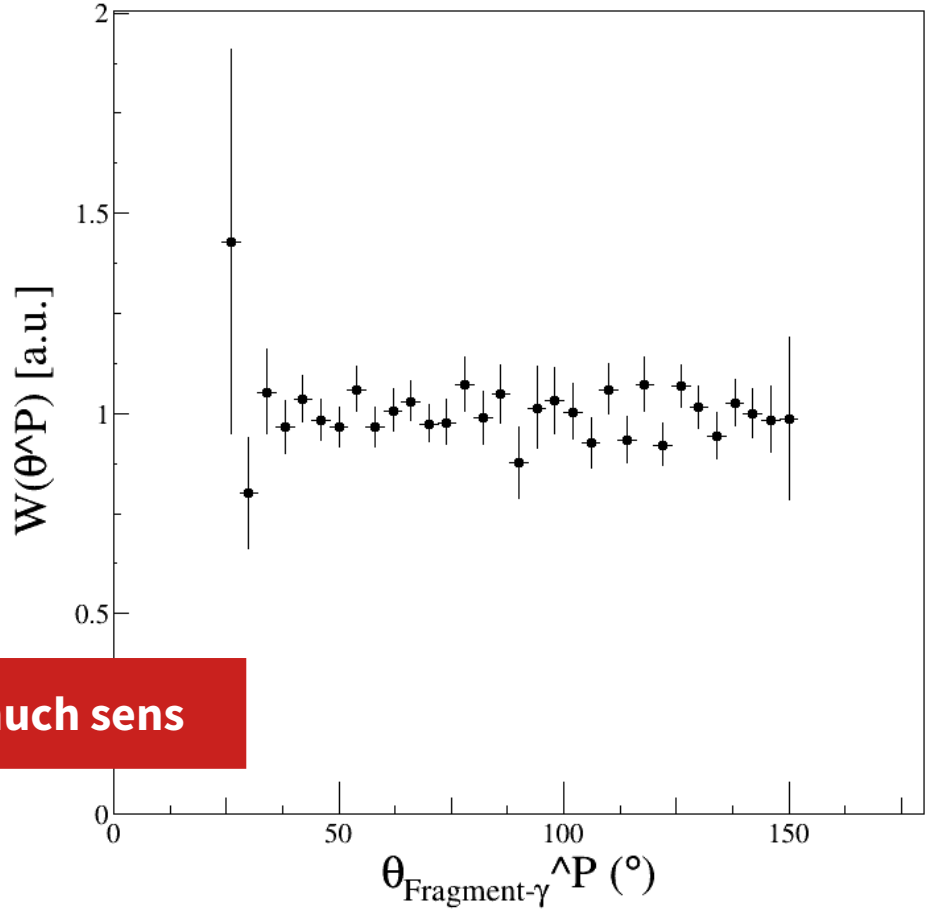


Normalized distributions for $2^+ \rightarrow 0^+$ run 230-234

Previous results



With $\vec{B} \times \vec{F}$



Doesn't make much sens

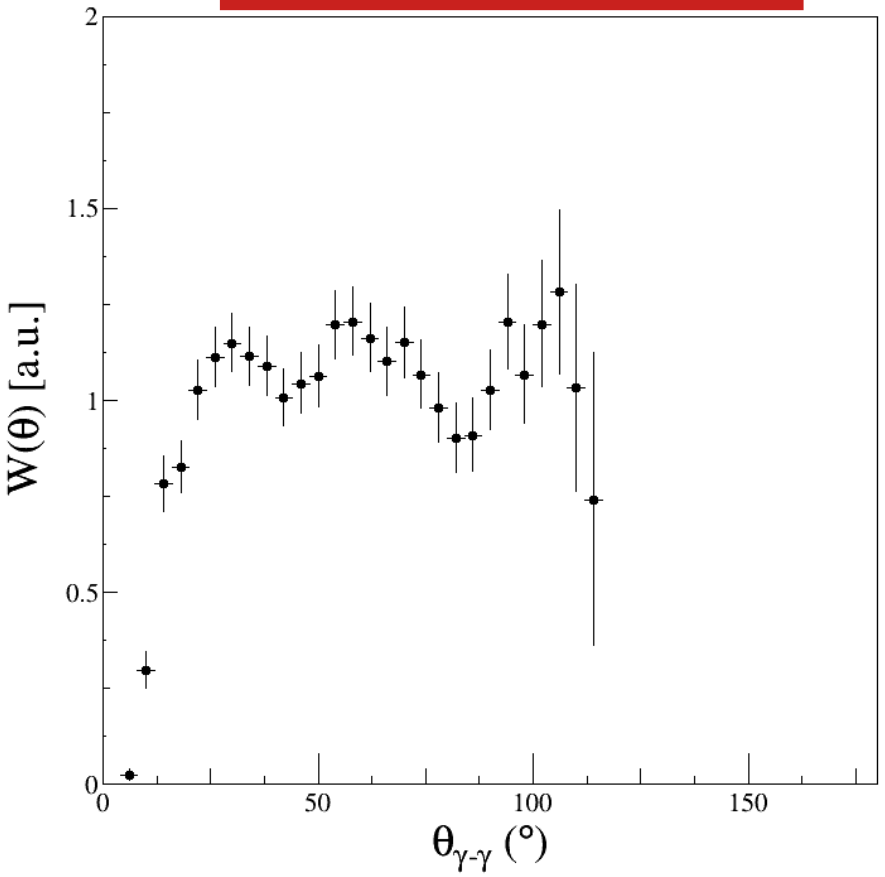
Angular correlation $4^+ \rightarrow 2^+ \rightarrow 0^+$ run 230-234

