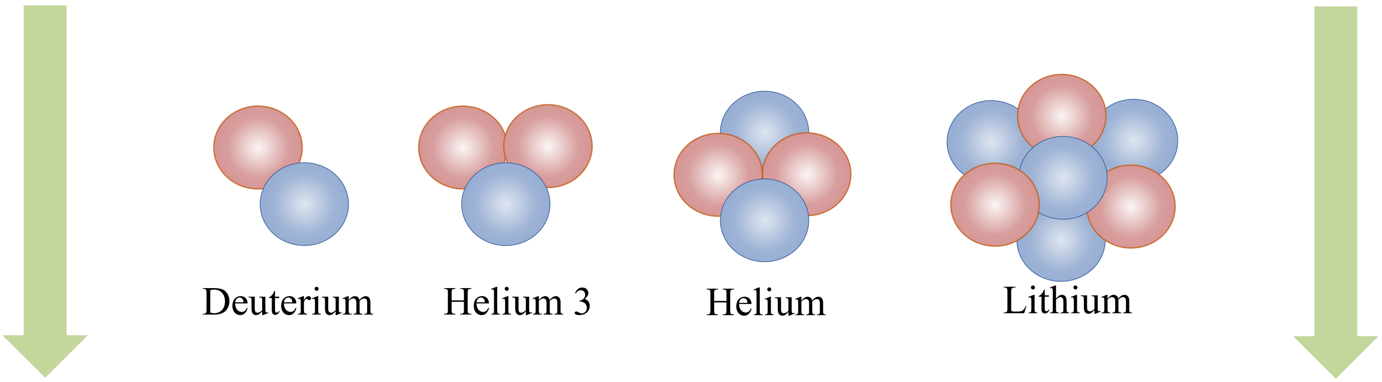
The Li-7 photodisintegration and New Photonuclear Studies at HIγS

Ioana KUNCSER (ELI-NP)

07.09.2026

Astrophysical motivation of the study

The light elements: produced in the early stages of the Universe



BBN predictions & low metallicity stars observations

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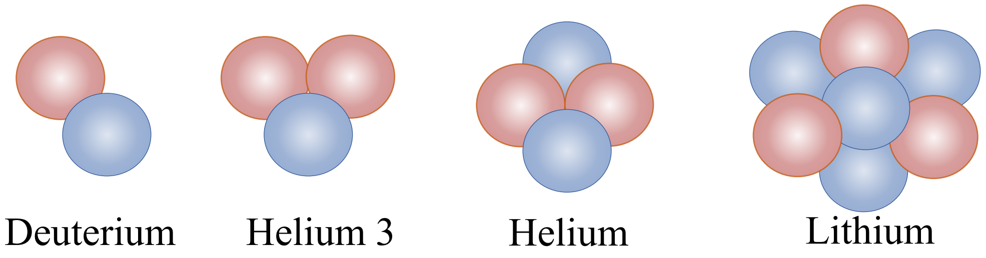

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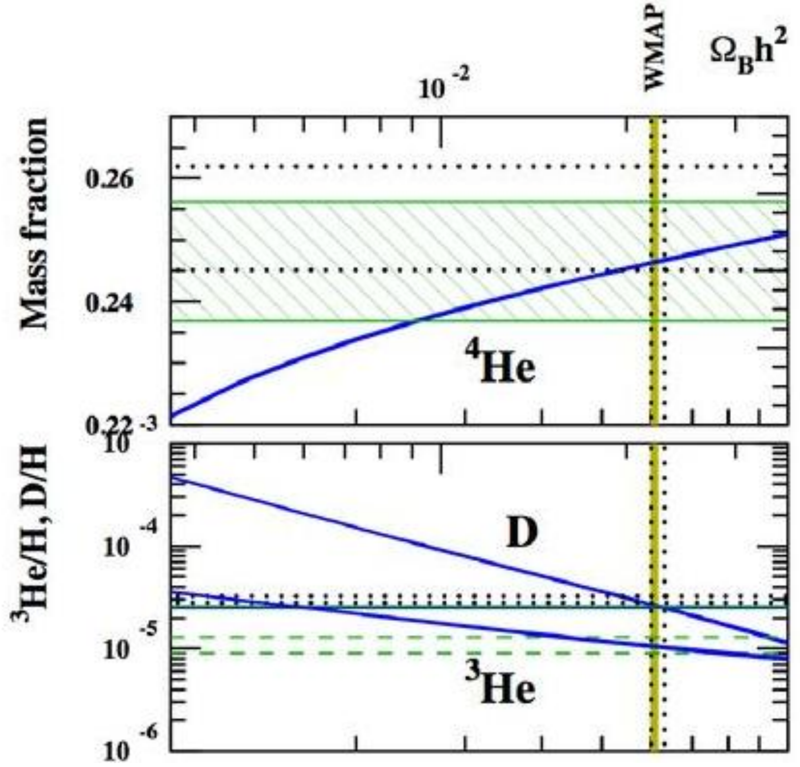

Astrophysical motivation of the study

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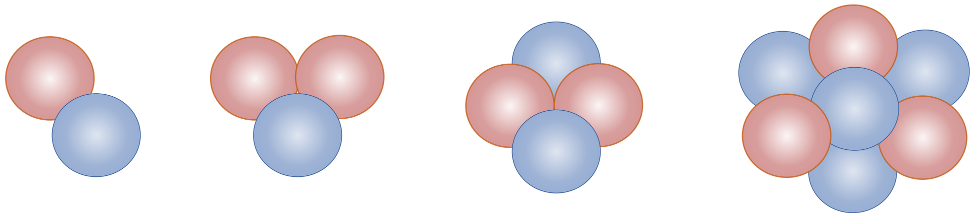
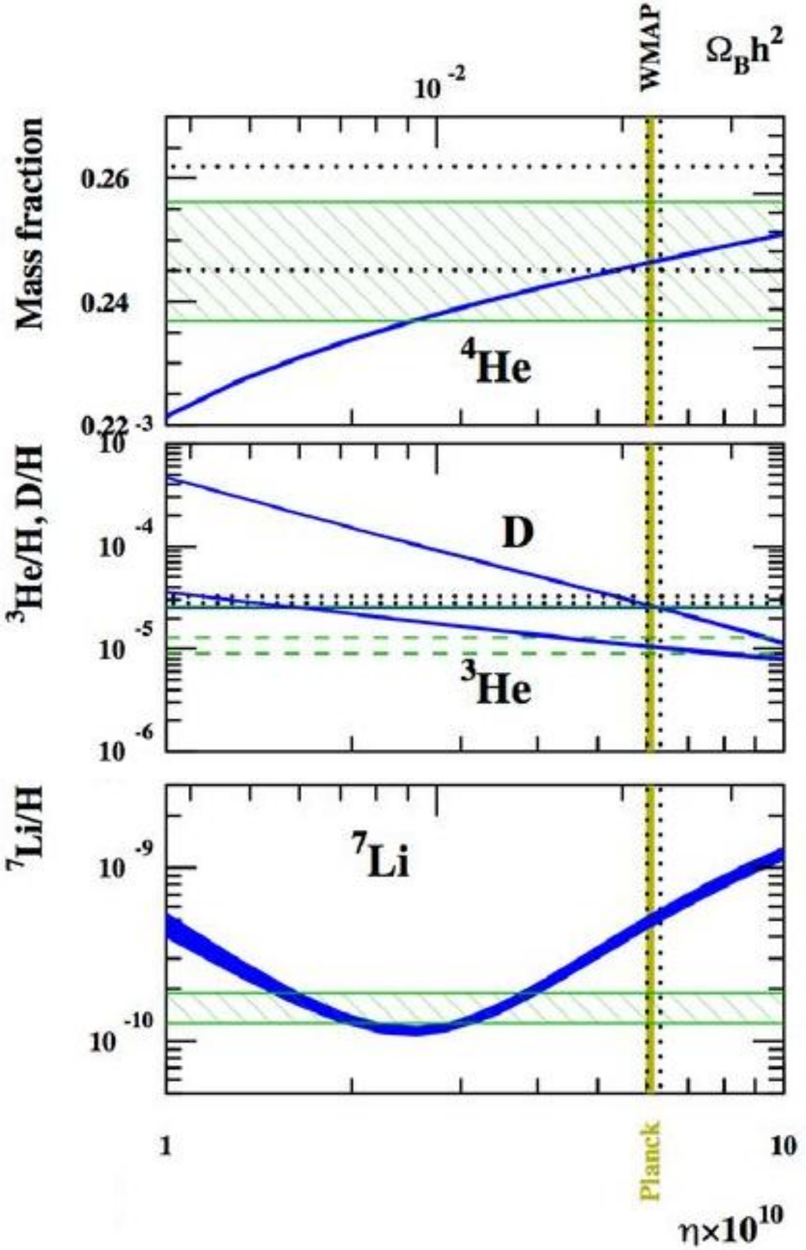


Deuterium Helium 3 Helium Lithium

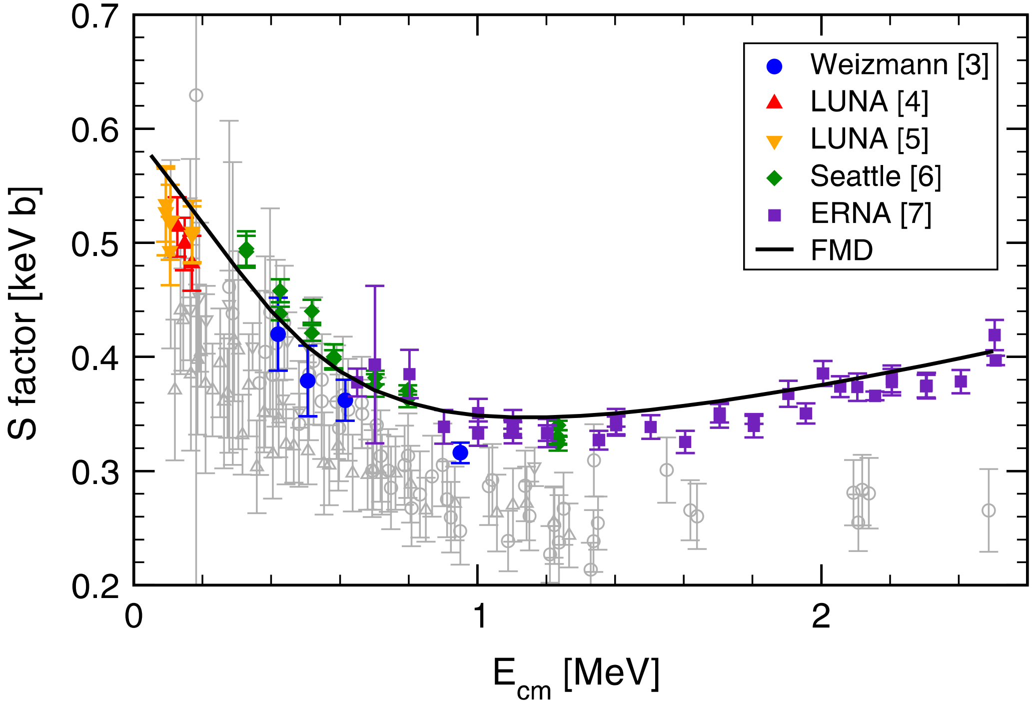
BBN predictions & low metallicity stars observations

