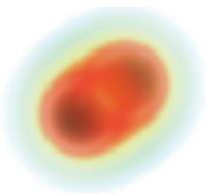
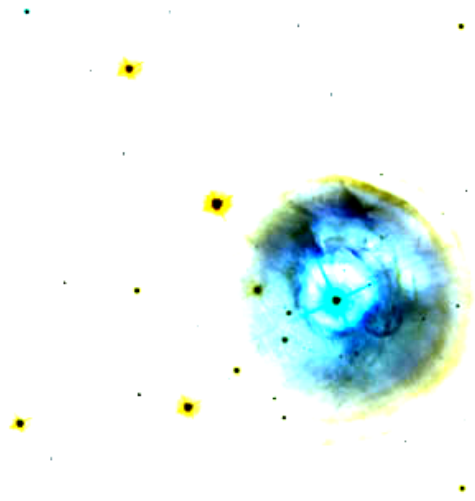
A Measurement Station for Deep Sub-barrier Fusion Cross Sections of Light Heavy-ion Systems

Marcel Heine for the STELLA Collaboration

IPHC/CNRS Strasbourg

11/23/2017

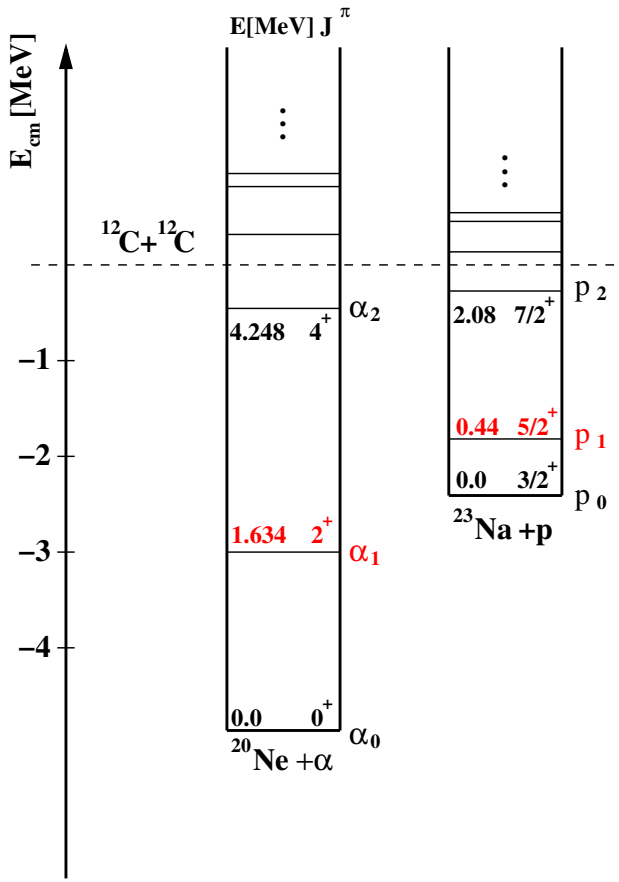




1. Experimental Scope
   - Fusion Cross Sections of Light Heavy-ion Systems
   - The (Incomplete) Story of Sub-barrier ^{12}C Fusion
2. The STELLA Station
   - The Detection System
   - STELLA at Andromède at IPN (Orsay)
3. Technical Developments around STELLA
   - Instant Calibration Routine $LaBr_3$
   - Proton-Alpha Separation
   - Background Estimation
4. Summary and Outlook

- detection of evaporation products and de-excitation gammas
- protons/alphas: $\leq$ 12 MeV
- gammas: 0.1...2 MeV

$$^{12}\mathrm{C} + ^{12}\mathrm{C} \rightarrow ^{24}\mathrm{Mg}^{*} \rightarrow ^{24}\mathrm{Mg} + \gamma;\ Q = 13.93\ \mathrm{MeV}$$
$$\rightarrow ^{20}\mathrm{Ne} + \alpha;\ Q = 4.62\ \mathrm{MeV}$$
$$\rightarrow ^{23}\mathrm{Na} + \mathrm{p};\ Q = 2.24\ \mathrm{MeV}$$
$$(\rightarrow ^{23}\mathrm{Mg} + \mathrm{n};\ Q = -2.60\ \mathrm{MeV})$$



- normalization: Faraday integrator + Mott-scattering detectors

The (Incomplete) Story of Sub-barrier ^{12}C Fusion

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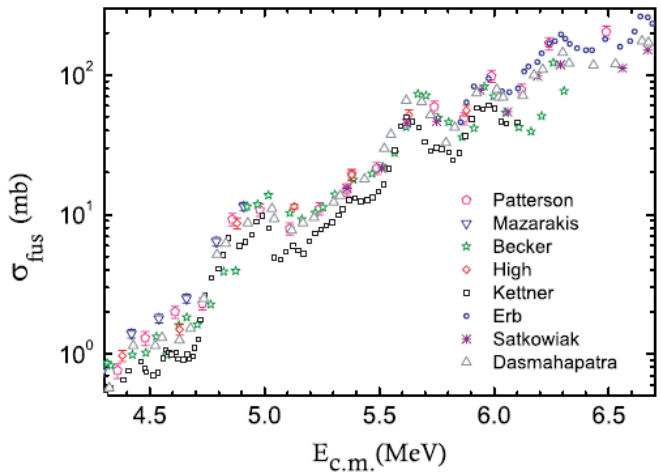
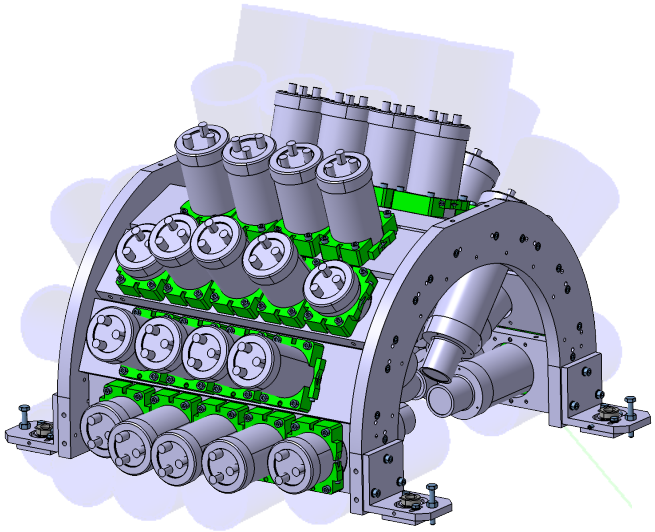
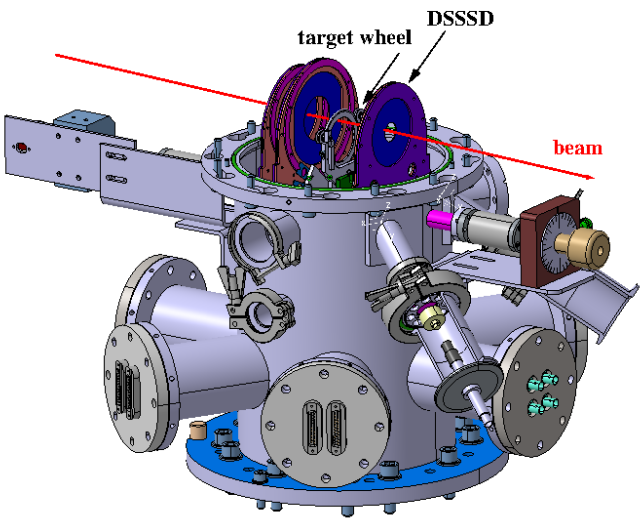
- gammas/particles
- thin/thick target



E.F. Aguilera *et al.*, PRC**73**, 064601, (2006)