Very preliminary results

A good test ?

- Should be independent of geometry
- Using tested event mixing

Unexpected distribution ?



Conclusions

- ^{124}Xe coulex has been investigated
- Preliminary results are not very encouraging
- Angular distributions seems to be washed out by some effect
- Still working on it...

Backup slides

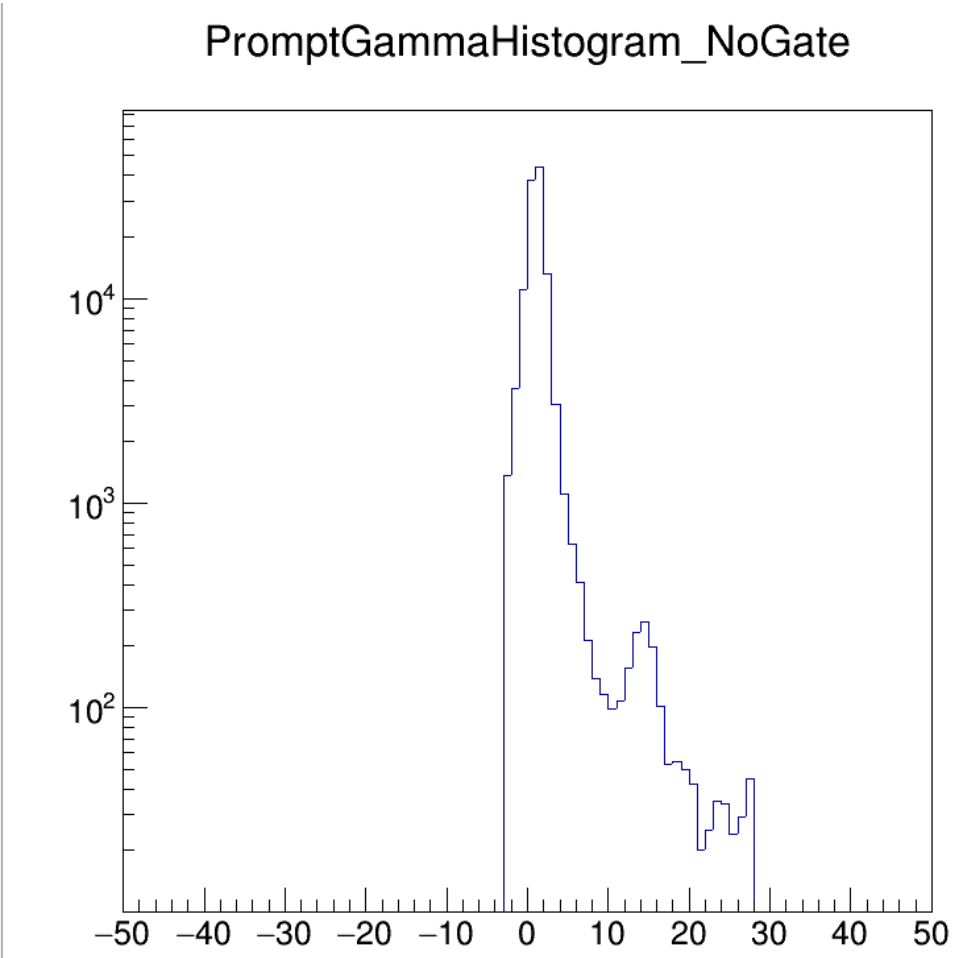
Analysis variable used for VAMOS reconstruction