^{7}Li observed abundance is 3-4 times lower than expected from BBN

COSMOLOGICAL Li PROBLEM

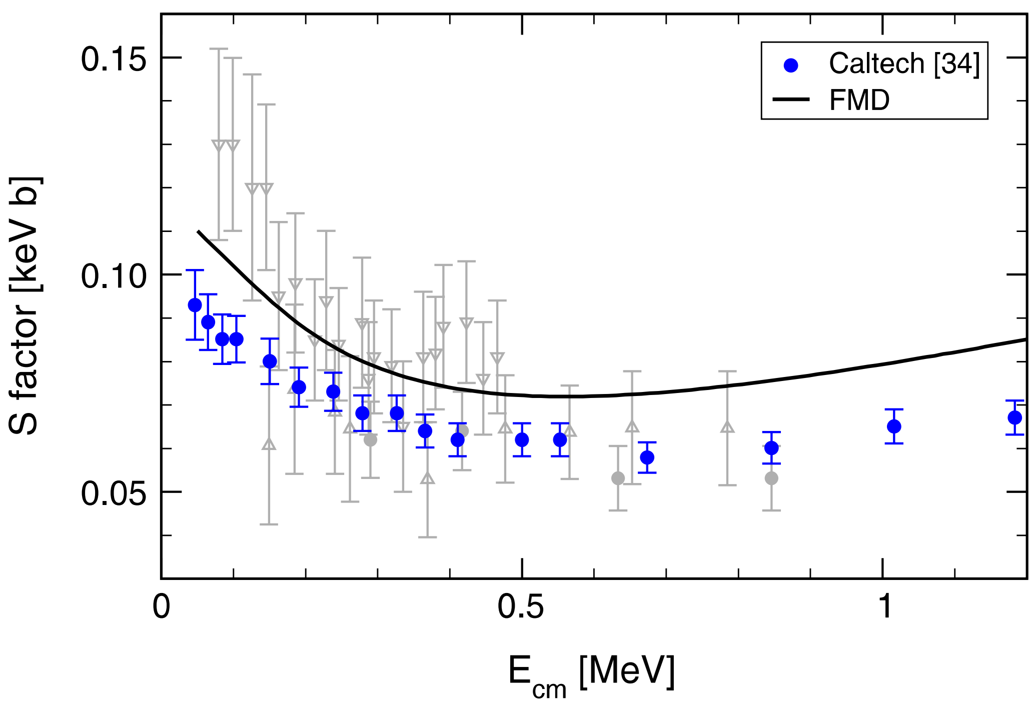


$^{3}He\ (\alpha,\gamma)\ ^{7}Be$



well studied

$^{3}H\ (\alpha,\gamma)\ ^{7}Li$



few experiments

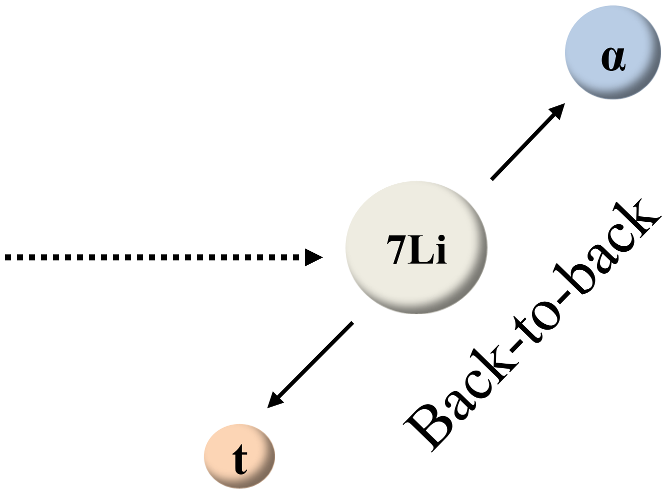
(α-beam, 3H target, Ge detectors)

Reciprocity theorem

$$\frac{\sigma_{Bb\to Aa}}{\sigma_{Aa\to Bb}} = \frac{(2j_A+1)(2j_a+1)}{(2j_B+1)(2j_b+1)} \cdot \frac{k_{Aa}^2}{k_{Bb}^2} \cdot \frac{1+\delta_{Bb}}{1+\delta_{Aa}}$$

*Photons: $2j_\gamma + 1 = 2$

The inverse reaction: $^{7}Li\,(\gamma,\alpha)\,^{3}H$ (γ-beam, 7Li target, charged particle detectors)

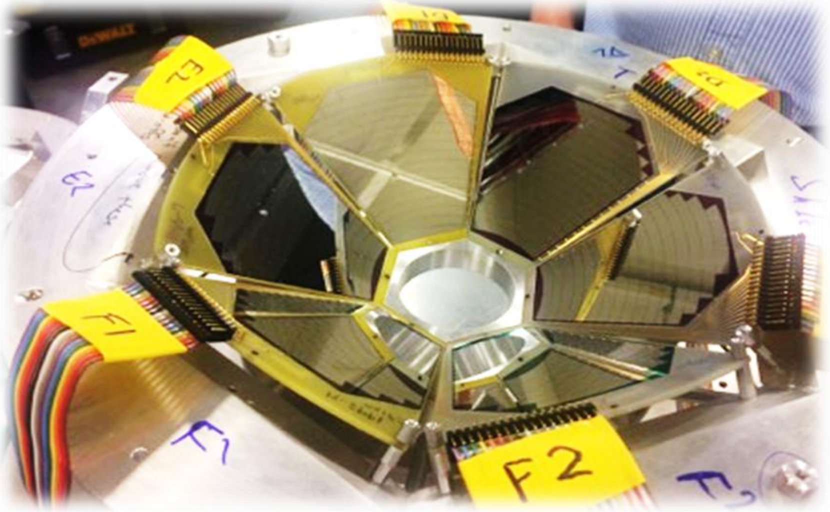


$$\frac{\sigma_{\alpha t\to Li\gamma}}{\sigma_{Li\gamma\to\alpha t}} = \frac{(2s_{Li}+1)\cdot 2}{(2s_\alpha+1)(2s_t+1)} \cdot \frac{\frac{E_\gamma^2}{c^2}}{2m_{\alpha t}E_{\alpha t}} \cdot (1+\delta_{\alpha t})$$

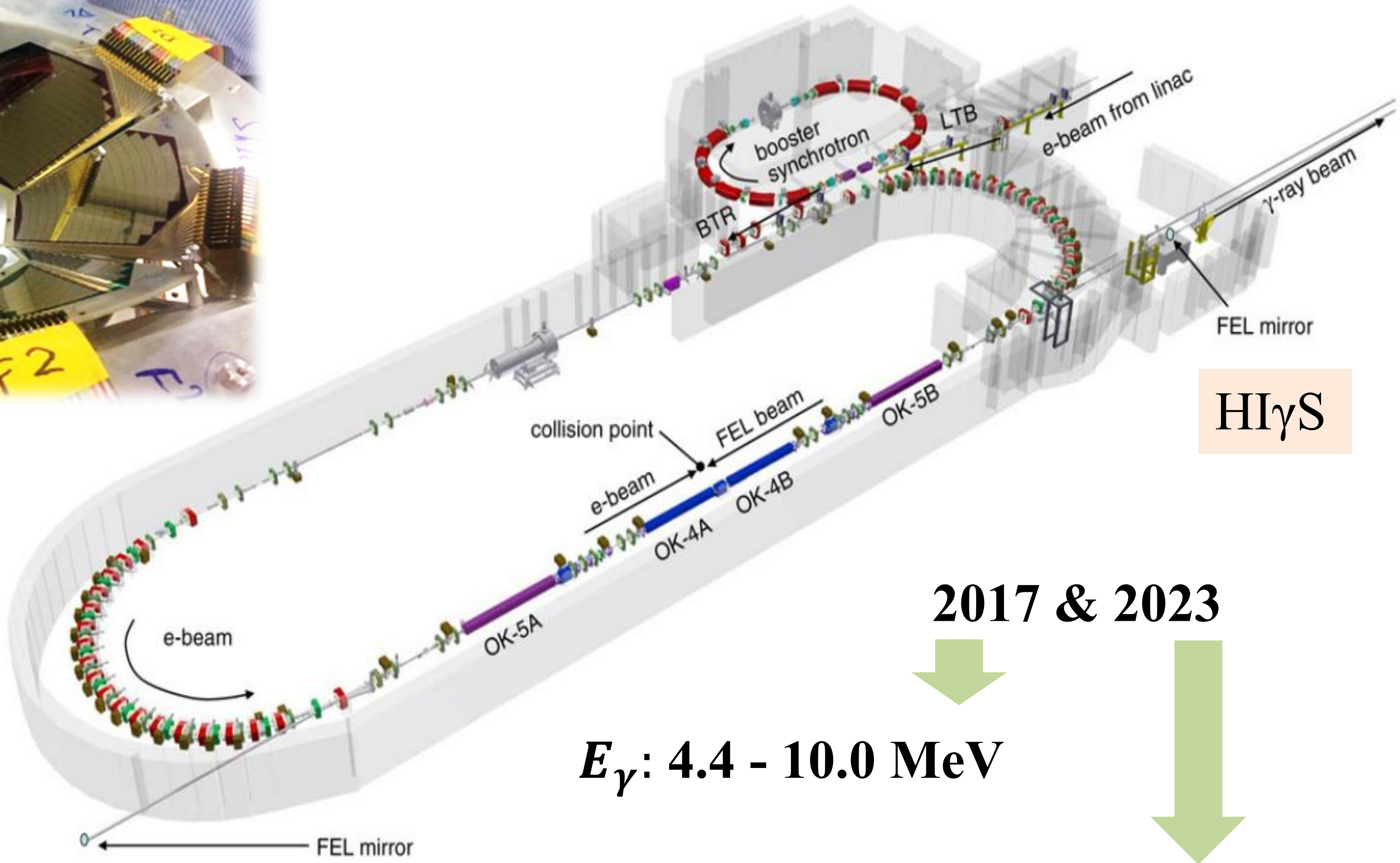
$$\frac{\sigma_{\alpha t\to Li\gamma}}{\sigma_{Li\gamma\to\alpha t}} = 0.00125 \cdot \frac{E_\gamma^2}{E_{\alpha t}} \quad \sim \frac{1}{80} \; at\ E_\gamma = 6\ MeV$$