- resonances
- extrapolations

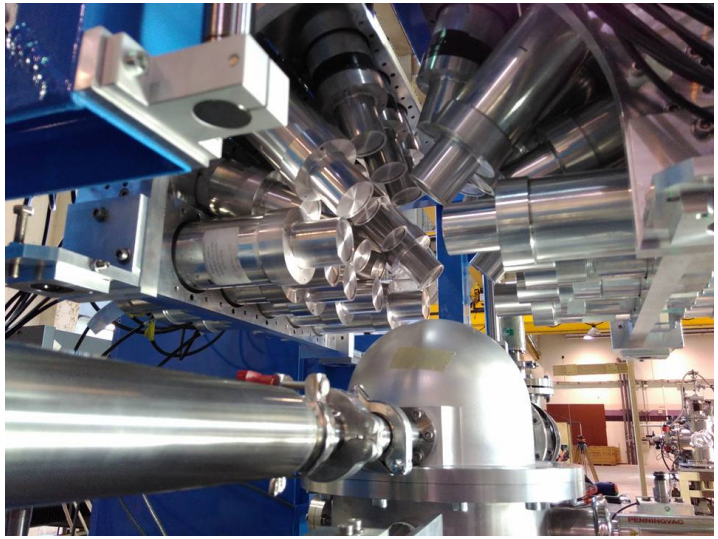


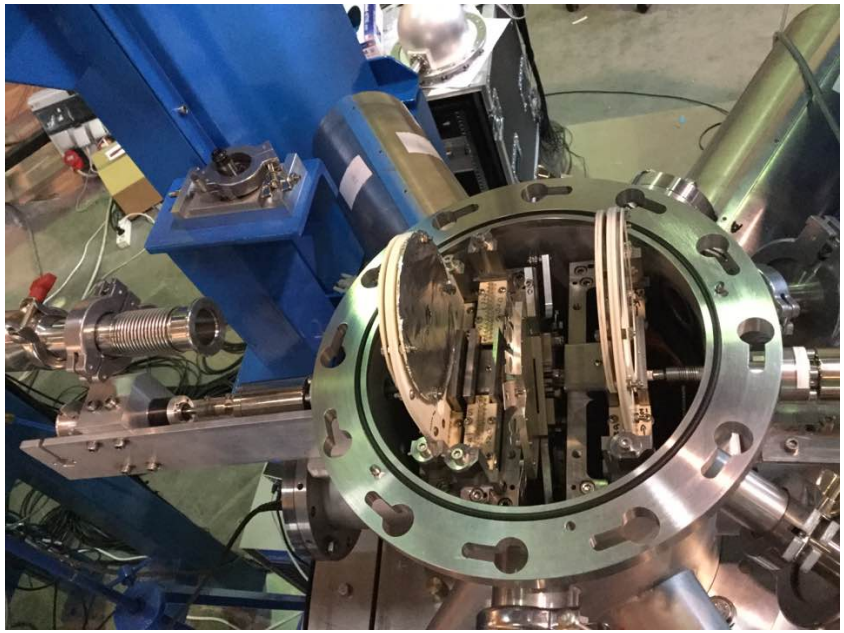


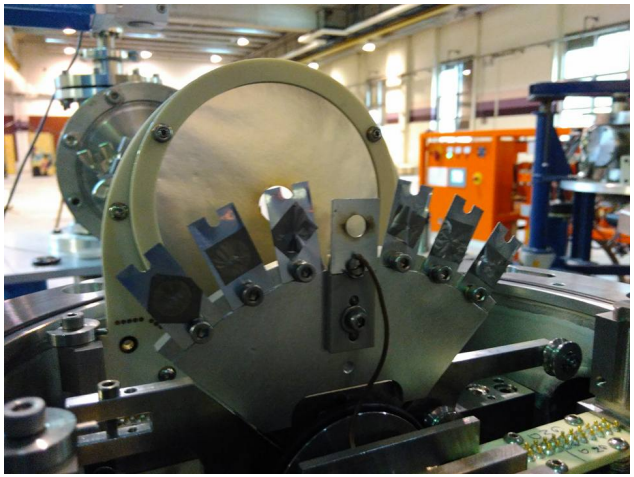
M. Krauth, G, Heitz, P. Dené

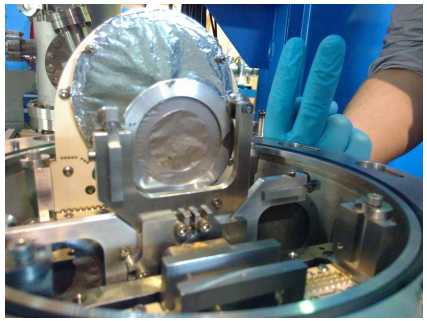
- 36 $LaBr_3$ with the **UK FATIMA** collaboration
- three annular DSSSD
- trigger less time stamped data streams
- rotating target mechanism
- ultra-high vacuum: 10^{-8} mbar (carbon build-up)
- monitor detectors: normalization
- Faraday cup: beam current
- high intensity stable beam: **Andromède** at IPN (Orsay)

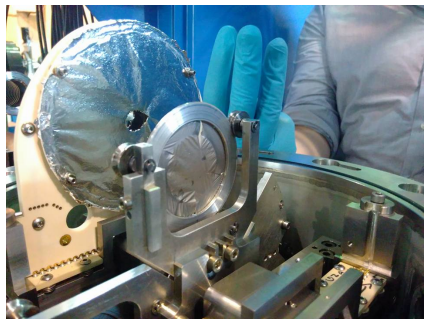
STELLA at Andromède at IPN (Orsay)