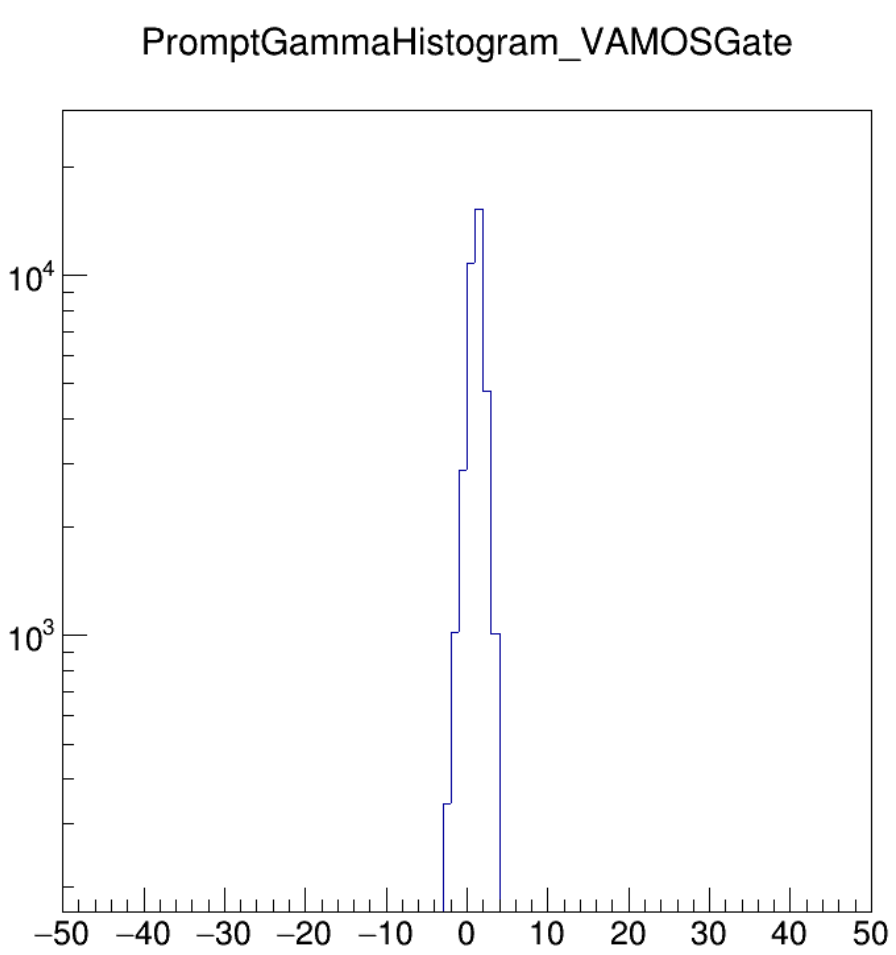
- List of Cut apply to VAMOS data to select Xe coulex
  - Prompt gamma with AGATA — (LTS – TSHit – Offset) < With
  - Fragment PID
    - Ionisation chamber only : — ICE vs Σ ICE
    - ToF vs ICE : — ICE vs Beta
  - Target position — TP_X vs TP_Y
  - Fragment angle — TP_Theta vs TP_Phi
  - Cline Criteria for Coulex — Beta vs Fragment Angle

In the next slides : No gate (left panel) vs all gate (right panel)