Set-up at HIγS

SIDAR



LiF/Mylar



HIγS

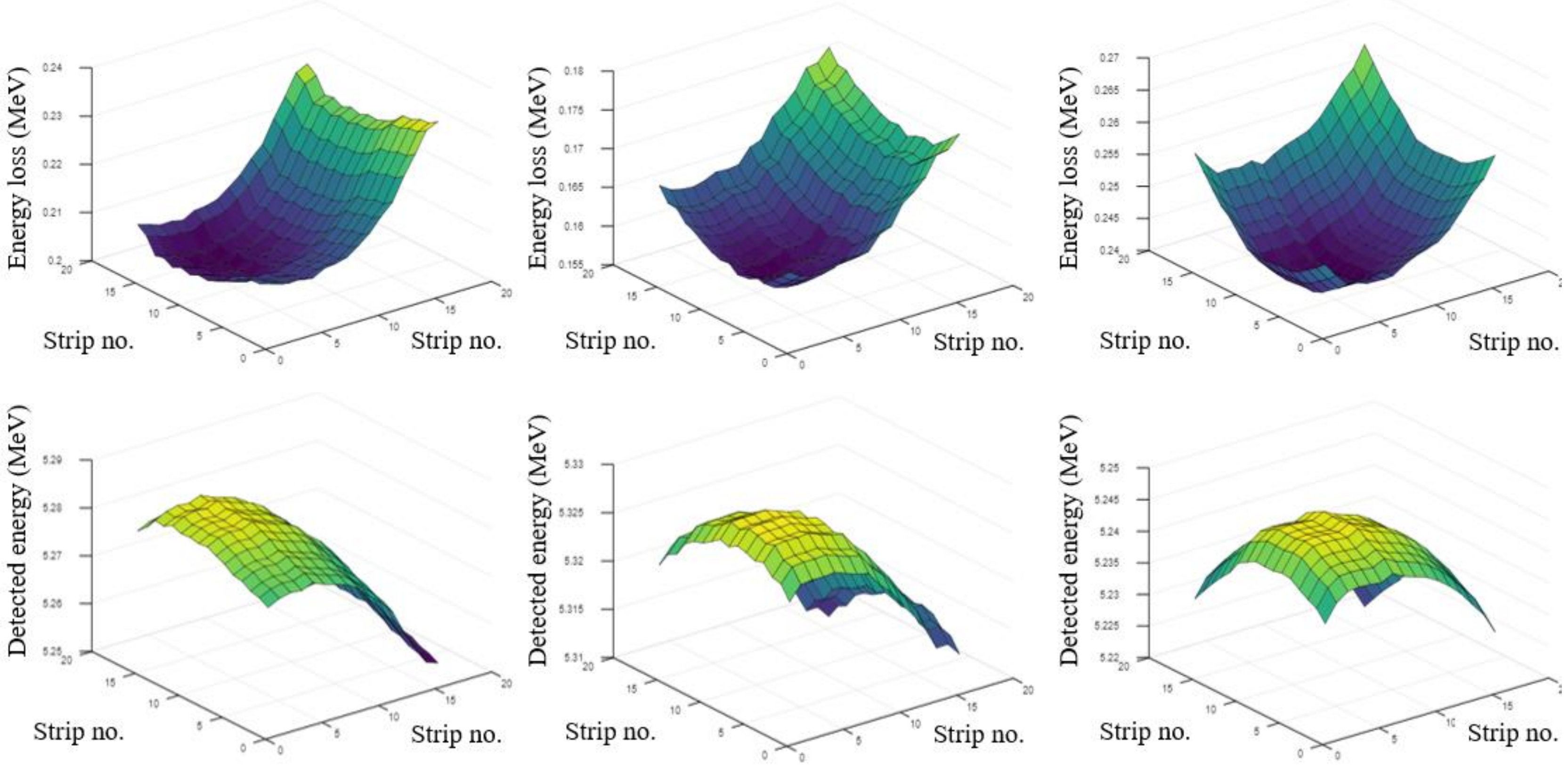
2017 & 2023

E_{γ}: 4.4 - 10.0 MeV

E_{γ}: 3.7 – 6.0 MeV

Set-up at HIγS. Target

Measured with DSSSDs from the α particles energy loss

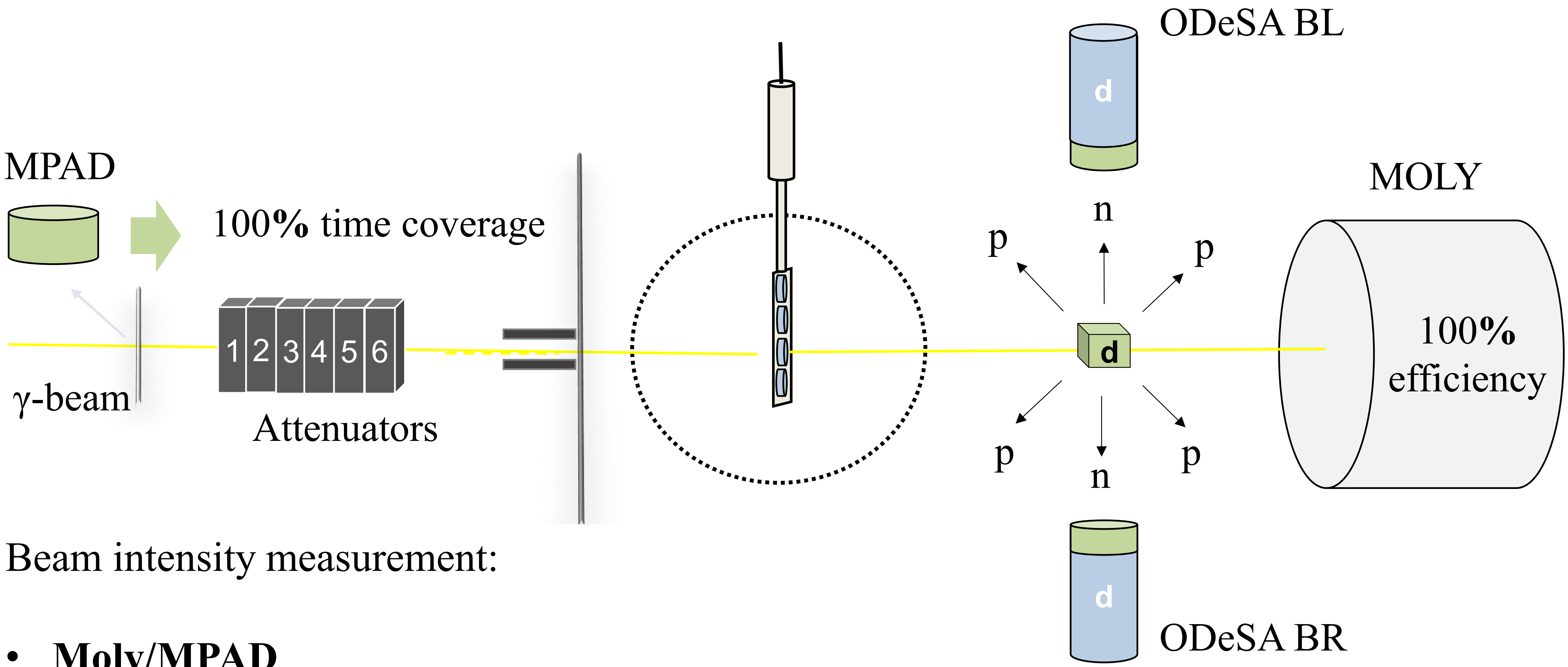


thermal evaporation of LiF on Mylar 135 μg/cm^2

INFN/LNS Target Lab

E_γ $[MeV]$	LiF thickness [μg/cm^2]	INFN [μg/cm^2]
3.7	73 ± 4.2	74
4.0 – 4.5	139.3 ± 4.7	131
5.0 – 6.0	193.3 ± 2.9	201

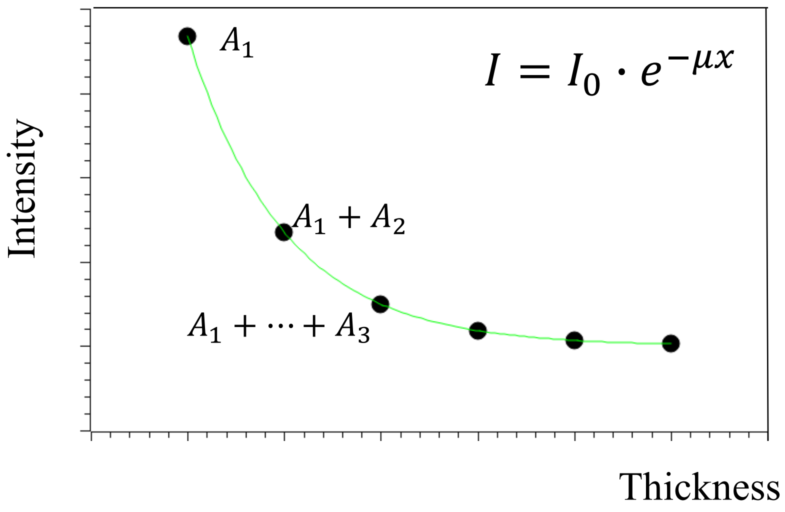
Set-up at HIγS. Beam Intensity



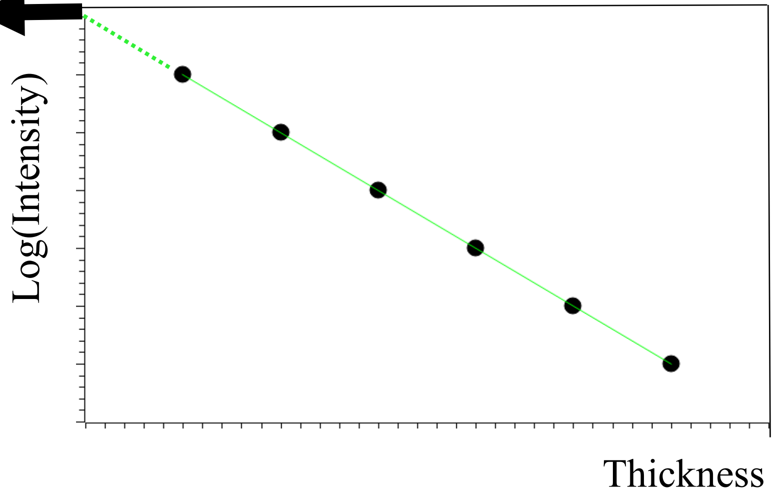
Beam intensity measurement:

- **Moly/MPAD**
- Deuterium photodisintegration

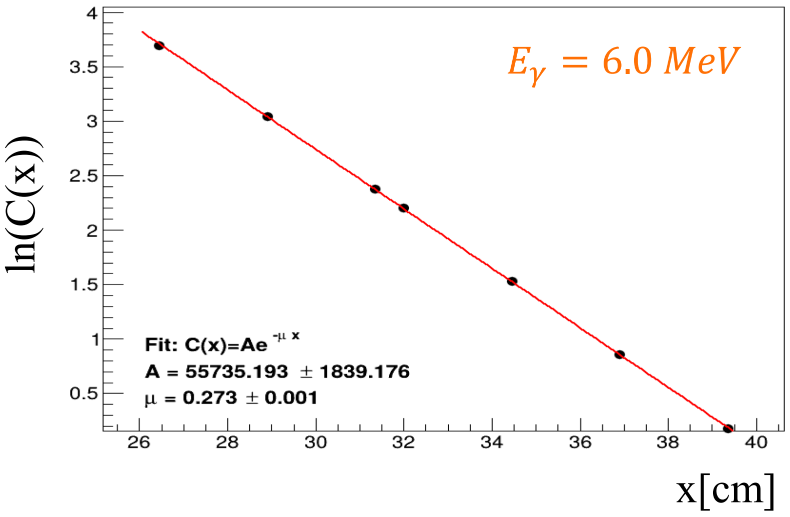
Set-up at HIγS. Beam Intensity I



No Attenuation Value

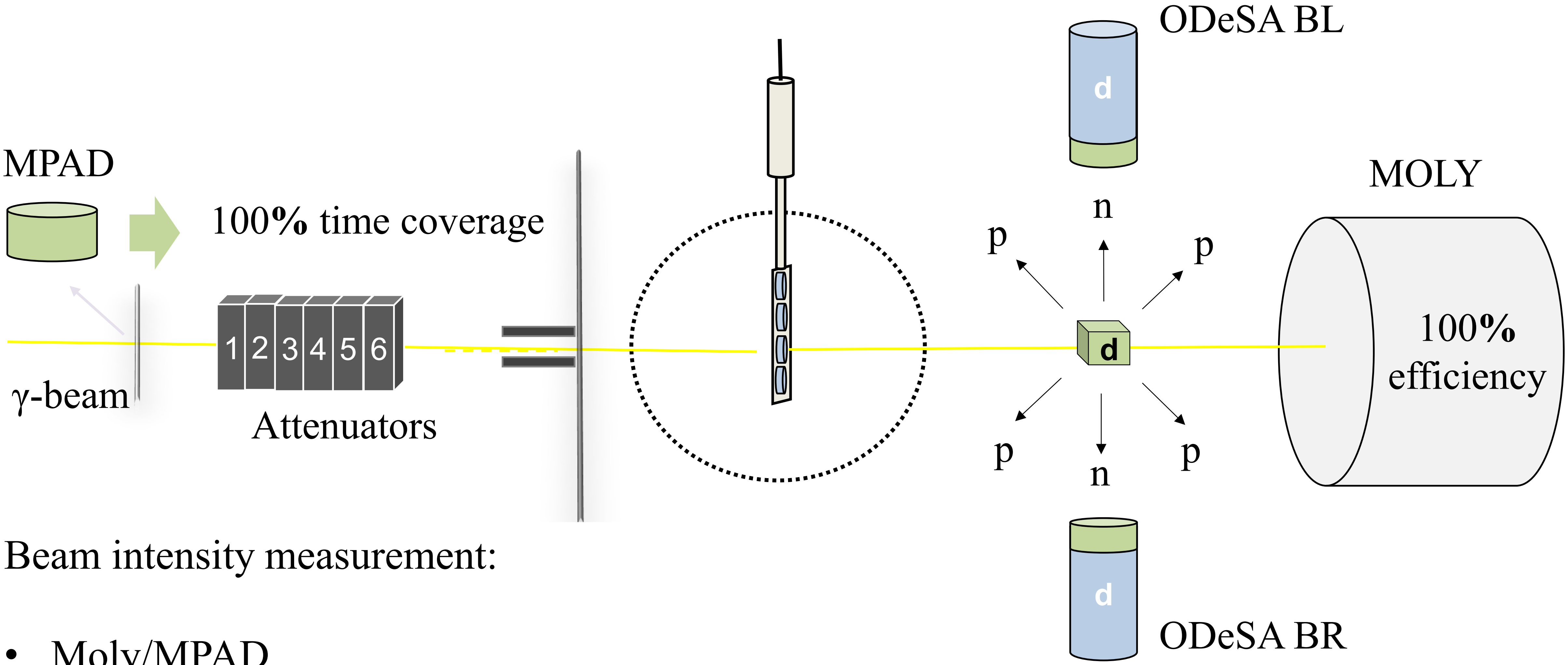


Intensity measurement during the run



- Intersection: no attenuation value
- Slope: effective attenuation
- 10^7 photons/h (5% unc.)

Set-up at HIγS. Beam Intensity



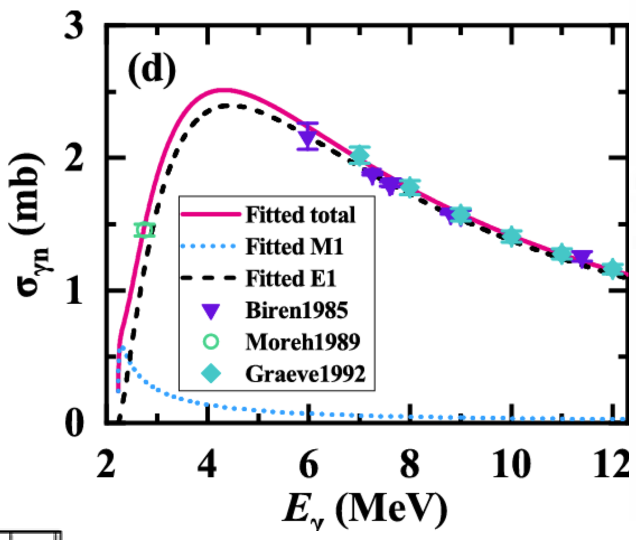
Beam intensity measurement:

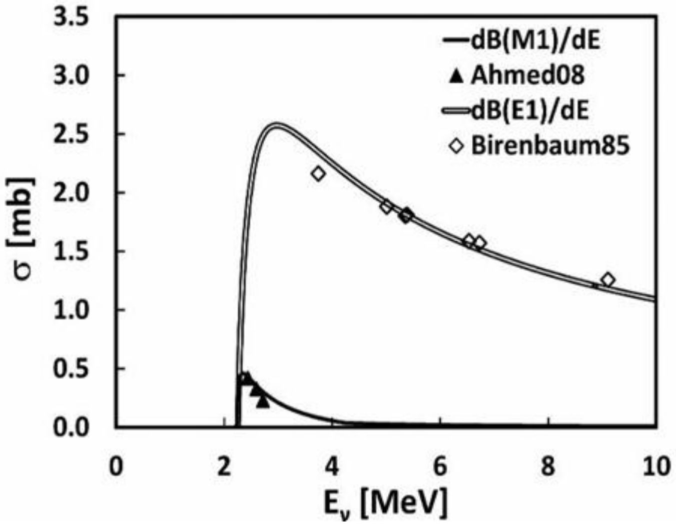
- Moly/MPAD
- **Deuterium photodisintegration**