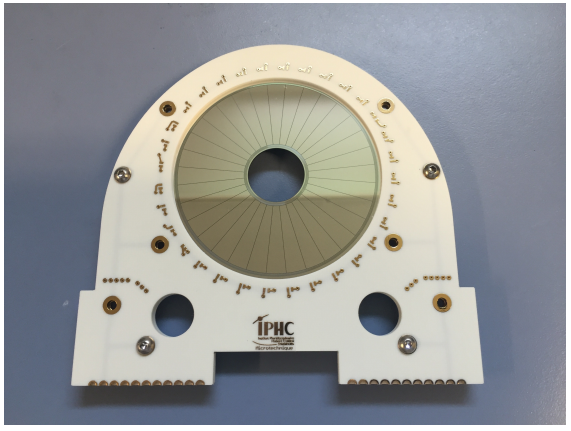


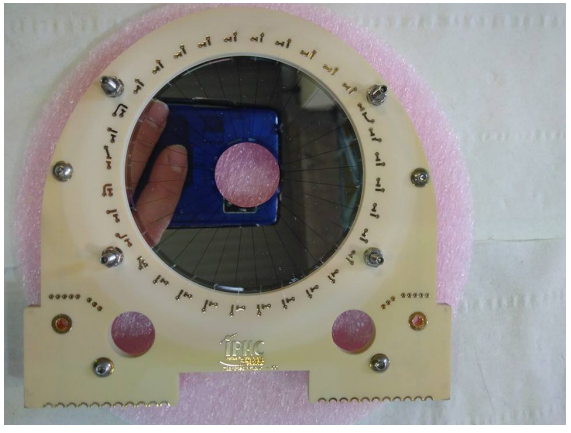


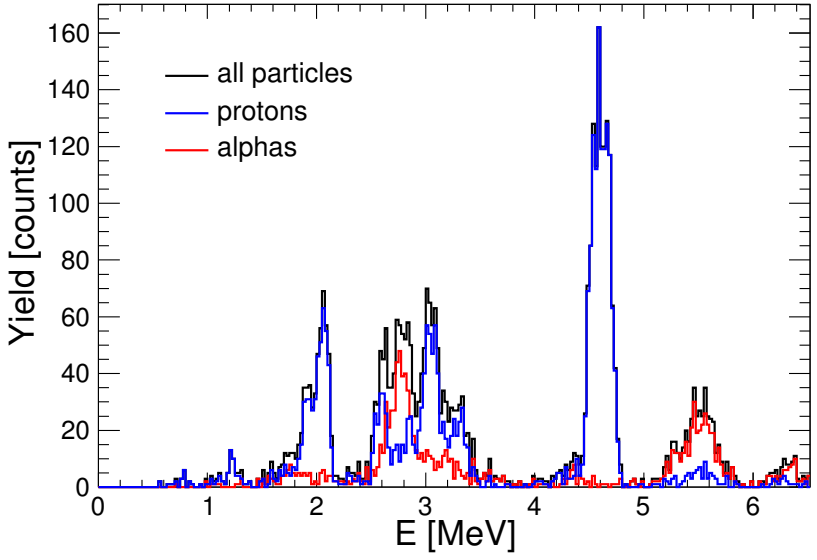


Charged Particle Detection with DSSSDs

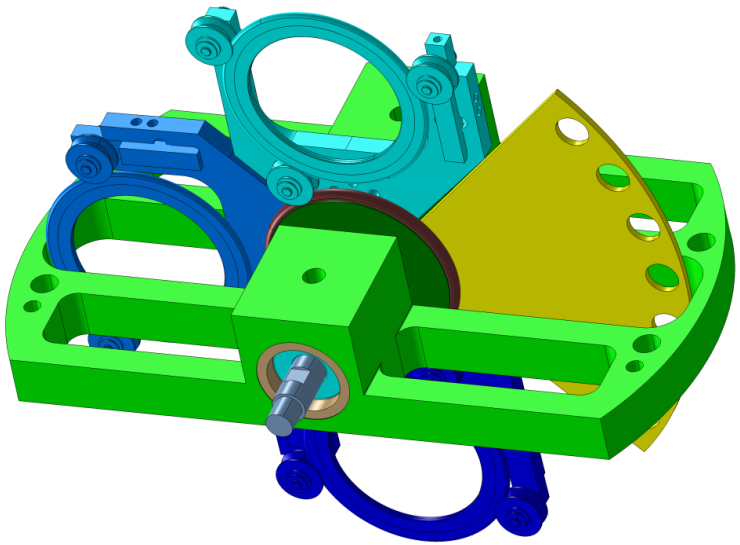
- annular Micron ® S1/S3 detectors
- strip pitch: 1505 μm/886 μm
- absorber foils for scattered beam
- 3 cm/6 cm up- and down stream: 25%/(4Π)







Rotating Target



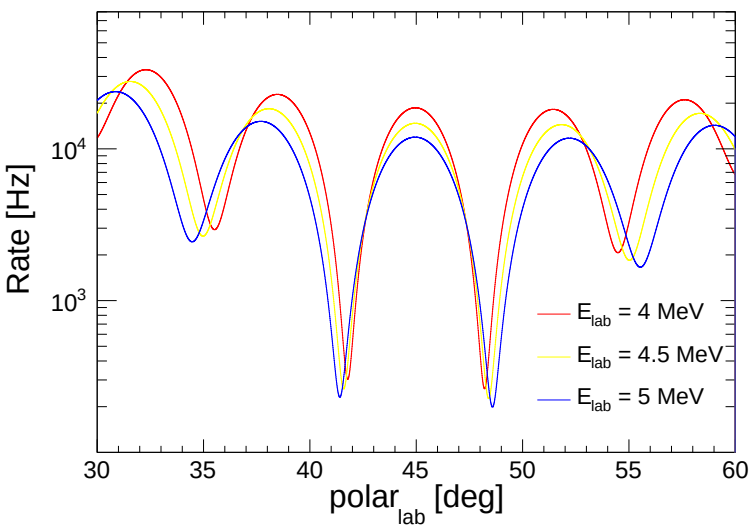
M. Krauth

- 2 mm beam spot size
- carbon foils of tens μg/cm^2
- up to 1000 rpm
- magnetic feed through into vacuum
- ✓ 23*24 h @ 100...200 rpm

1. 7 fixed target slots
2. 3 rotating targets ($\oslash$ = 4.6 cm): ~15 cm beam track

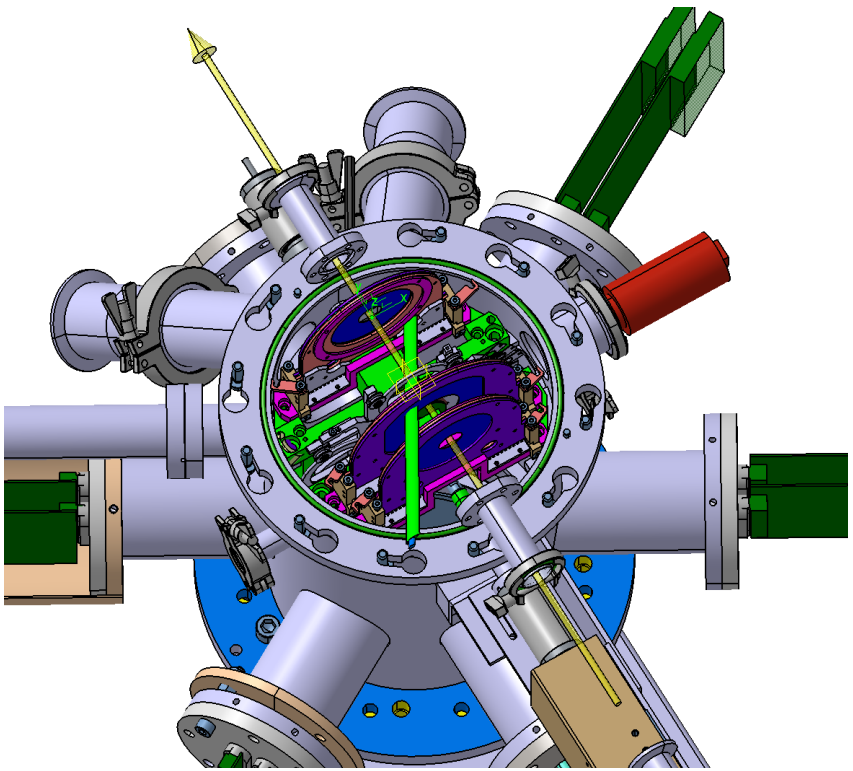
Monitoring the Mott-scattering of ^{12}C Beam

- standard surface barrier particle detectors
- placed at 45° deg polar angle in chamber extension:



$d = 25$ cm, $r = 0.025$ cm,

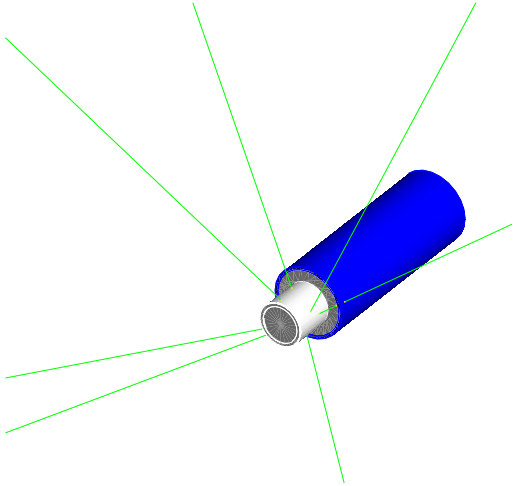
$I_{beam} = 5$ pμA



P. Dene

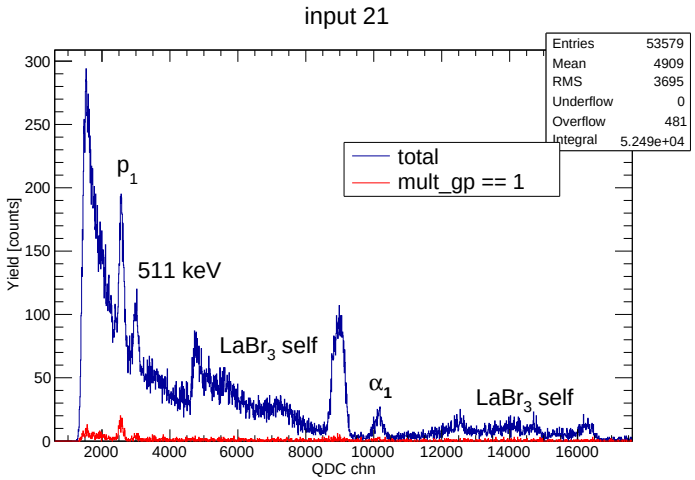
Gamma Detection with UK FATIMA

P. Regan, IASEN, 2014

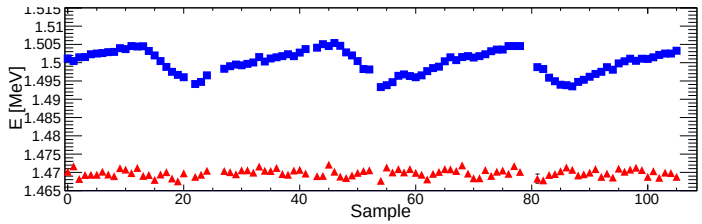


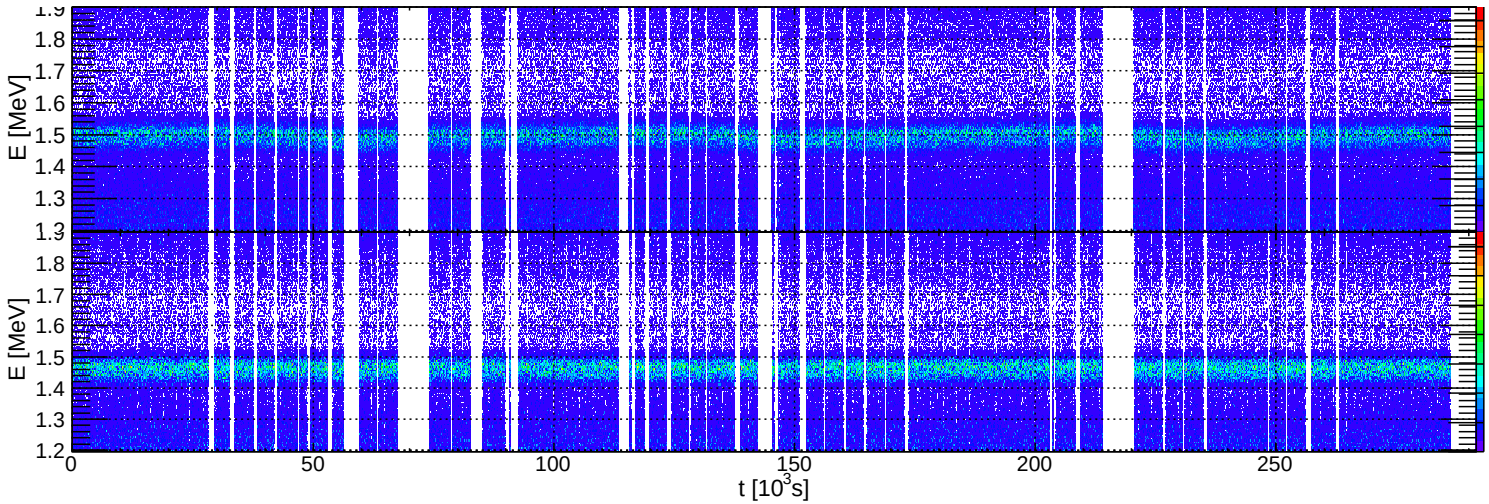
- timing precision in the order of ns
- simulation study for optimized crystal (1.5″x2″) placement
- geometrical acceptance: 21%/(4Π)
- full-energy peak detection: 8%@440 keV, 2%@1634 keV
- simulation of ^{138}La decay for walk correction: ±10 keV/d
- Compton recovery of time sync offsets

Temperature Drift of the $LaBr_3$



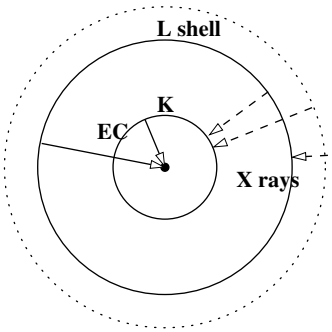
- ~ 3 days of data; 45 min blocks
- drift of 1.47 MeV line: 15 keV
- since calibration: 30 keV

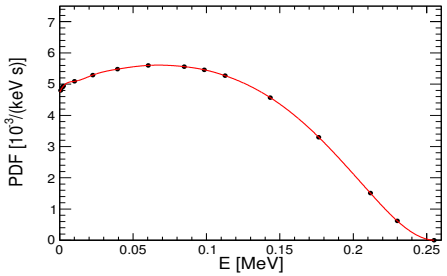


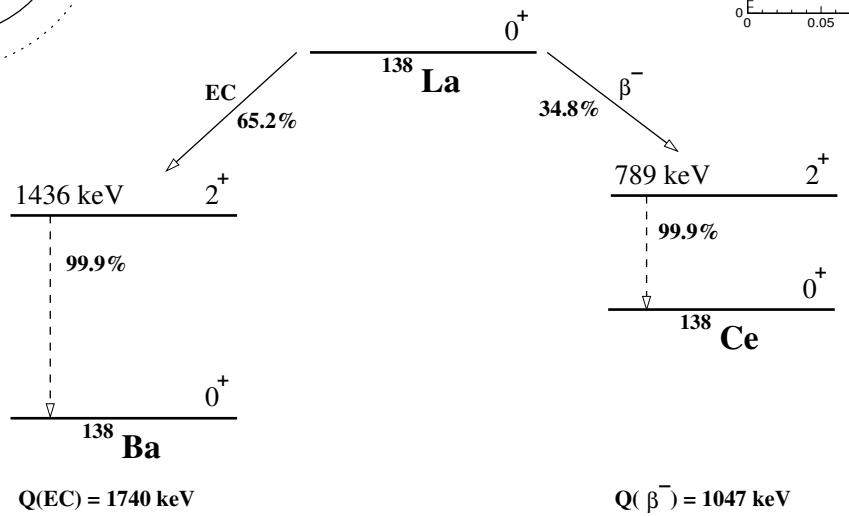


The Decay of ^{138}La

$T_{1/2} = 1.05 \cdot 10^{11}$ a, nat. ab. = 0.090% $\Rightarrow A = 90$ Bq



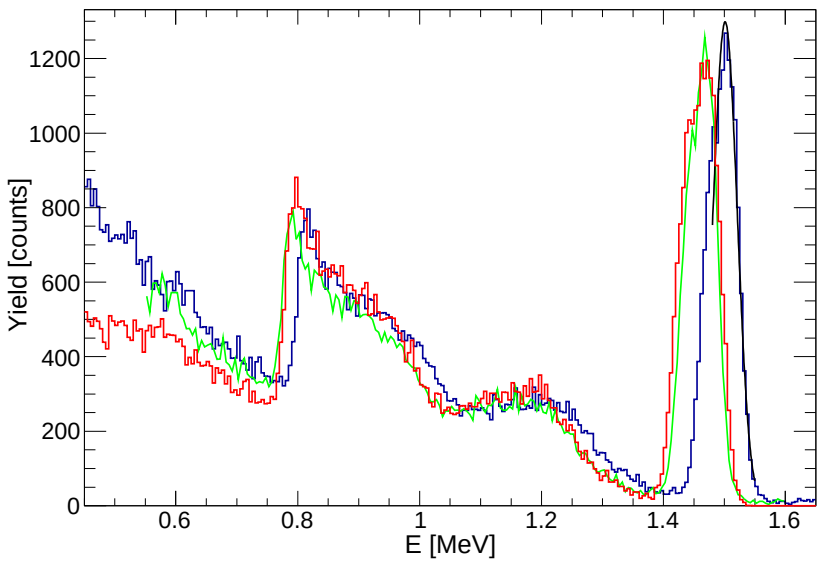




→ Simulate decay pattern of crystals placed in the gamma array and fit experiment data to the values of the nominal energy depositions.

Comparison of the Simulated Mask with the Experiment

fit: bin content and energy value



- red: simulation
- blue: experiment
- (black: exponential)
- green: fit - exponential

^{152}Eu run:

- linear energy response
- energy resolution

... in ROI

- small correction (dotted blue) in current data ($\Delta T \approx 10°C$)
- helpful to know the gates don't drift

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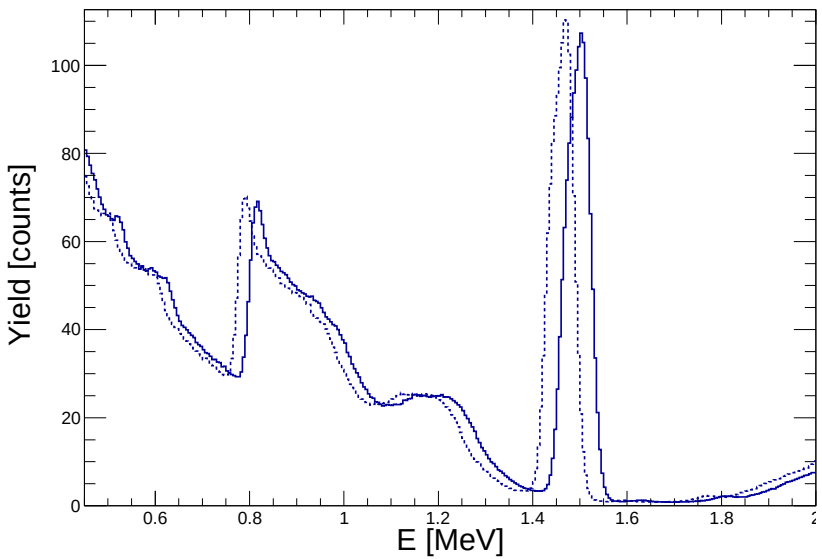