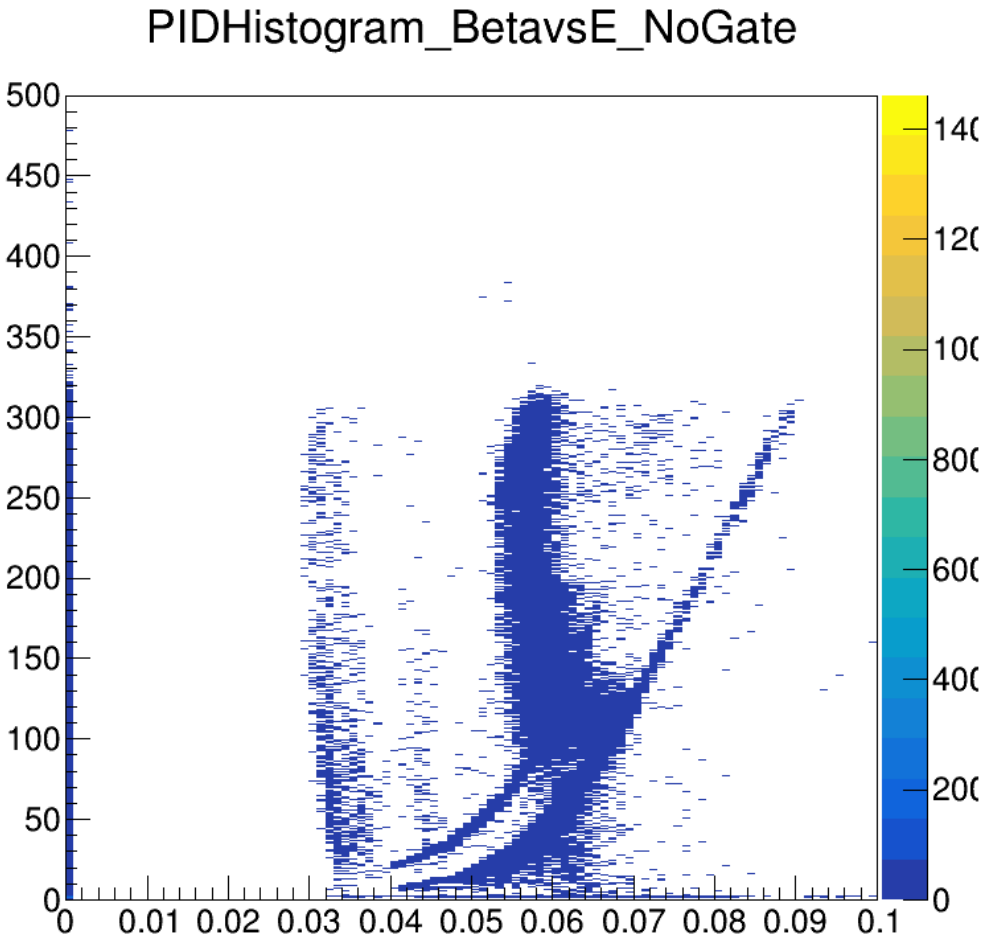
Prompt gamma gate

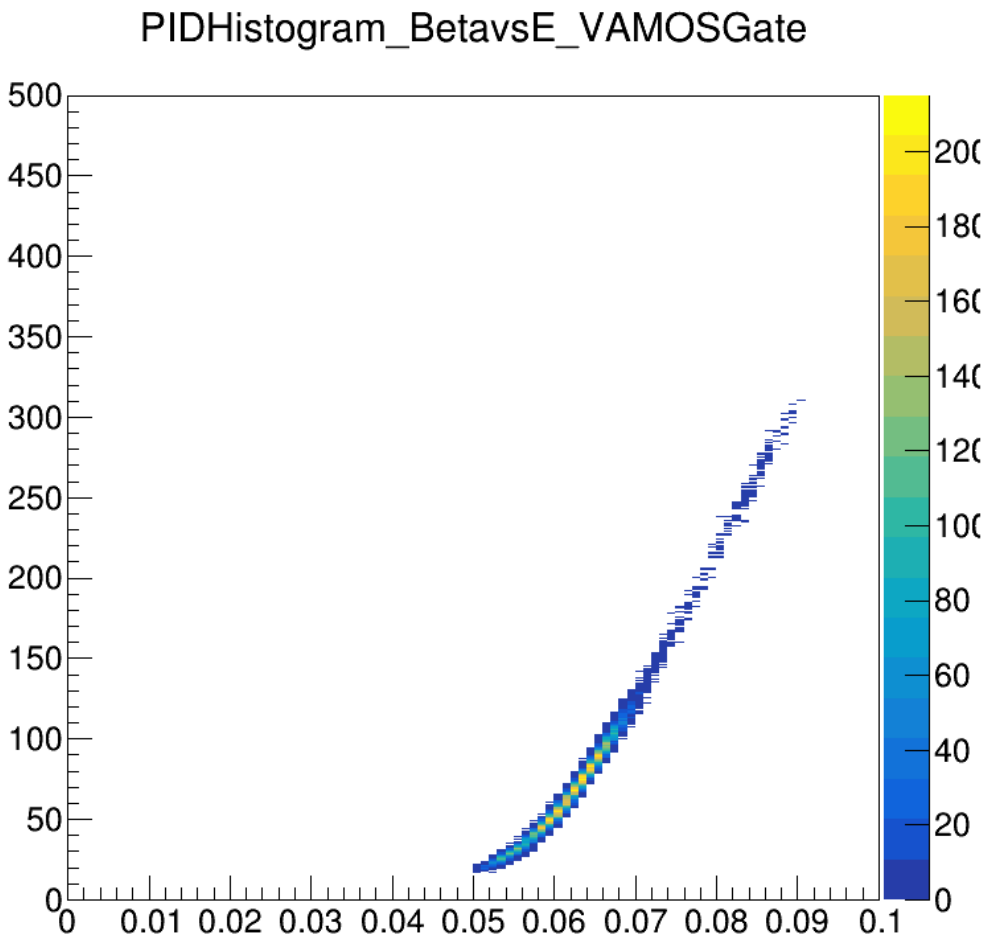
Gate width = +- 40 ns (+- 4 ticks)