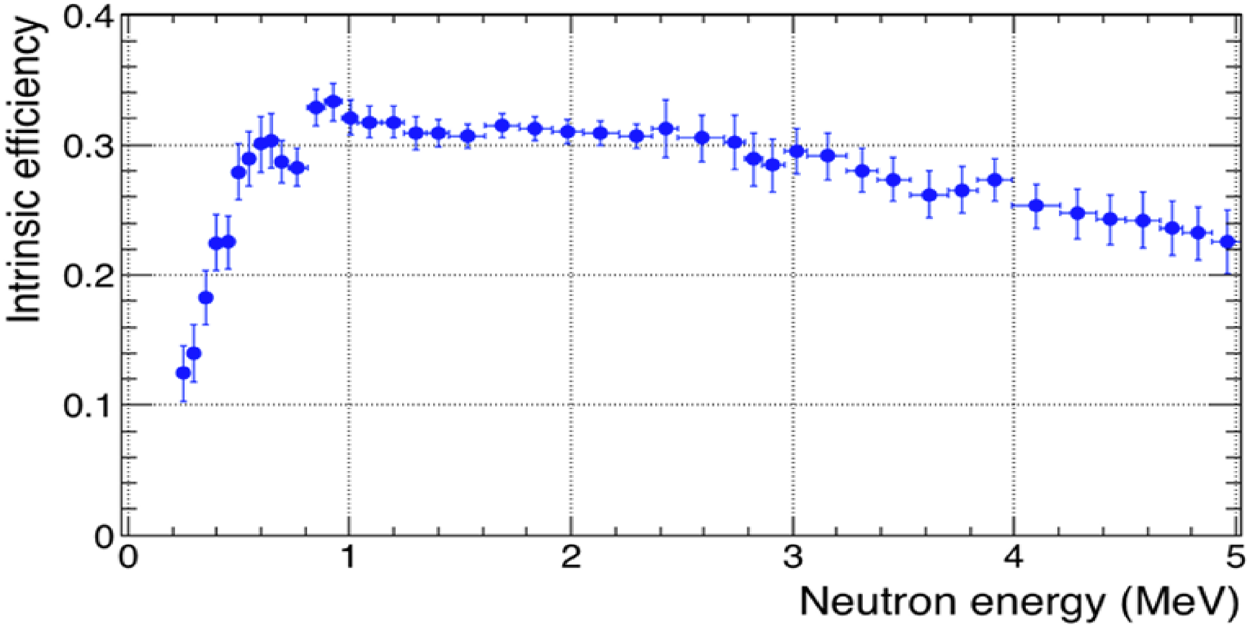
Set-up at HIγS. Beam Intensity II

$d+\gamma=n+p+2.2\ \mathrm{MeV}$

$$I_\gamma=\frac{N}{\frac{d\sigma}{d\Omega}\cdot\Delta\Omega\cdot\varepsilon\cdot N_d\cdot t}$$





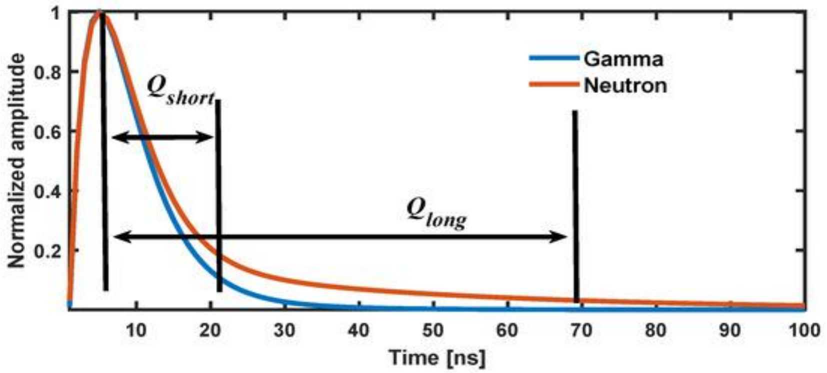


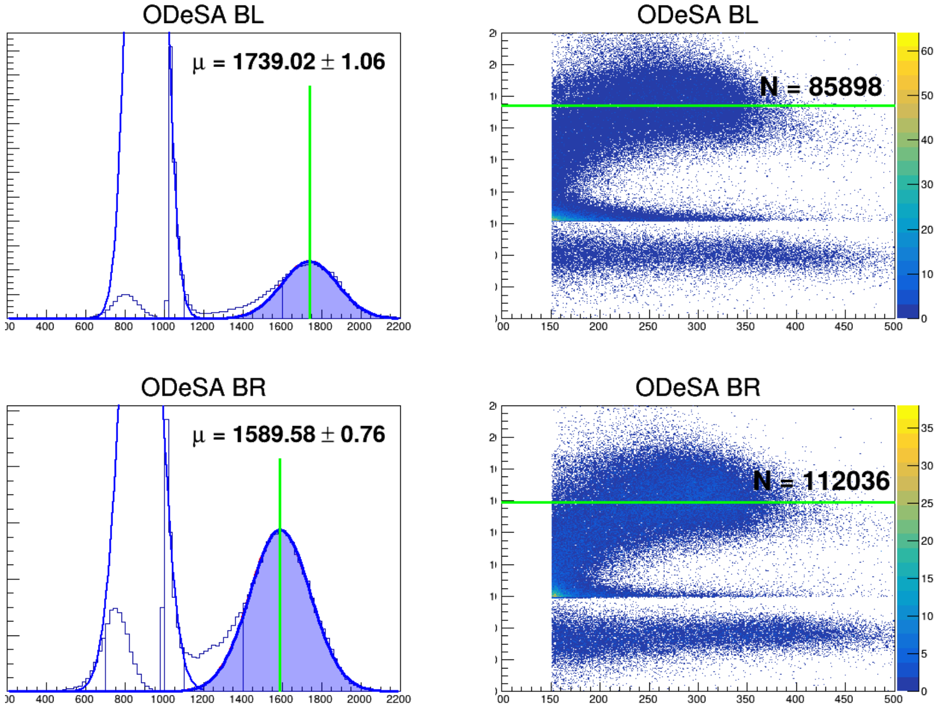
«High-Precision Measurement of D(γ,n),p Photodisintegration Reaction and Implications for Big-Bang Nucleosynthesis»
Y. J. Chen et al.

«Photodisintegration cross section of deuteron»
M.Odsuren et al.

«The ORNL Deuterated Spectroscopic Array – ODeSA»
M. Febbraro et al.

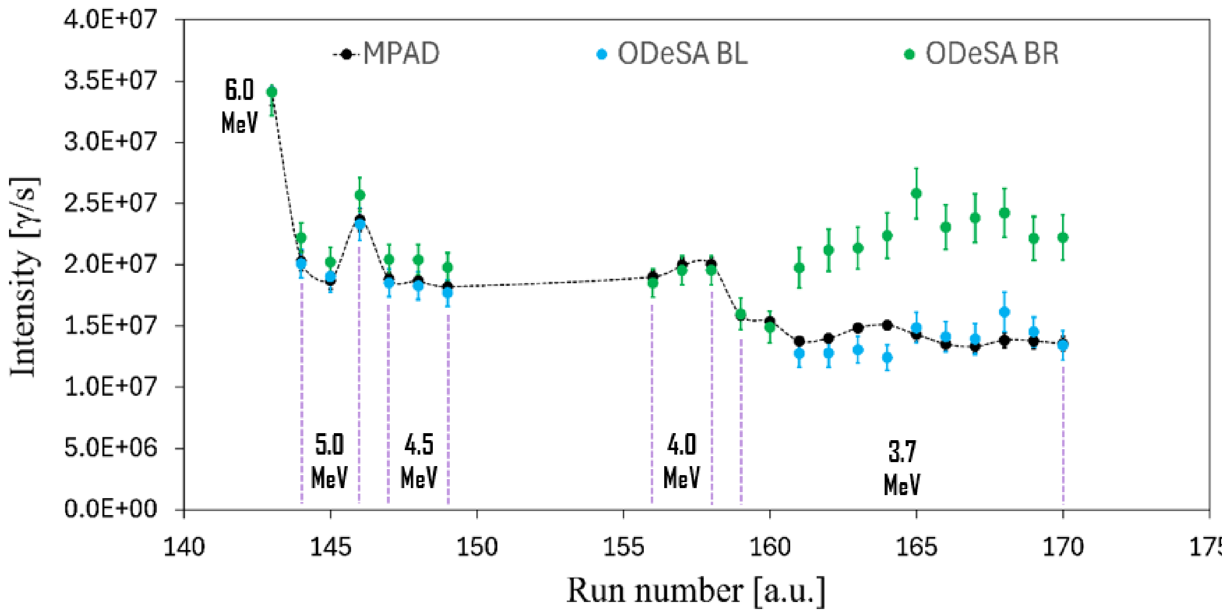
Set-up at HIγS. Beam Intensity





Run nr.	E_γ/E_n [MeV]	ε_{int} [%]	$\left.\frac{d\sigma}{d\Omega}\right\rvert_{\theta=90^\circ}$ [mb/sr]	I_{MPAD} [$10^7\gamma$/s]	I_{BL} [$10^7\gamma$/s]	I_{BR} [$10^7\gamma$/s]
166	3.7 / 0.75	28.0 ± 0.6	0.028 ± 0.001	1.35 ± 0.06	1.41 ± 0.12	2.31 ± 0.18
156	4.0 / 0.90	33.0 ± 0.6	0.029 ± 0.002	1.90 ± 0.05	-	1.85 ± 0.11
147	4.5 / 1.15	32.0 ± 1.0	0.029 ± 0.002	1.88 ± 0.05	1.85 ± 0.11	2.04 ± 0.12
144	5.0 / 1.40	31.0 ± 1.0	0.028 ± 0.001	2.03 ± 0.08	2.01 ± 0.12	2.22 ± 0.12
143	6.0 / 1.90	31.0 ± 1.7	0.026 ± 0.001	3.41 ± 0.11	3.41 ± 0.19	3.41 ± 0.19