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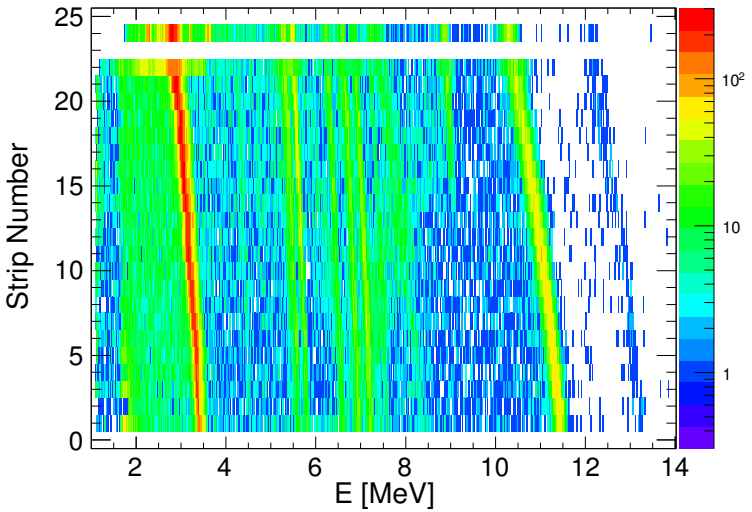
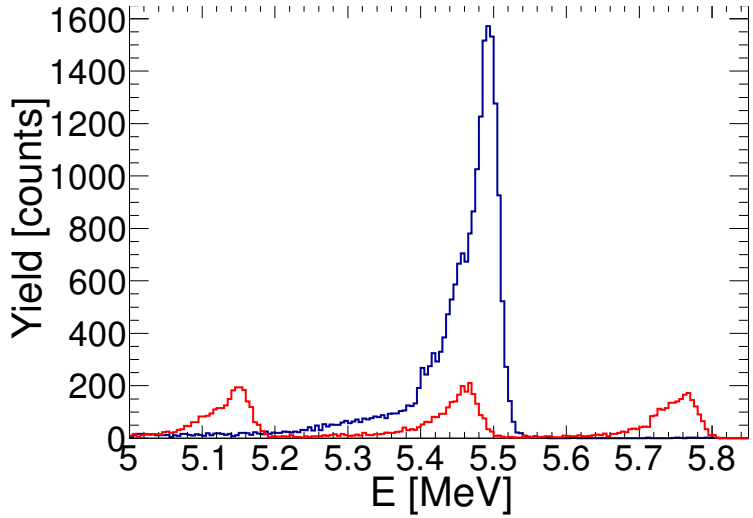
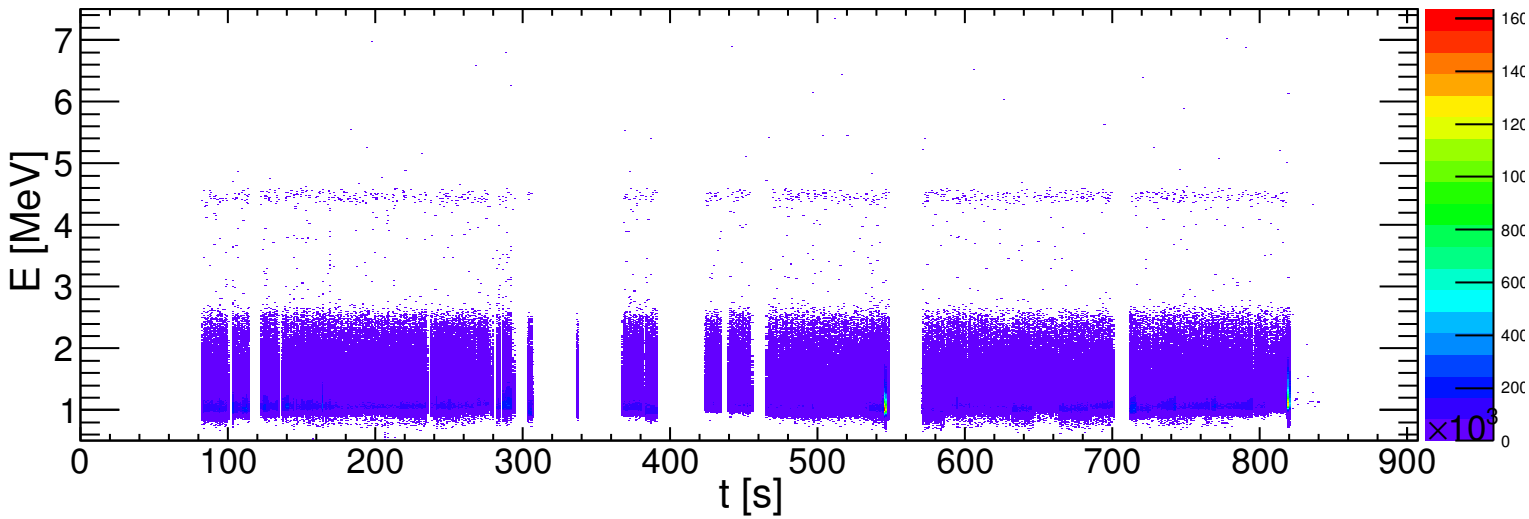
Kinematics from Fusion Reactions and Source Runs

- calibration run at $E_{beam} = 10.4$ MeV



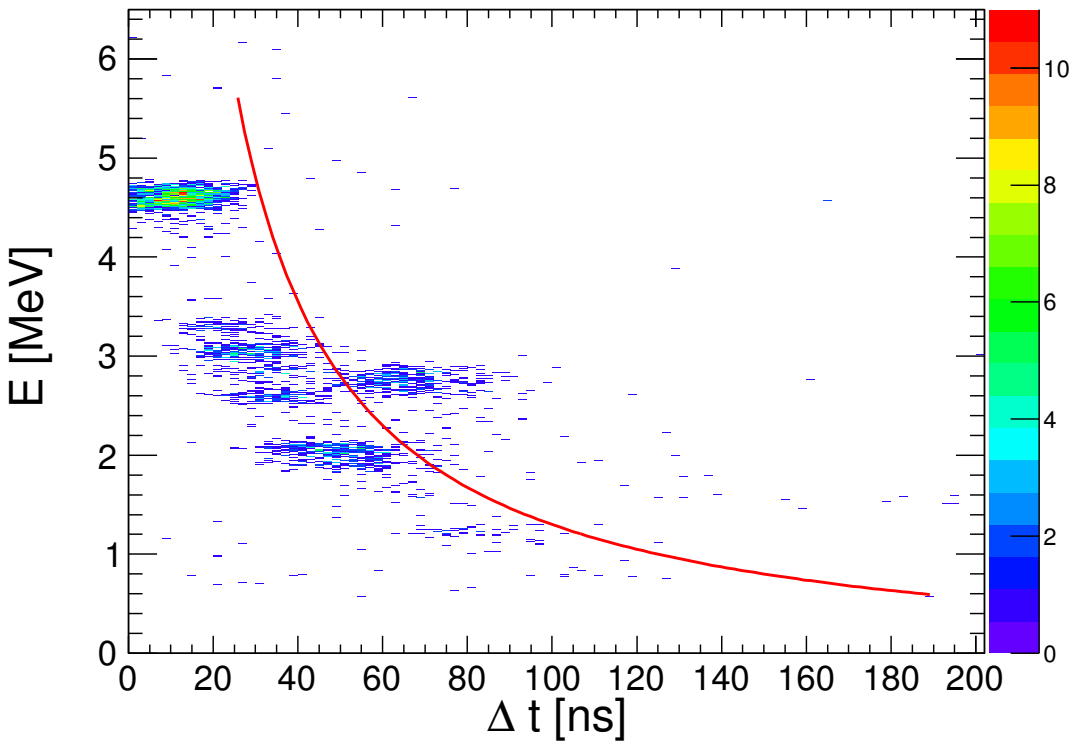
- 10days of data: 30 keV drift @ 5.49 MeV