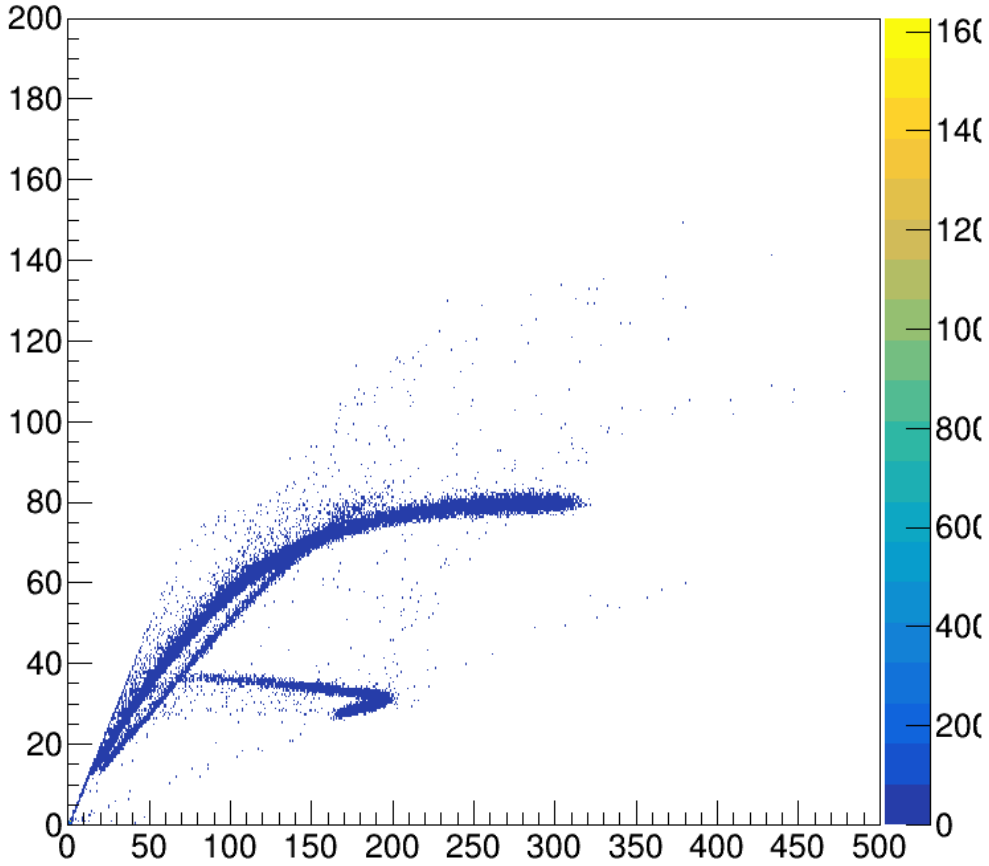


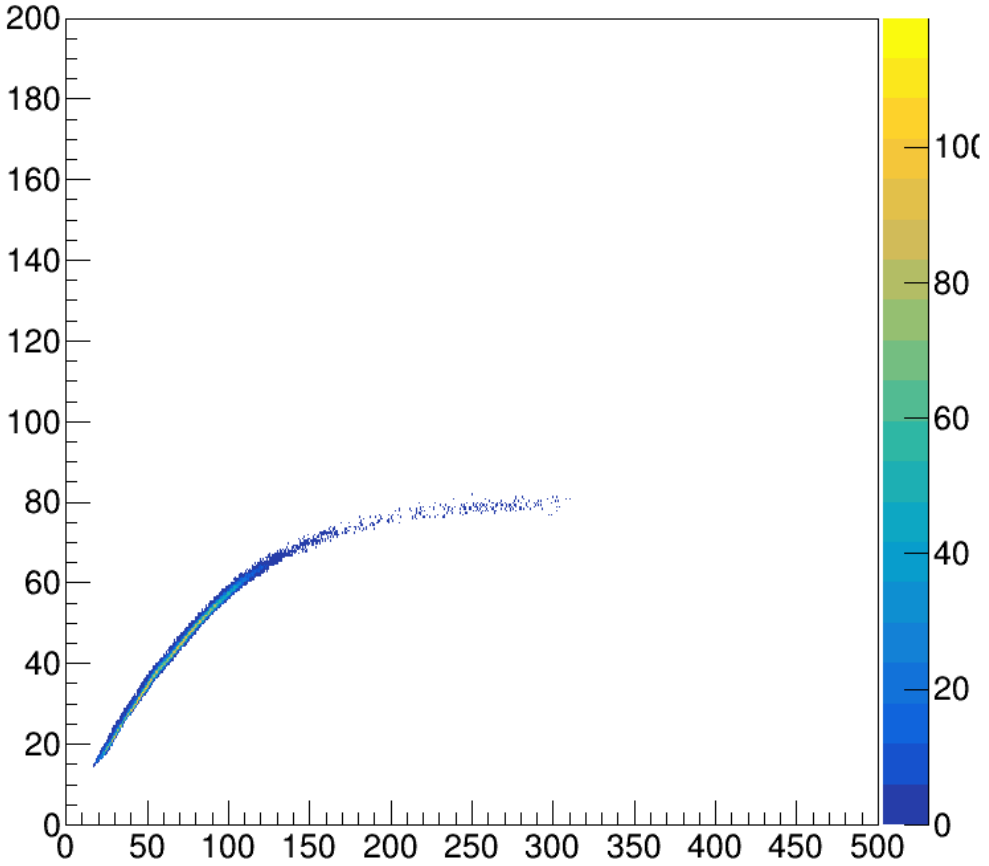
Fragment PID : Beta vs E



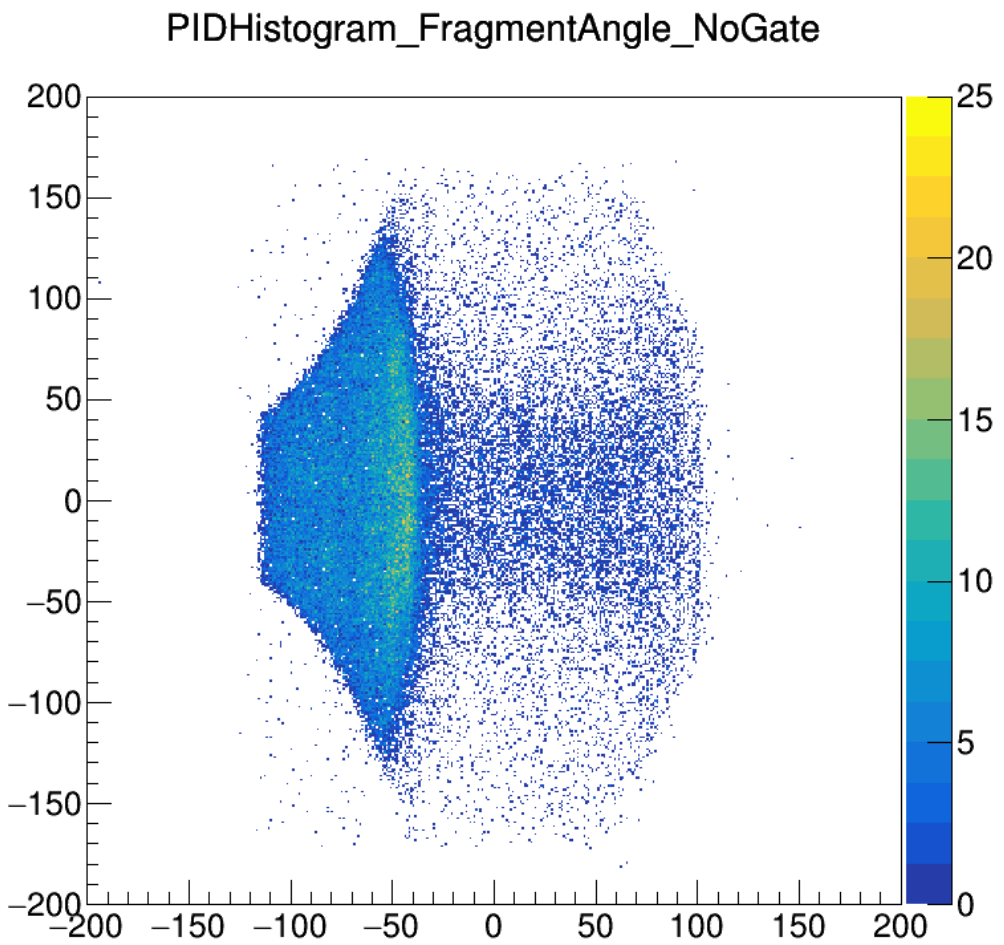


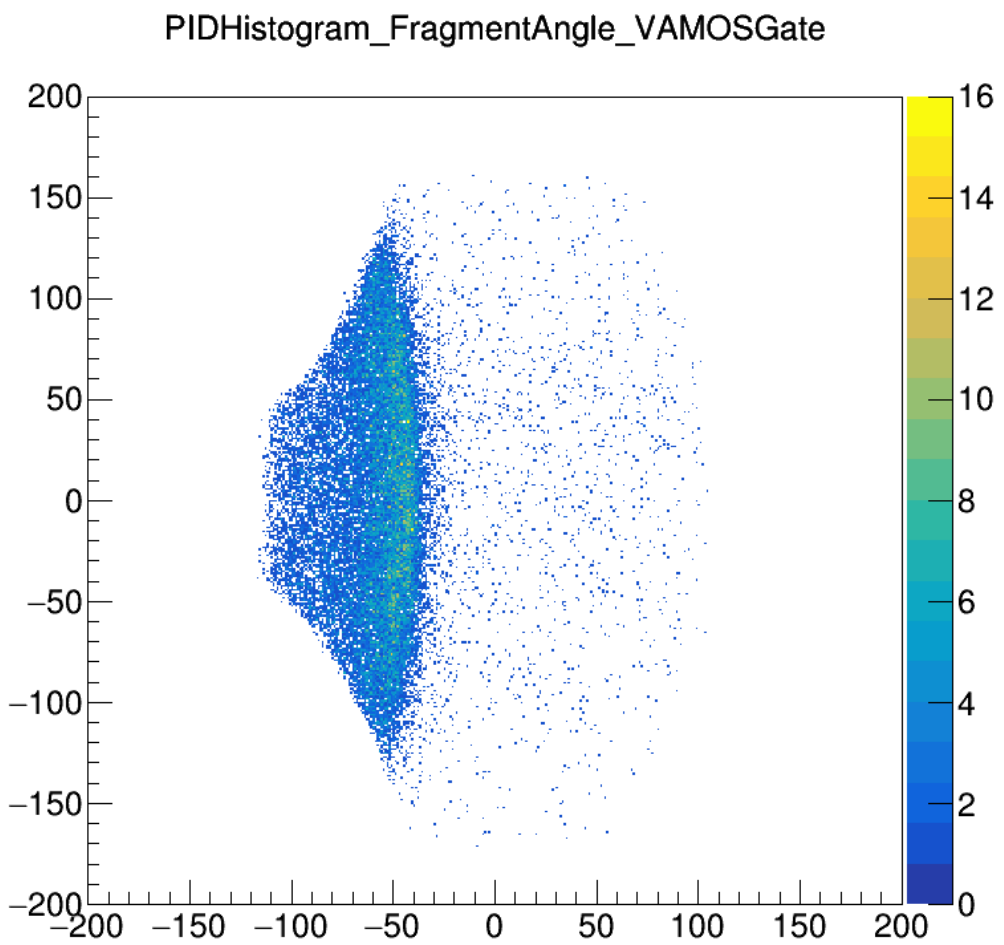
Fragment PID : E vs DE



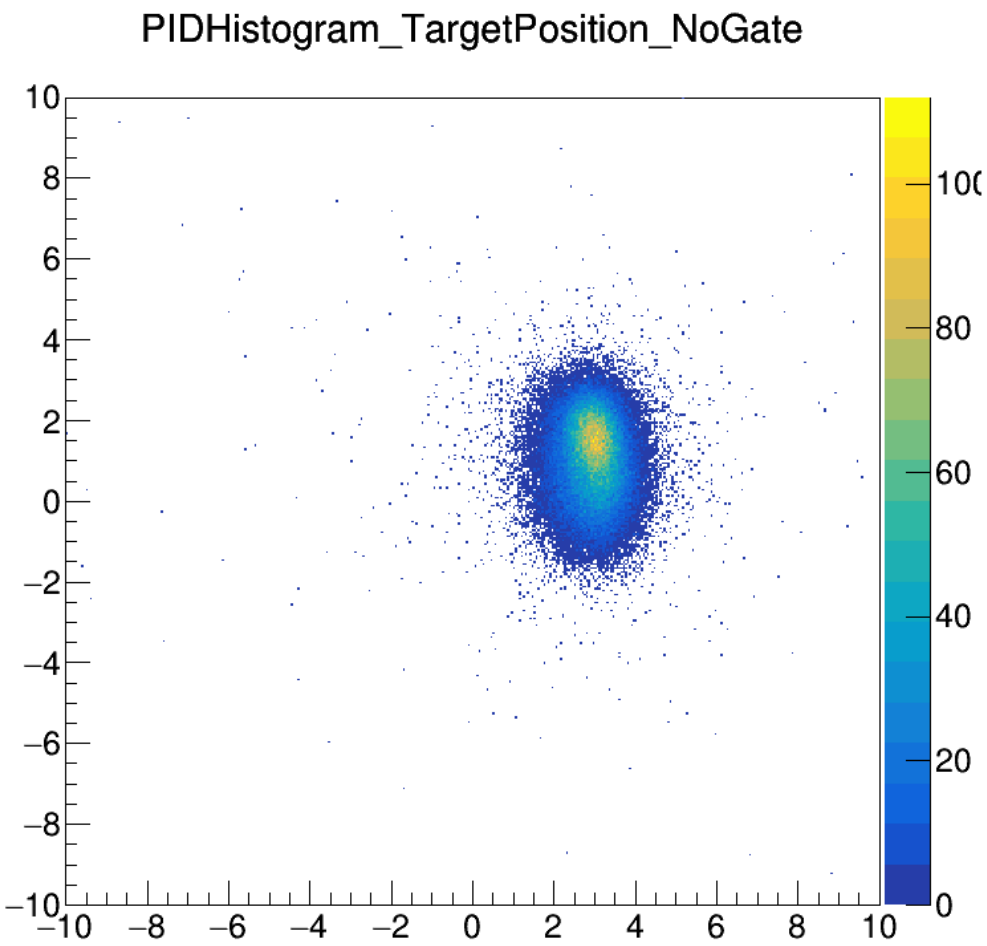


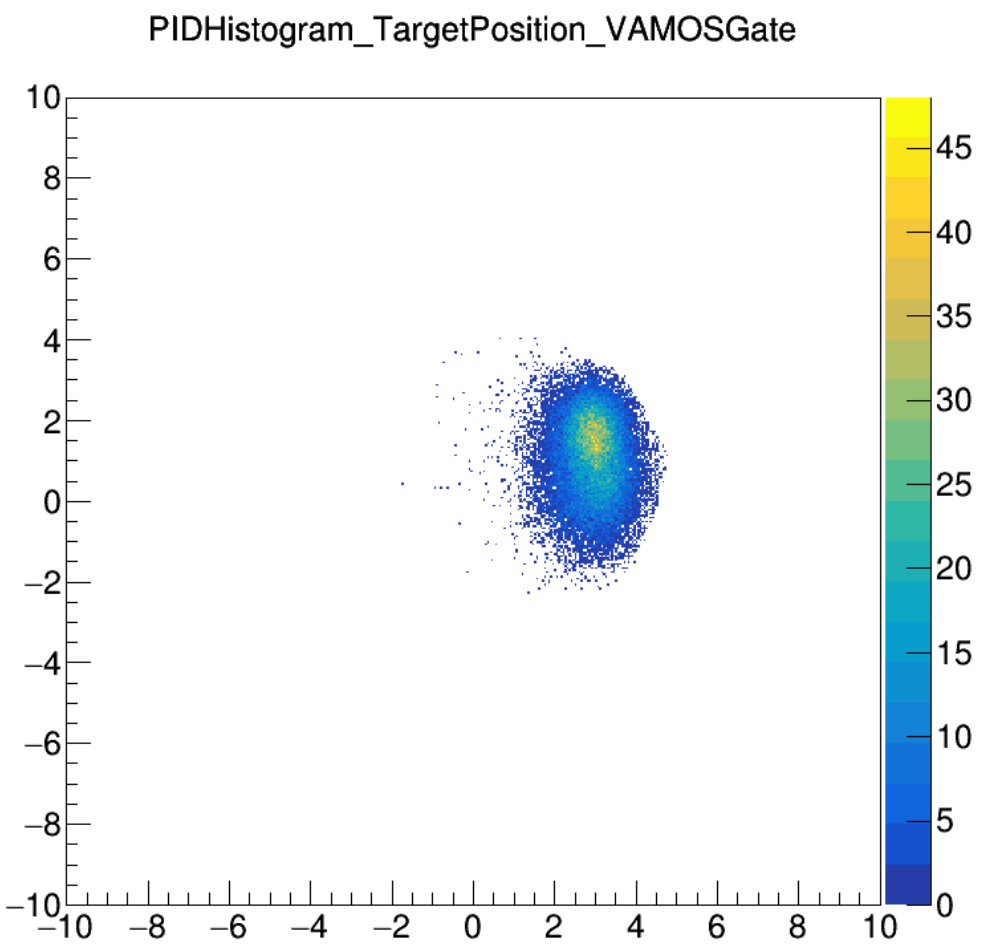
Fragment angle gate : Theta vs Phi





Target position : X vs Y





Comment on kinematics plot

- **Following formula were used to make kinematics**
  - Fragment in VAMOS frame
    - Fragment Vx = - sin(TP_Theta)cos(TP_Phi)
    - Fragment Vy = sin(TP_Phi)
    - Fragment Vz = Cos(TP_Theta)cos(TP_Phi)
  - Fragment in Laboratory Frame → Rotation around Y of -29°
  - MWDC angle Correction to align kinemati line → Rotation around Y of -20 mrad (consistent with Emmanuel)

I have the impression that I have a shomehow an inversion of the X axis and thus also on angle but these formula provide best doppler correction & kinematics description

Remark for gamma angle reconstruciton

- **Following formula were used to get Doppler correction**
  - Gamma ray vector is reconstructed using the following formula
    - Vx = -trackY + TP_X
    - Vy = -trackX – TP_Y
    - Vz = trackZ
  - Gamma in Laboratory Frame → Rotation around Y of -29°
  - To optimize the Doppler correction an additional rotation of 200 mrad around Z is performed
  - Observed Doppler energy resolution at 350 kev
    - Sigma = 1.7 keV
    - FWHM = 4 keV