Particle identification trough PSD

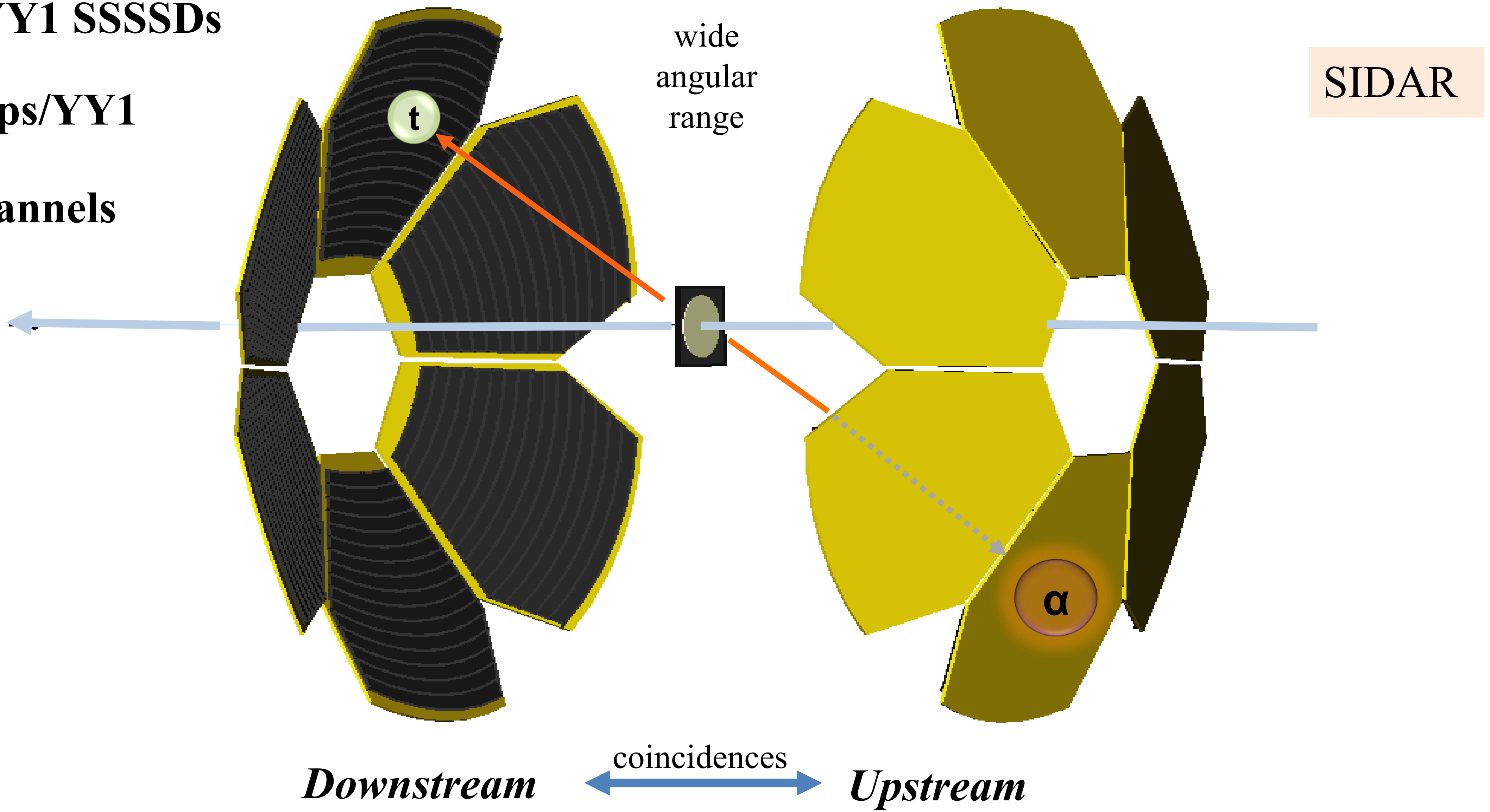


Set-up at HIγS. Detectors

2 x 6 YY1 SSSSDs

16 strips/YY1

192 channels

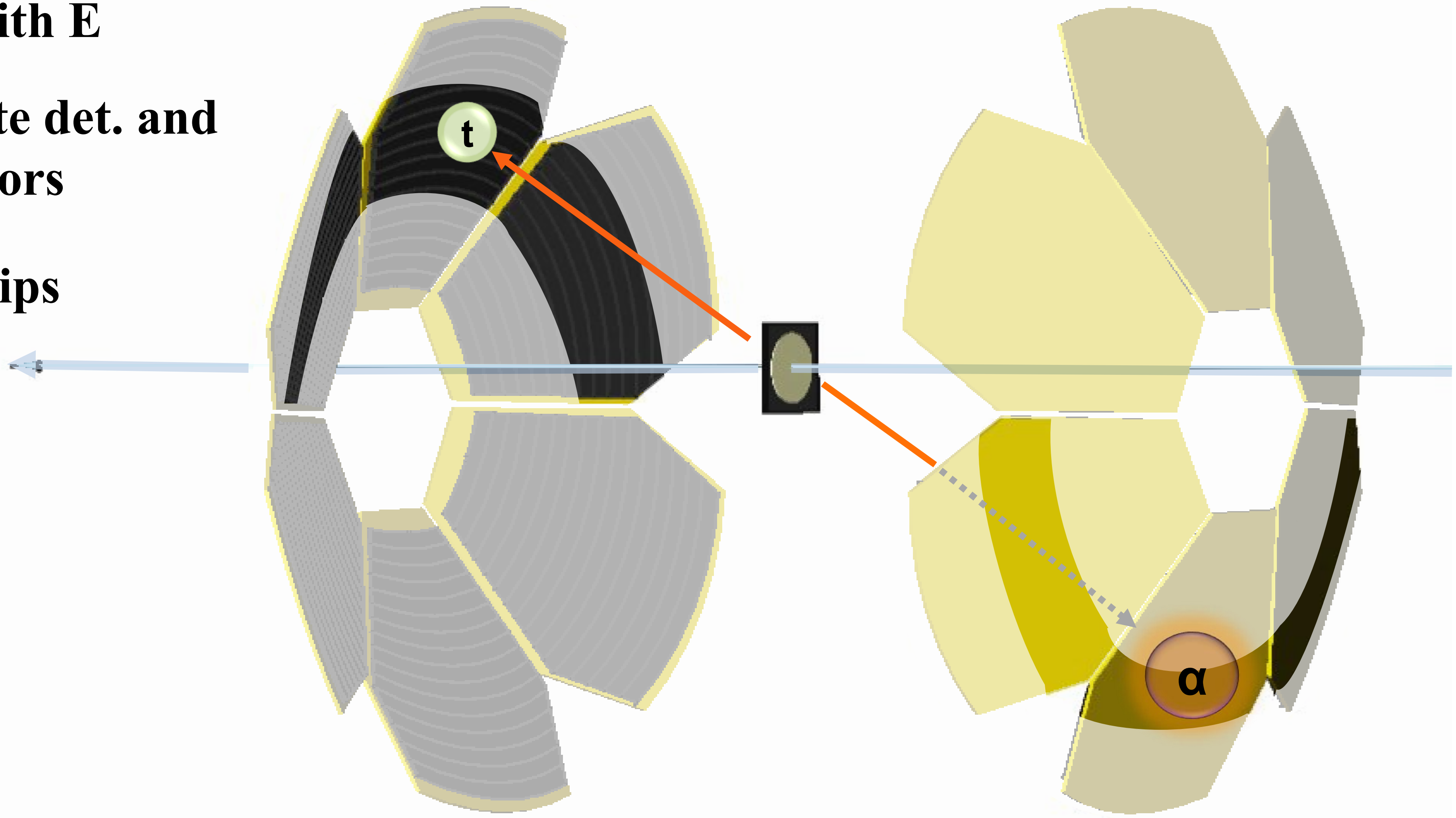


Data analysis. Sorting algorithm

veto with E

opposite det. and neighbors

± 3 strips



Downstream coincidences *Upstream*

Data analysis. Efficency and Simulations

Source measurement: $\varepsilon_{geom} = 38.66\%$ (4% unc.)

Geometric calculation: $\varepsilon_{geom} = 38.93\%$

VIKAR: Monte Carlo code for complete simulations of two-body reaction experiments, including broadening and acceptance terms from the beam, target and detectors, including energy loss, energy and angular straggling, and detector segmentation and resolution effects

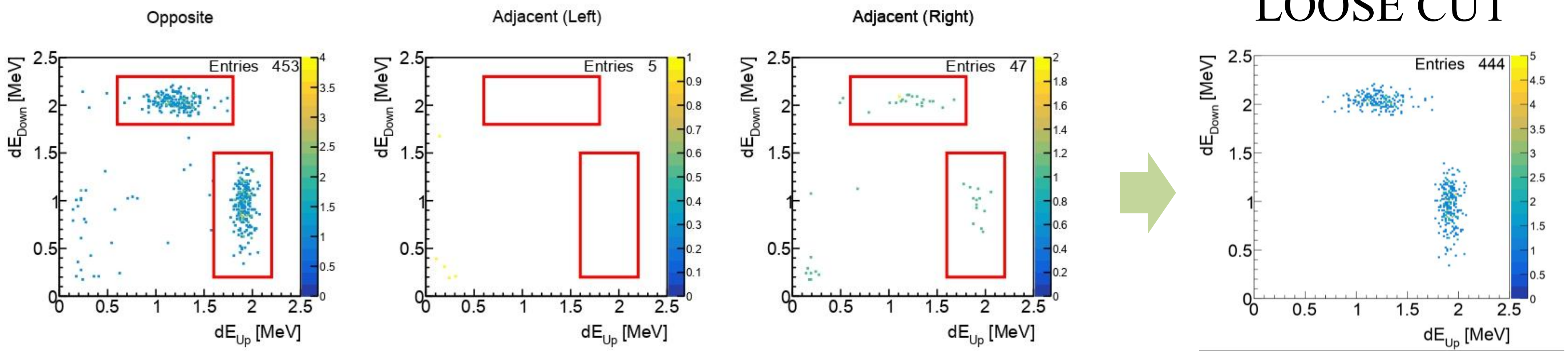
VIKAR SIMULATION:

- Real geometry of the set-up was implemented
- Dead strips and tresholds were taken in account
- Each strip was treated as an individual detector

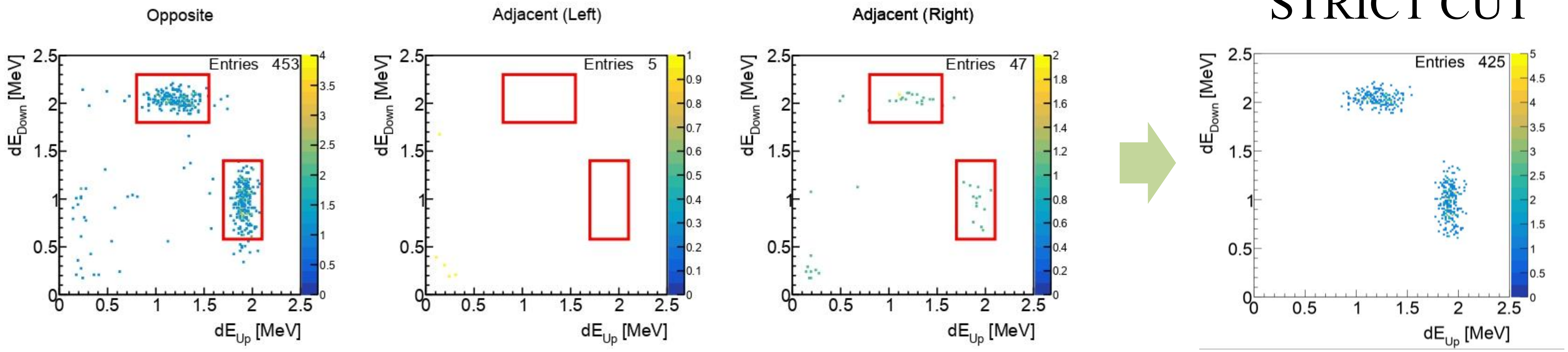
VIKAR Simulation: $\varepsilon_{geom} = 38.01\%$

Data analysis. Bg Subtraction at 6.0 MeV

LOOSE CUT



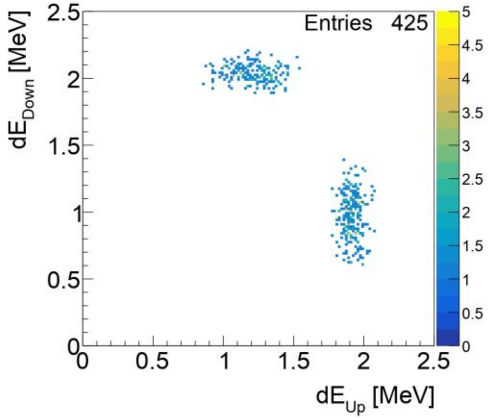
STRICT CUT



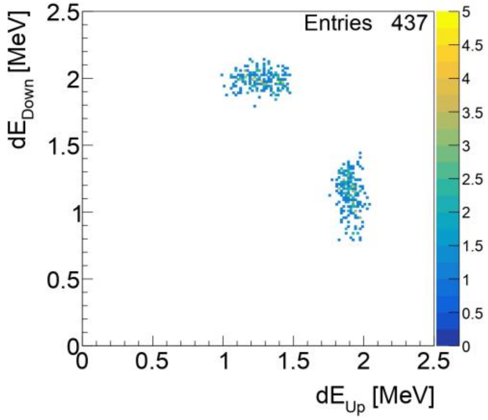
Data analysis. Bg Subtraction at 6.0 MeV

eli nuclear physics

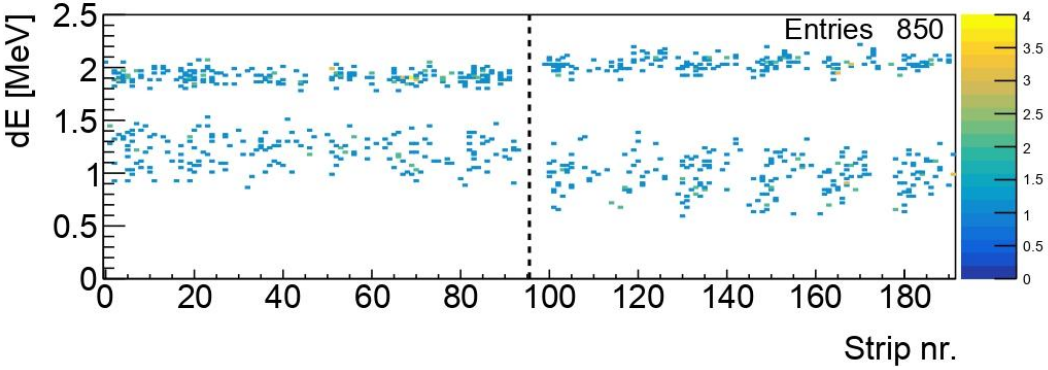
EXPERIMENT



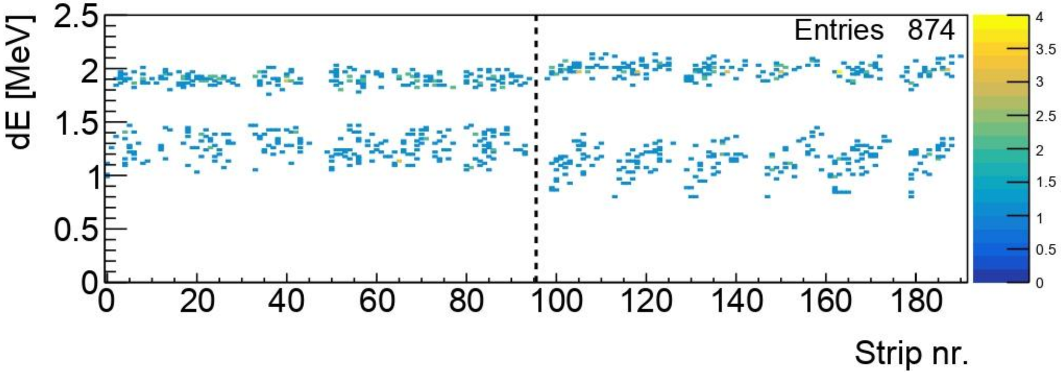
VIKAR



VIKAR ISOTROPIC (coinc.)