Discrimination of Reaction Channels

- synchronization of 1 GHz gamma DAQ and 125 MHz particle DAQ
- timing insufficient to resolve ToF gap between protons and alphas
- pulse form difference impacts timing though



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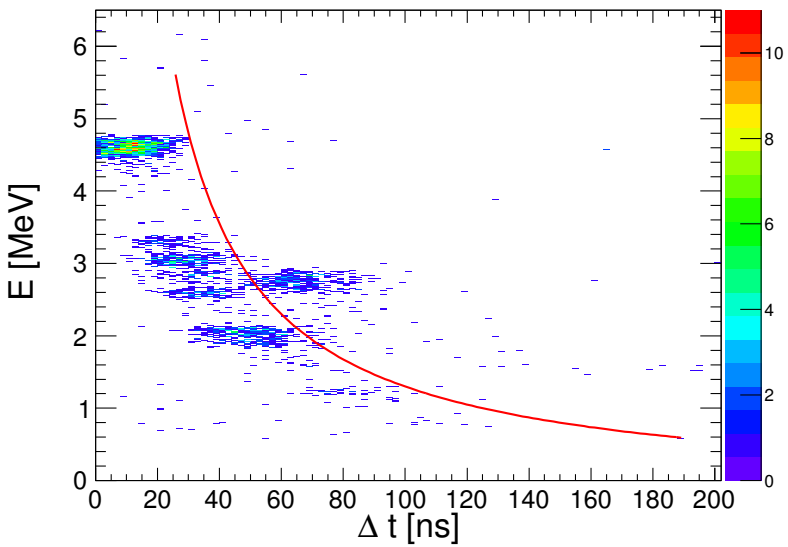
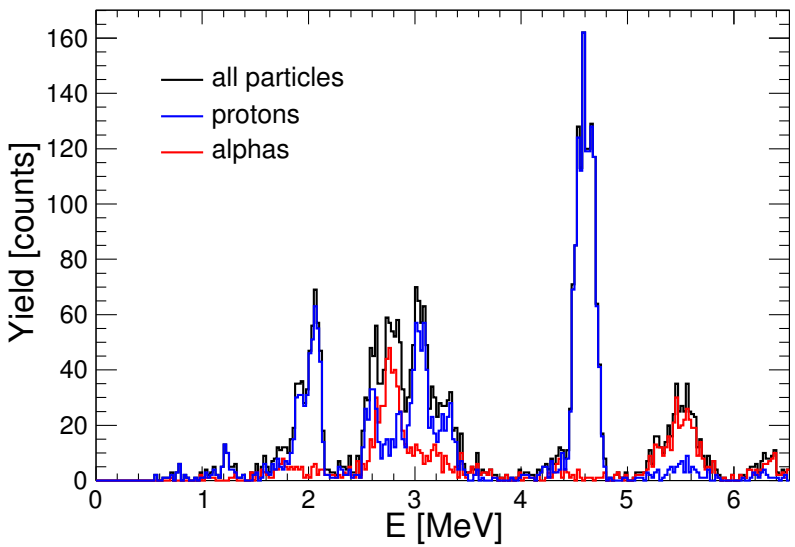
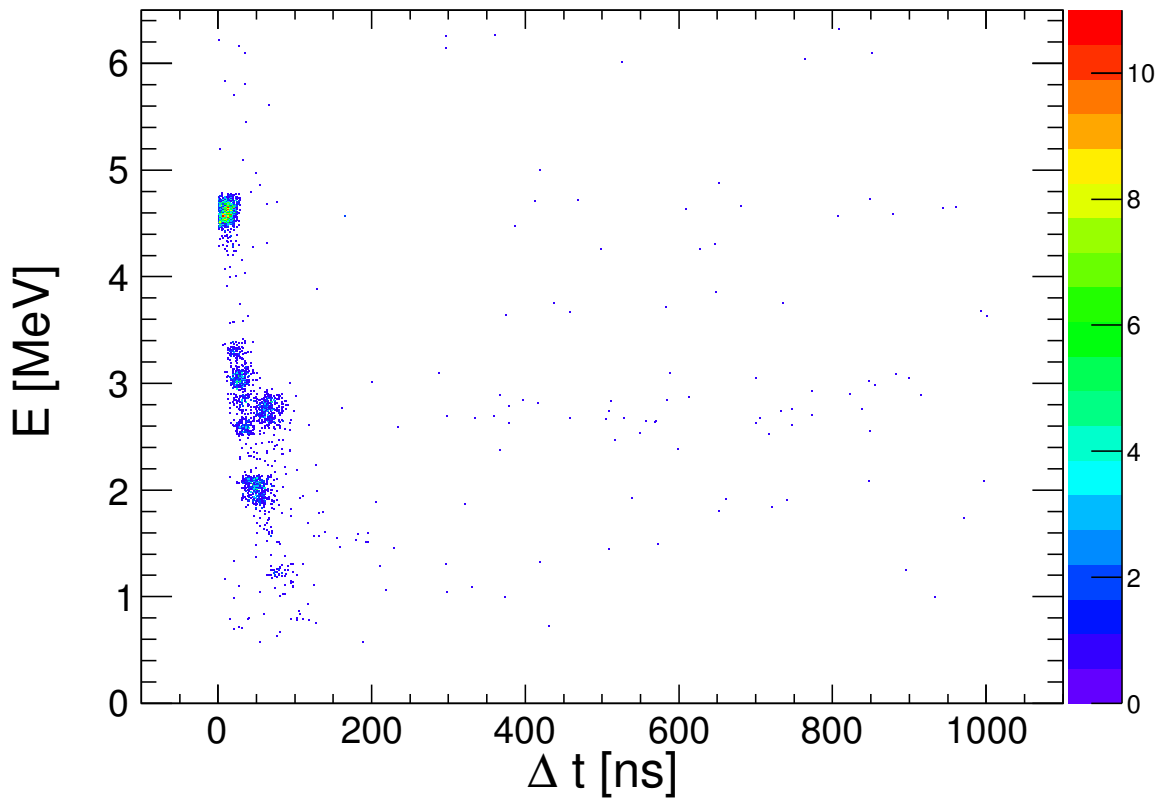




(^{12}C,^{12}C) @ $E_{beam} = 10.4$ MeV

- time difference between gammas and particles Δt
- separation of proton and alpha distributions



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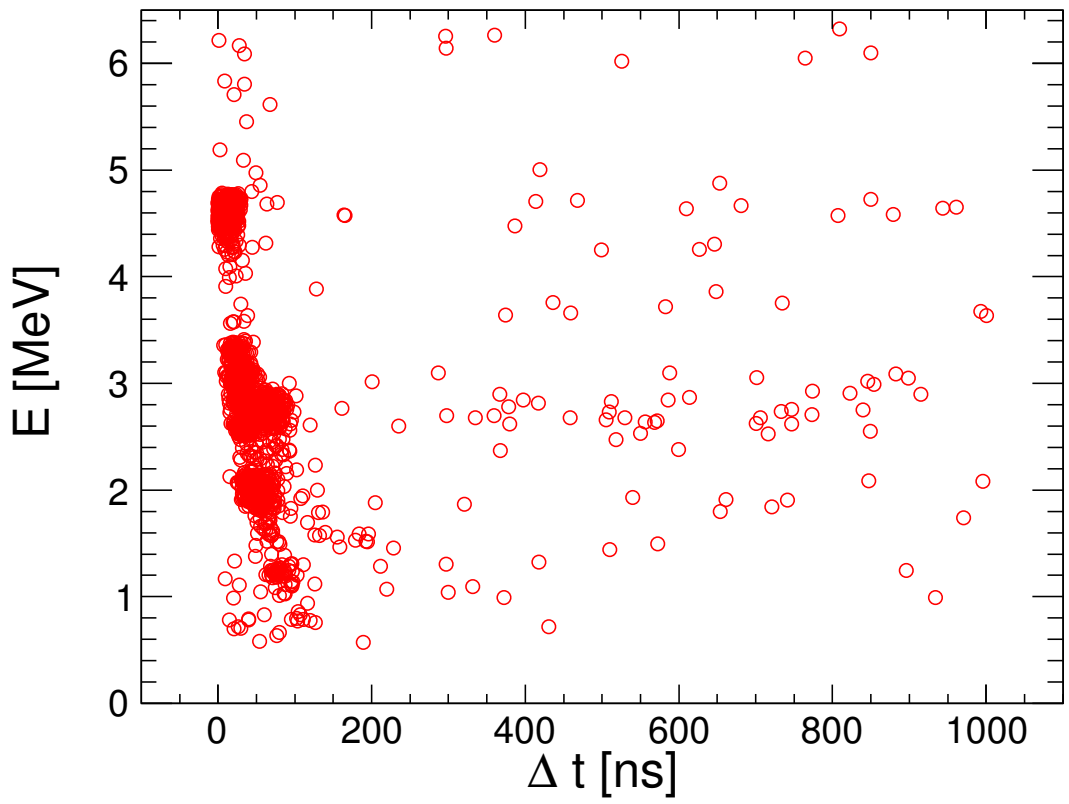
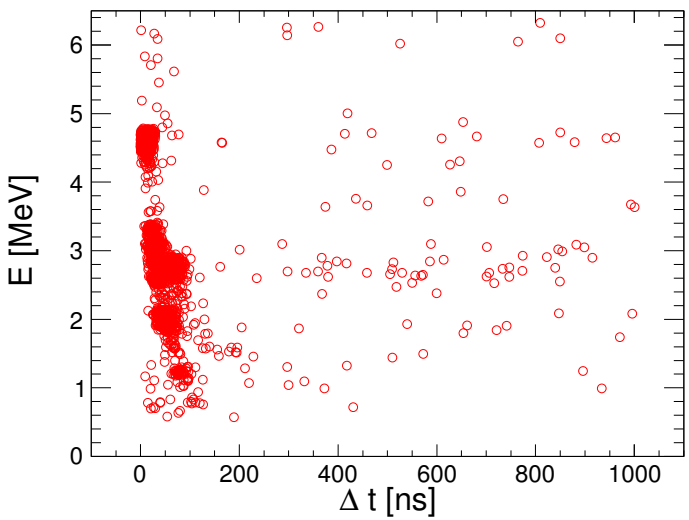