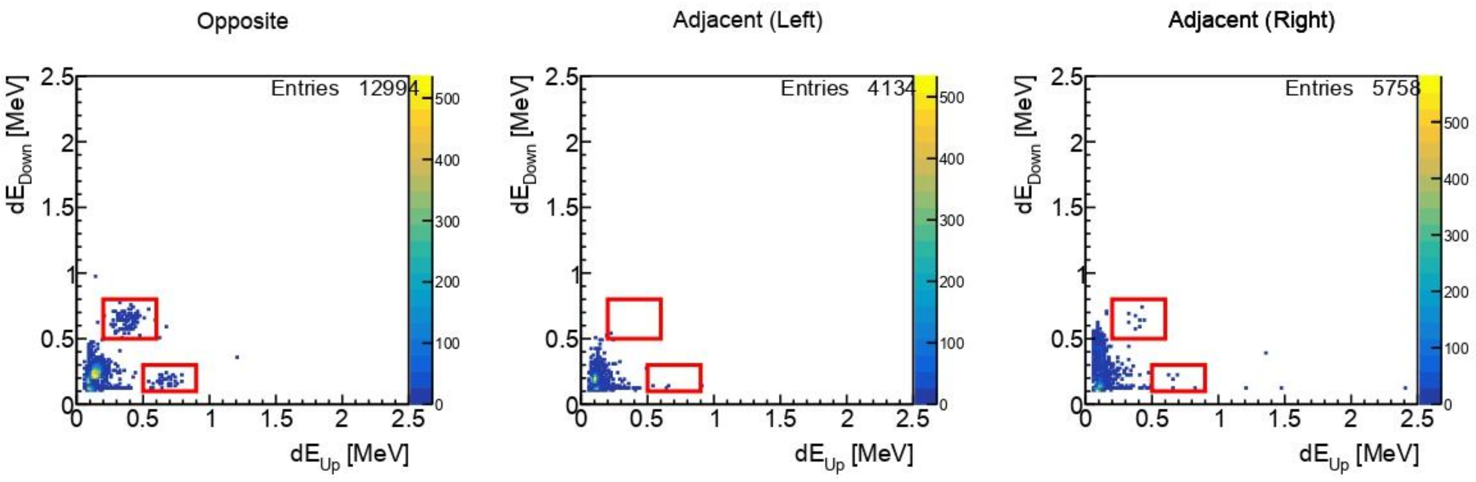


VIKAR

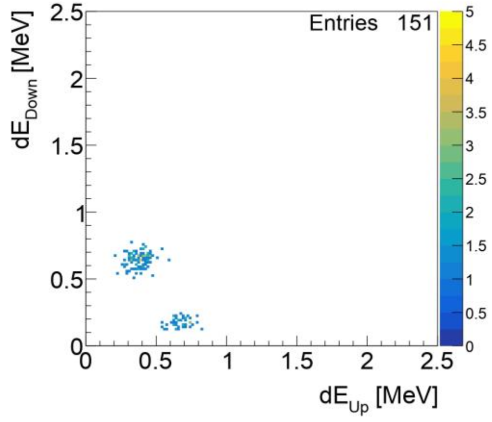


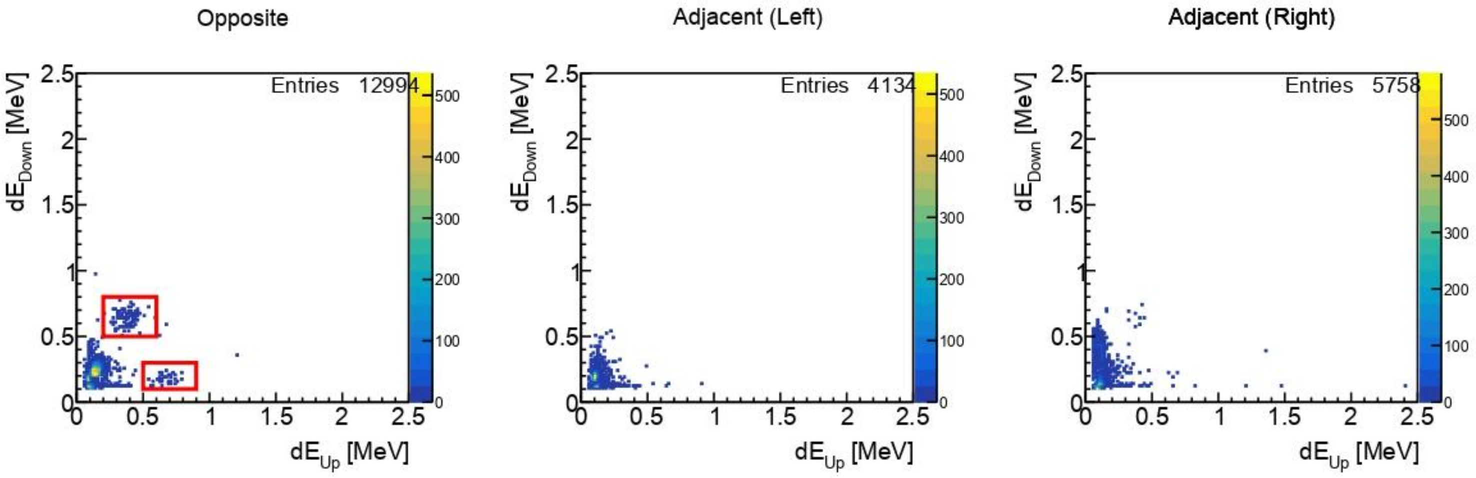
The NOMINAL CUT was chosen based on agreement with the simulation

Data analysis. Bg Subtraction at 3.7 MeV

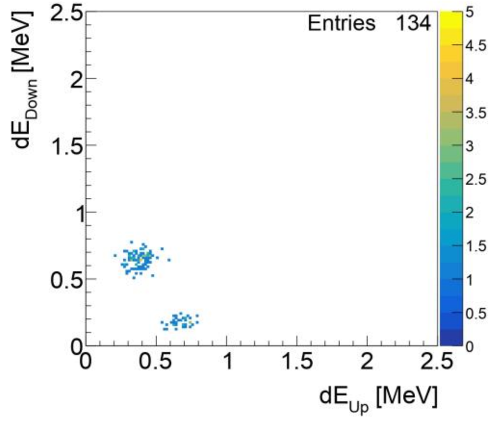


LOOSE CUT



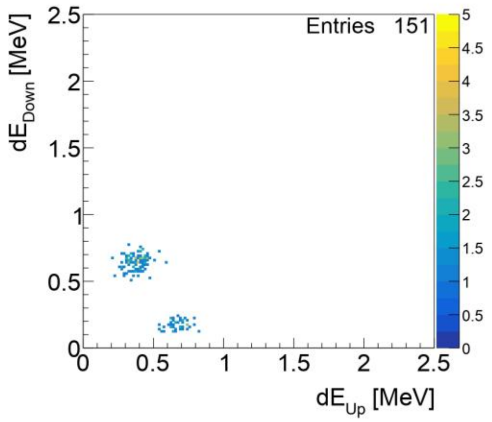


STRICT CUT

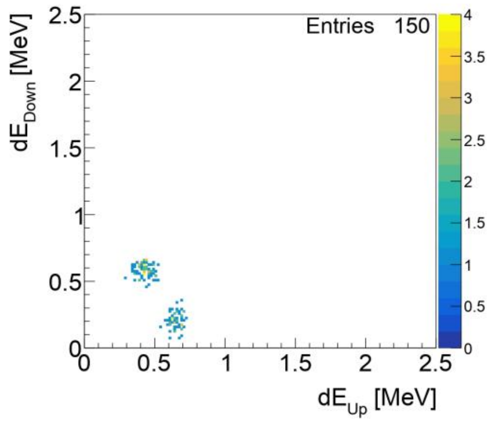


Data analysis. Bg Subtraction at 3.7 MeV

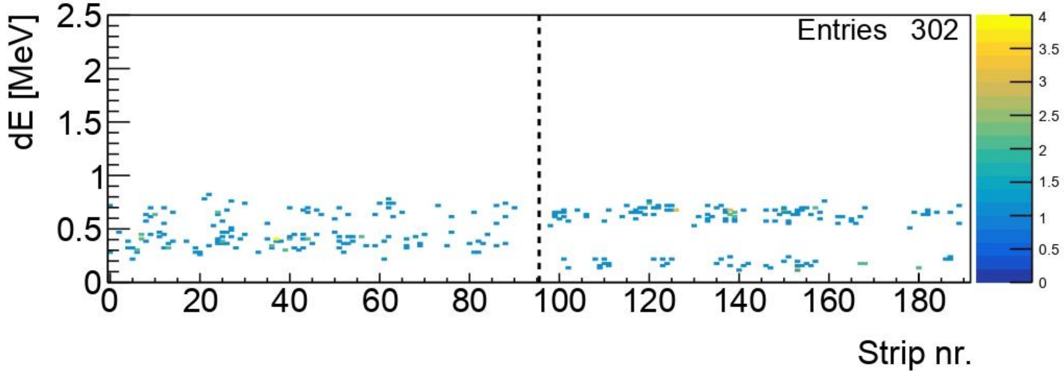
EXPERIMENT



VIKAR



EXPERIMENT



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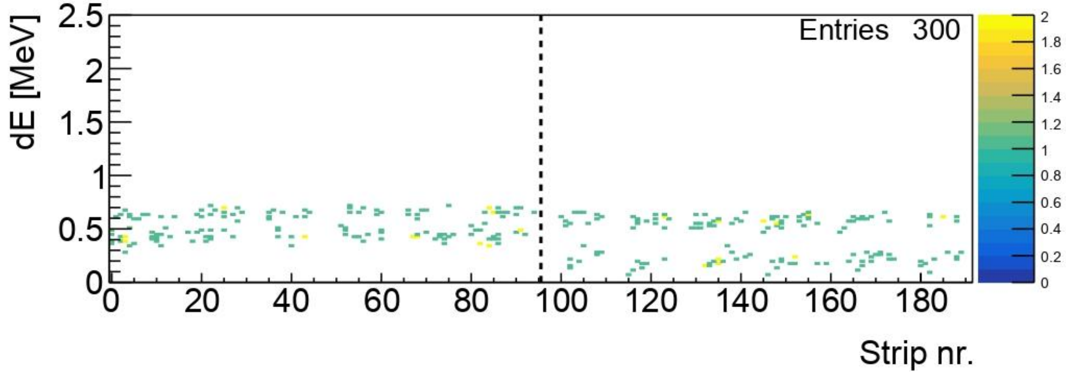
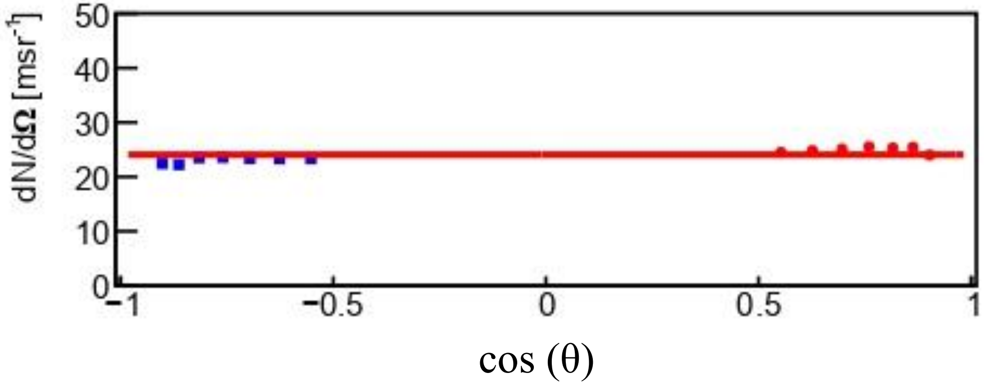


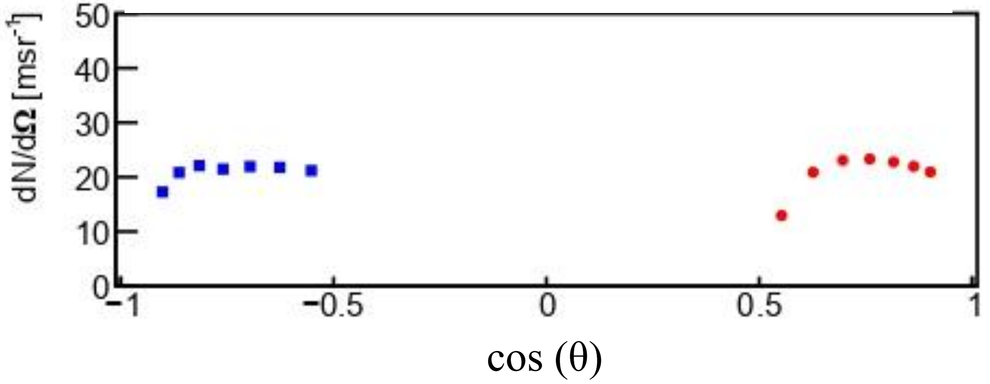
The NOMINAL CUT was chosen based on agreement with the simulation

Data analysis. Angular Distrib at 6.0 MeV

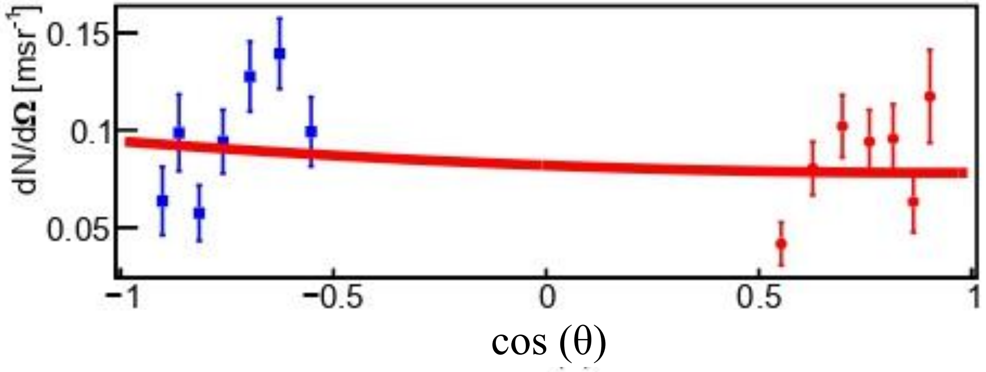
VIKAR ISOTROPIC (no coinc.)



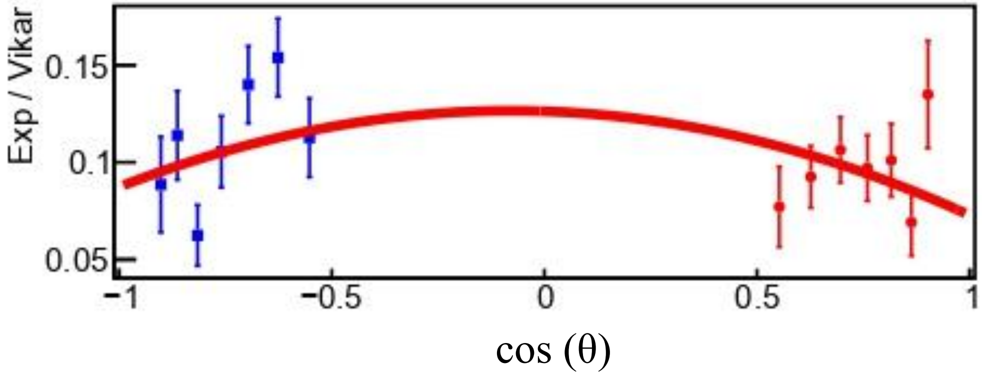
VIKAR ISOTROPIC (coinc.)



RAW ANG. DISTRIB.

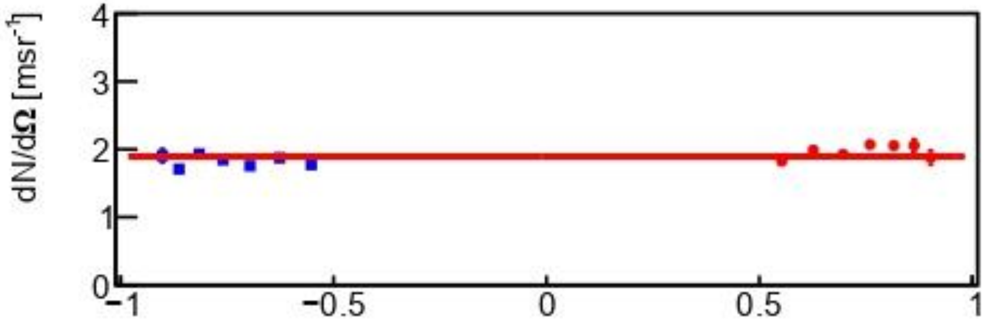


CORRECTED ANG. DISTRIB.



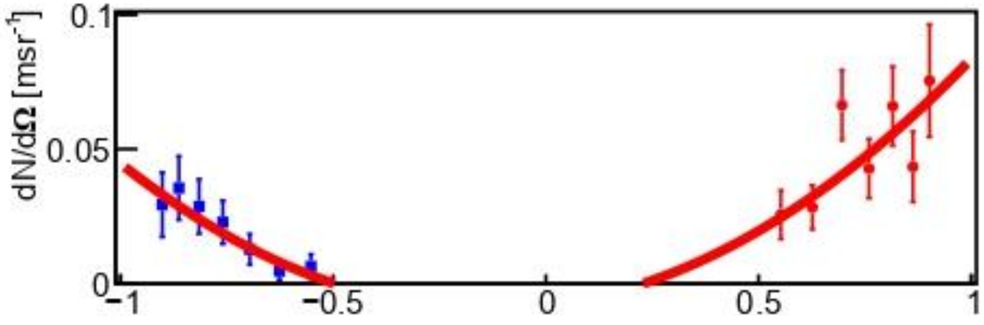
Data analysis. Angular Distrib at 3.7 MeV

VIKAR ISOTROPIC (no coinc.)



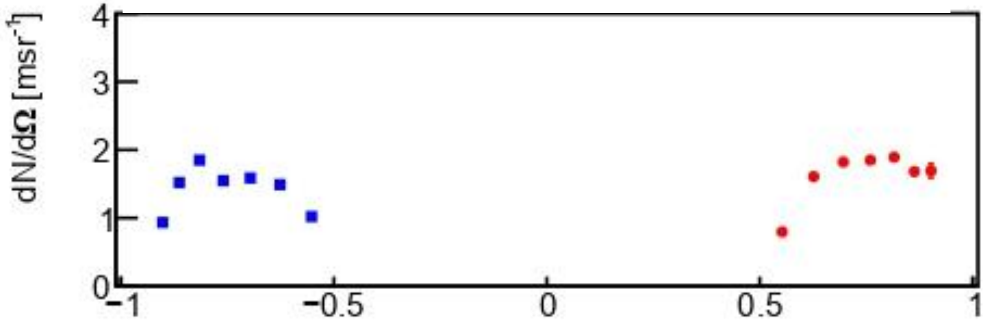
cos (θ)

RAW ANG. DISTRIB.



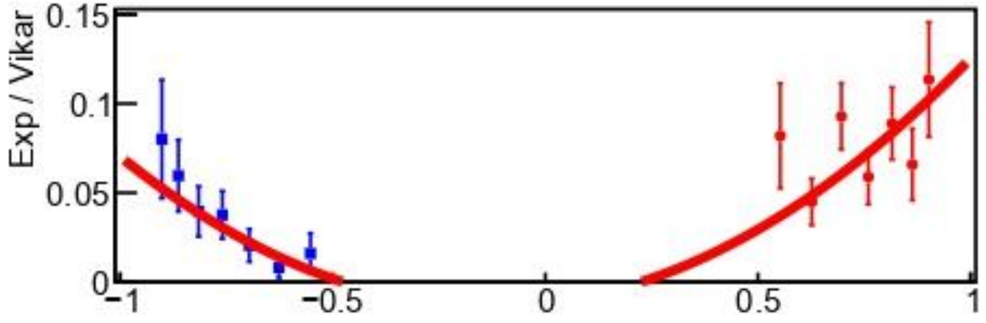
cos (θ)

VIKAR ISOTROPIC (coinc.)



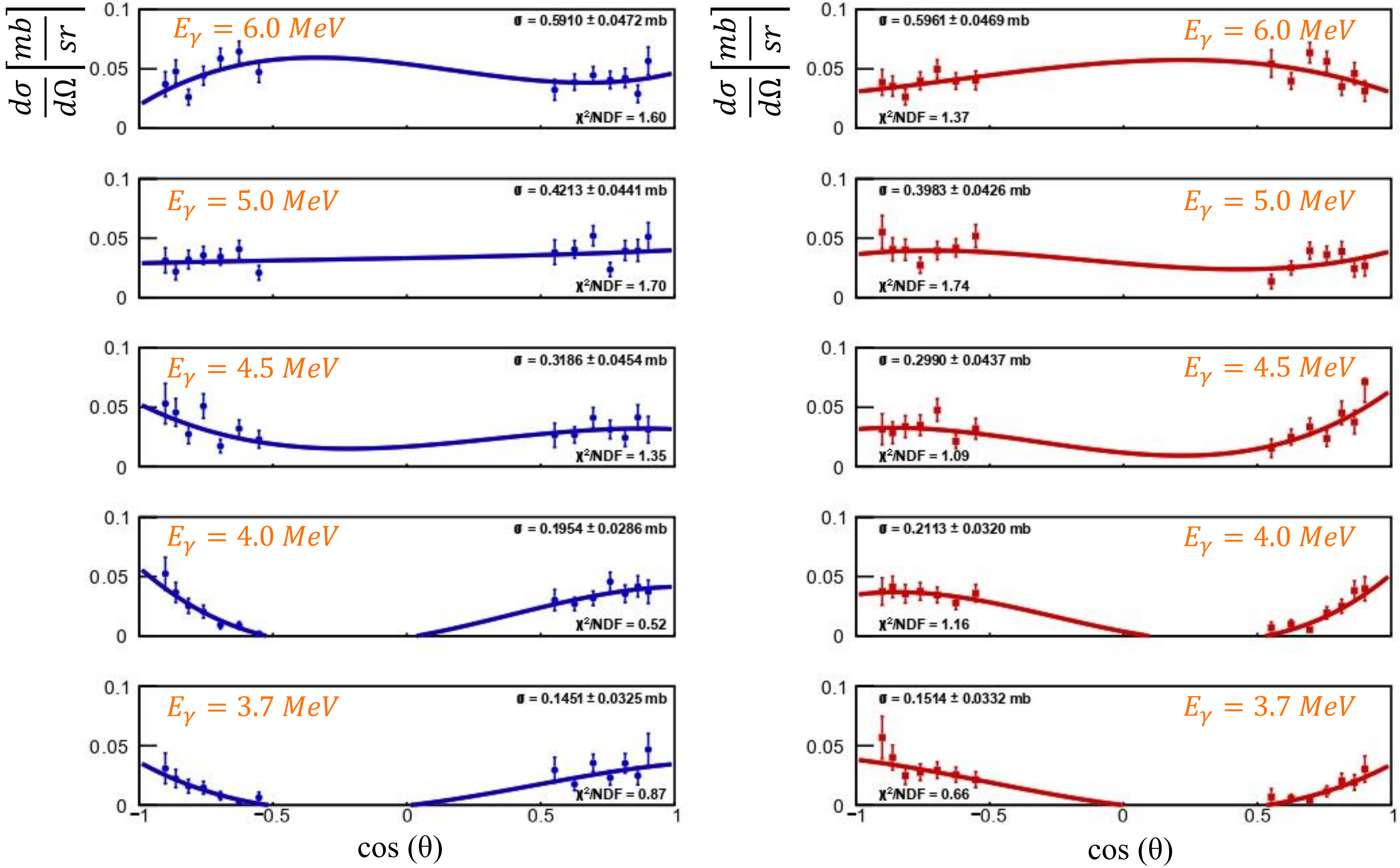
cos (θ)

CORRECTED ANG. DISTRIB.



cos (θ)