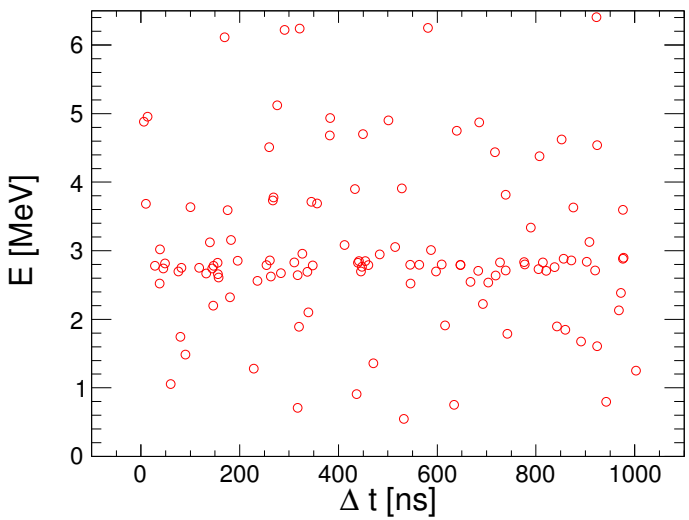
Event Mixing with Arbitrary Time Synchronization

- randomize time synchronization offset between gamma-particle clocks

→ coincidences from simultaneous events destroyed

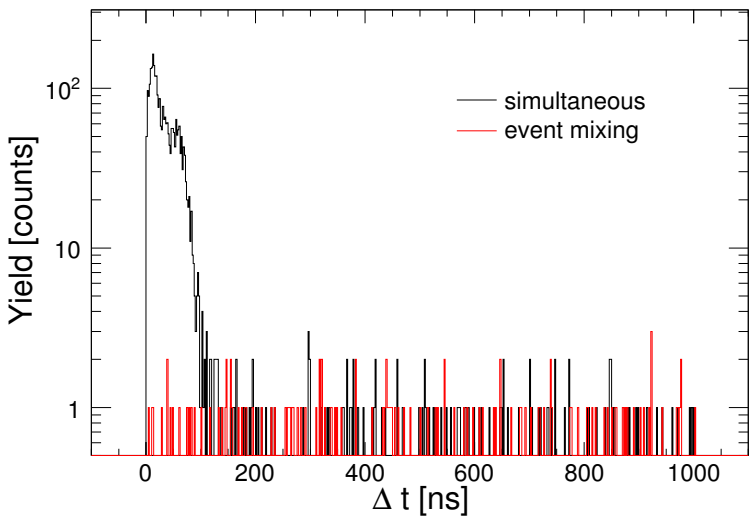
random ⊗ random = random

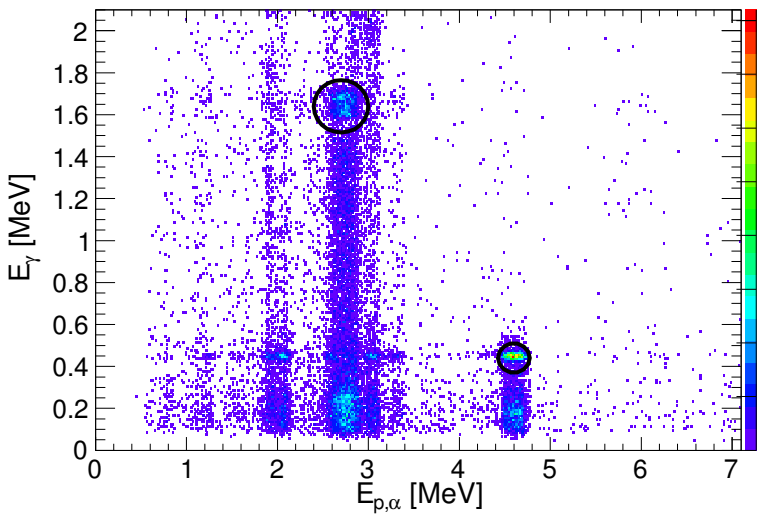




Extrapolation of Background into ROI

- project on time axis for background subtraction
- timing cut in addition to gamma and particle energy





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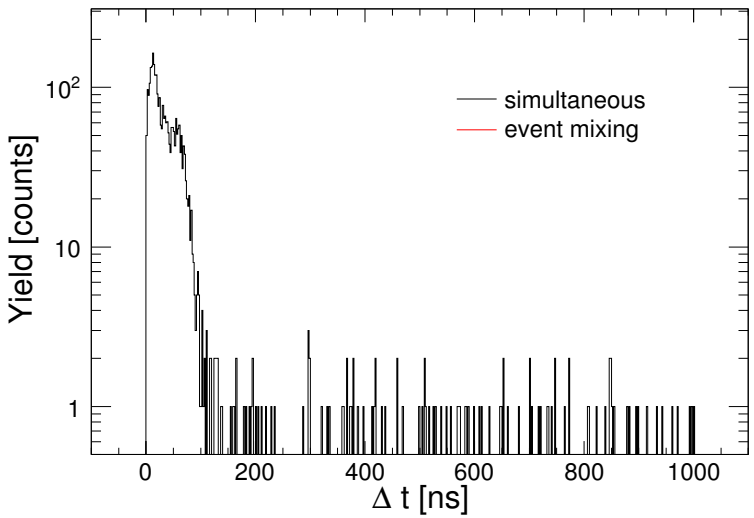

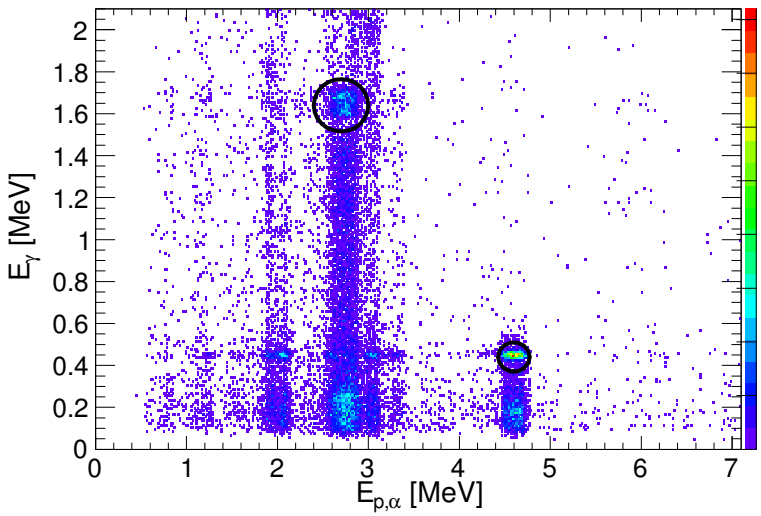

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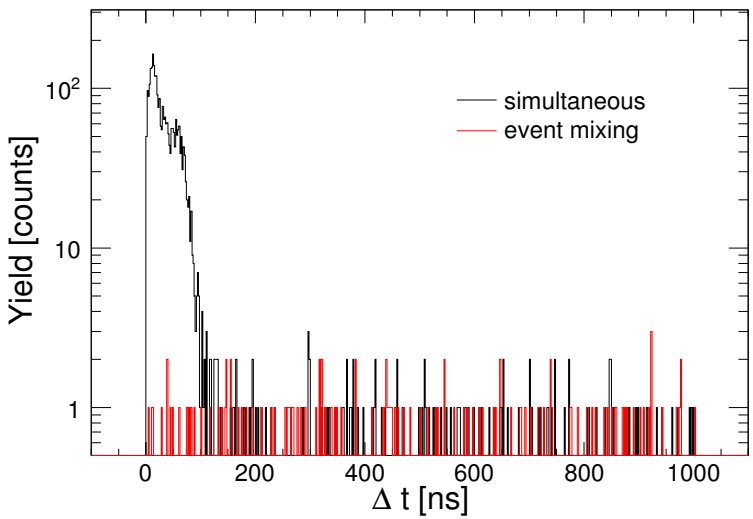

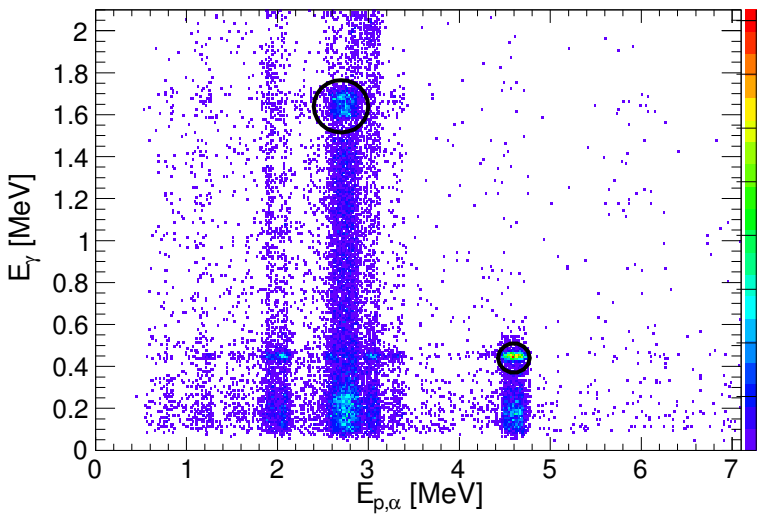

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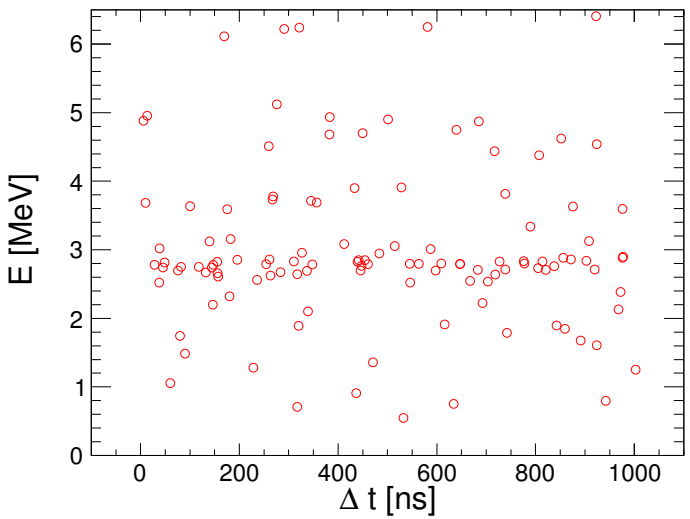
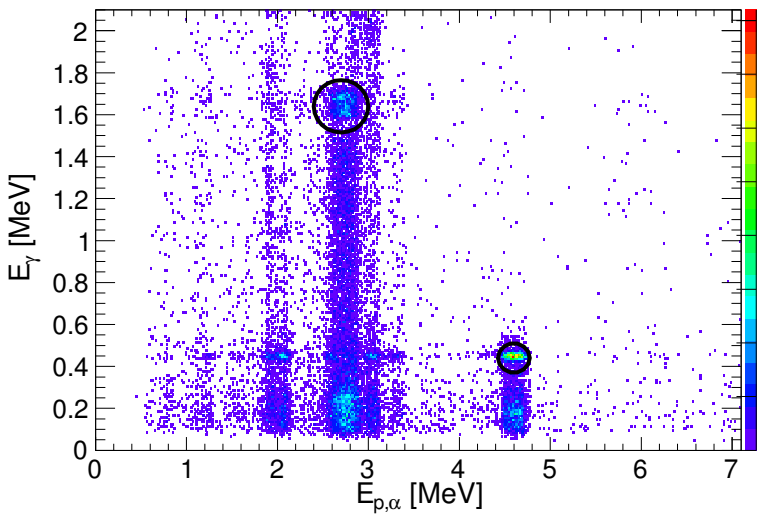
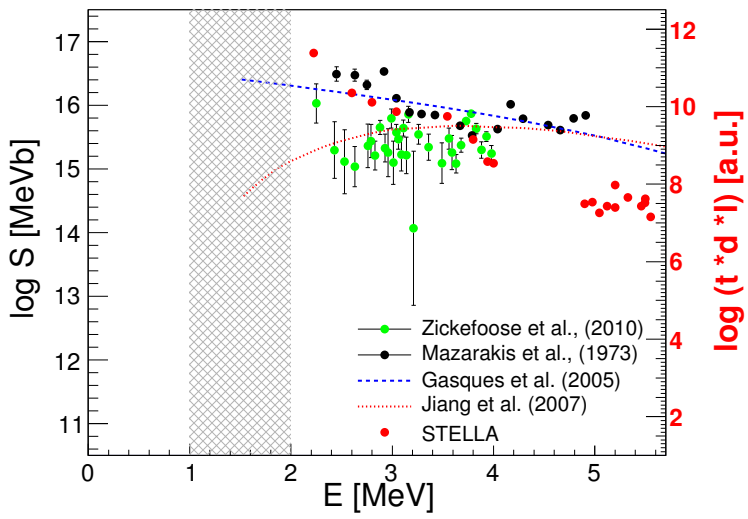




Summary:

- experimental scope
- detection system:
  - g-p detection
  - normalization
  - rotating target
- self calibration
- p-α separation
- bkrg. estimation

Outlook:



↪ physics: G. Fruet

Thank You For Listening!!

P. Adsley[1,2], F. Agnese[3], C. Beck[3], L. Charles[3], O. Clausse[3], S. Courtin[3,4], E. Dangelser[3], P. Dené[3], S. Della Negra[2], G. Fruet[3], L. Gross[3], F. Haas[3], F. Hammache[2], M. Heine[3], G. Heitz[3], M. Imhoff[3], D.G. Jenkins[1], O. Kirsebom[5], H. Kocher[3], M. Krauth[3], J. Lesrel[2], M. Loriggiola[6], C. Mathieu[3], A. Meyer[2], D. Montanari[3,4], L. Morris[1], M. Richer[3], P.H. Regan[7,8], M. Rudigier[7], C. Ruescas[3], N. de Séréville[2], C. Stodel[9], D. Thomas[3] and C. Wabnit[3]

[1] *University of York*, York, (UK)
[2] *IPN d'Orsay, CNRS/IN2P3, PSUD 11*, Orsay, (France)
[3] *IPHC/CNRS*, Strasbourg, (France)
[4] *USIAS/Université de Strasbourg*, Strasbourg, (France)
[5] *Åarhus Universitet* , Åarhus, (Denmark)
[6] *INFN-LNL*, Legnaro, (Italy)
[7] *University of Surrey*, Guildford, (UK)
[8] *National Physical Laboratory*, Teddington, (UK)
[9] *GANIL*, Caen, (France)