Data analysis. Differential Cross Section



$\sigma \quad = 0.591 \pm 0.047$ mb
$\sigma_{iso} = 0.574 \pm 0.035$ mb

$\sigma \quad = 0.421 \pm 0.044$ mb
$\sigma_{iso} = 0.469 \pm 0.032$ mb

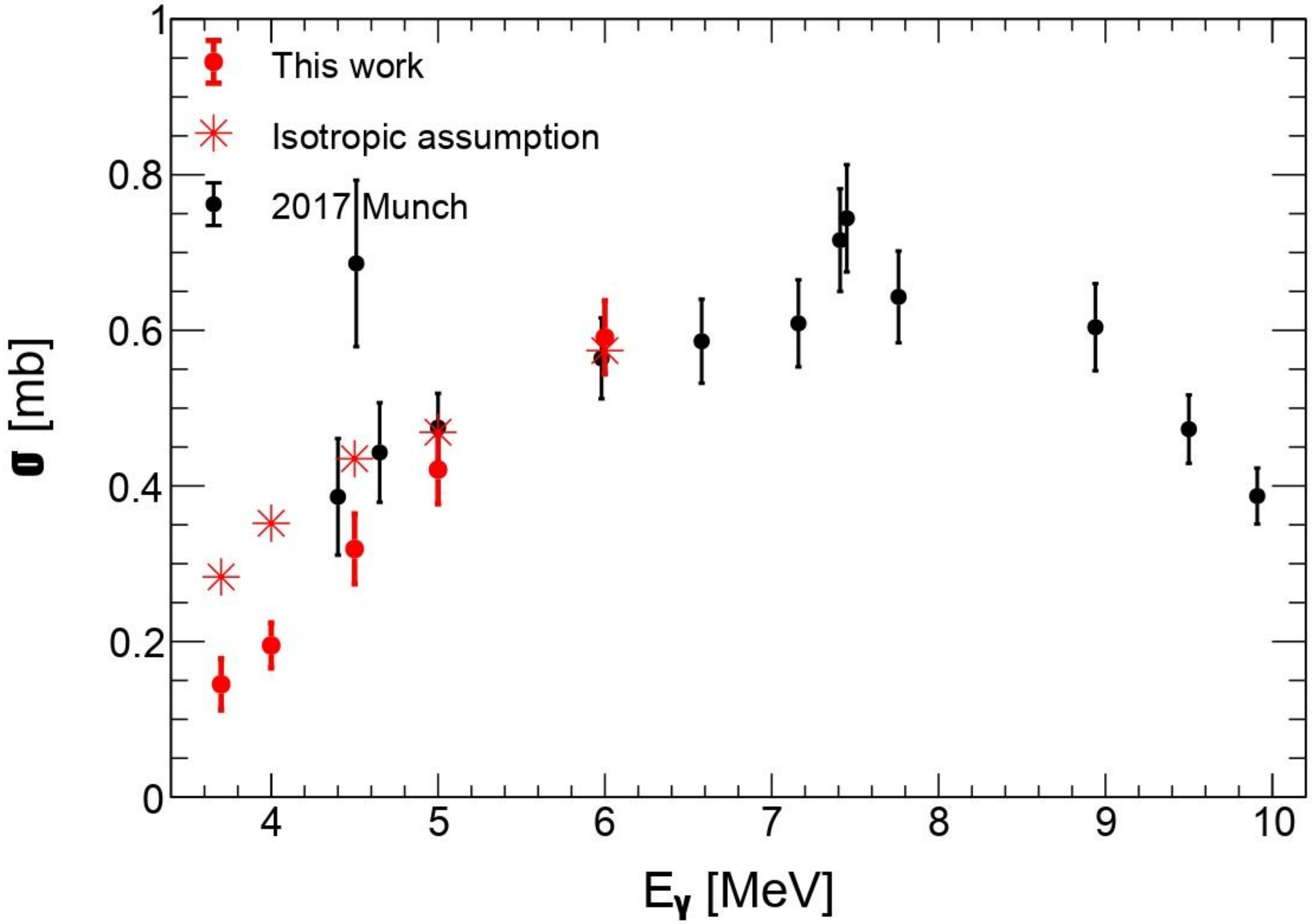
$\sigma \quad = 0.319 \pm 0.045$ mb
$\sigma_{iso} = 0.435 \pm 0.035$ mb

$\sigma \quad = 0.195 \pm 0.029$ mb
$\sigma_{iso} = 0.352 \pm 0.027$ mb

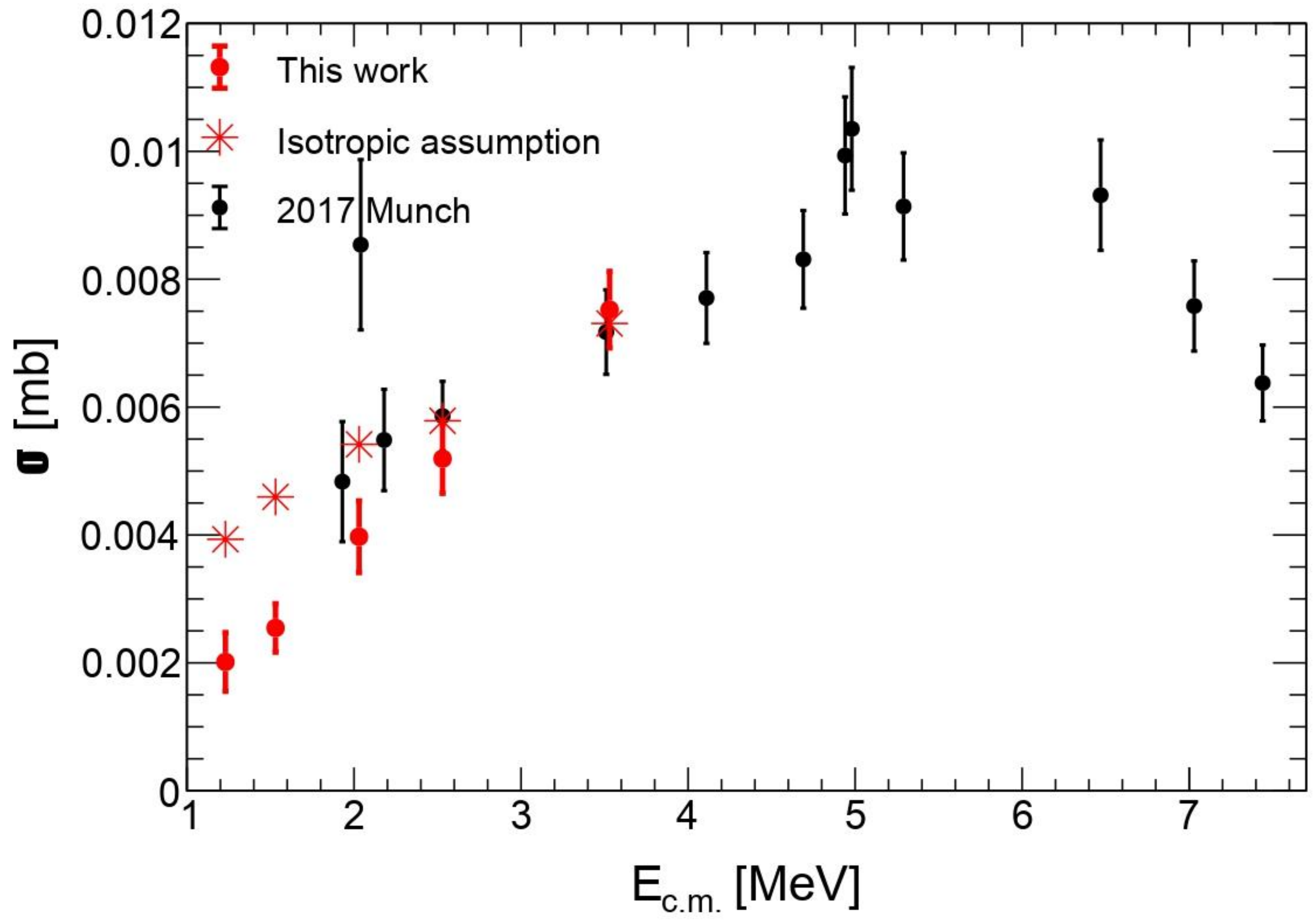
$\sigma \quad = 0.145 \pm 0.033$ mb
$\sigma_{iso} = 0.283 \pm 0.029$ mb

Fit: P0+P1+P2+P3

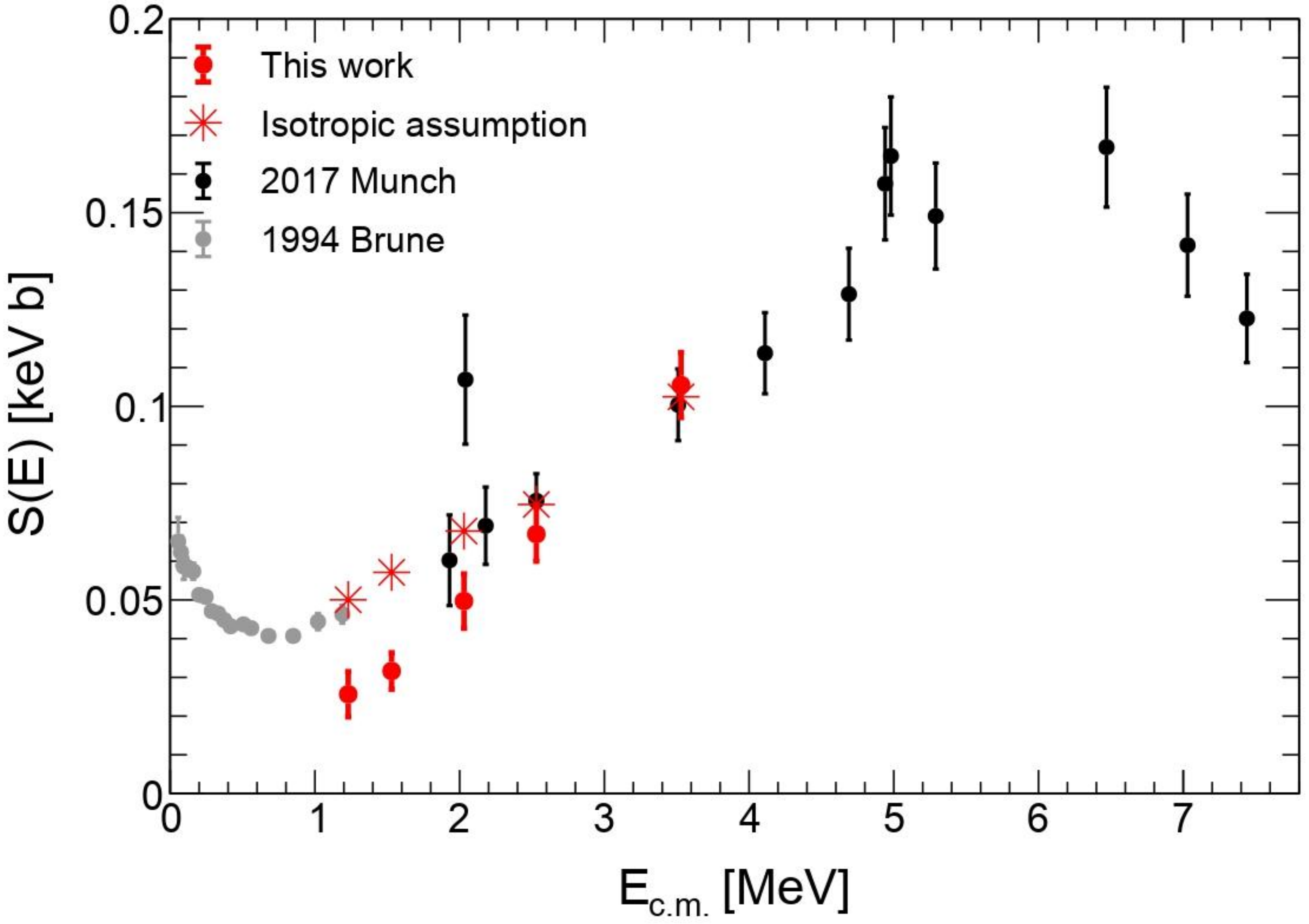
Data analysis. $^7Li(\gamma,\alpha)\,^3H$ cross section



Data analysis. $^{3}H(\alpha,\gamma)\,^{7}Li$ cross section



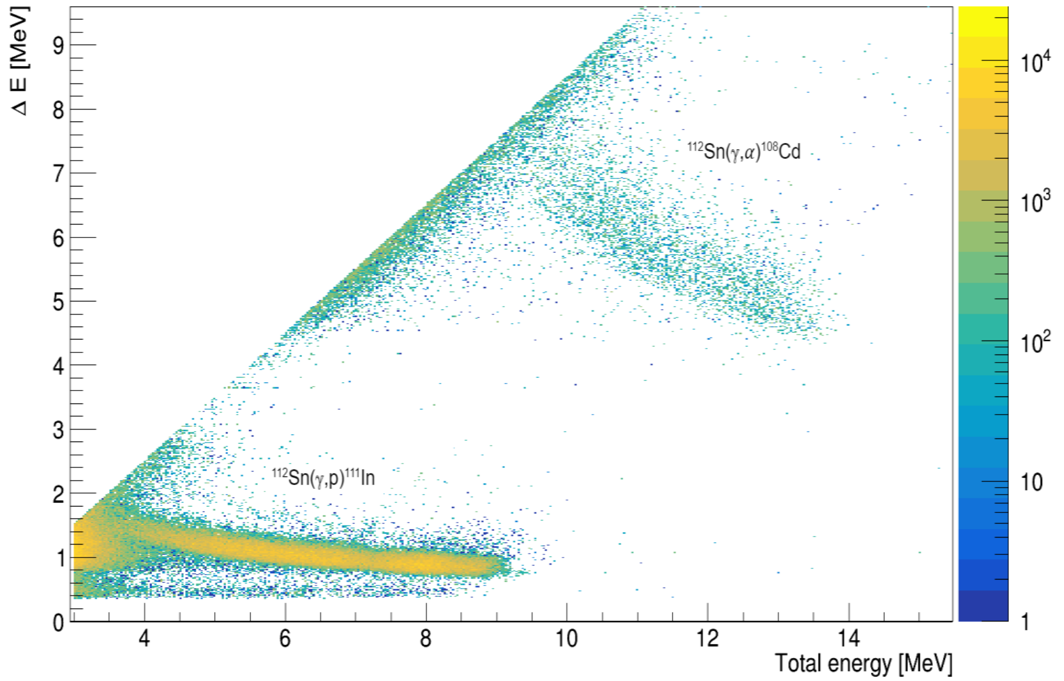
Data analysis. Astrophysical S-factor

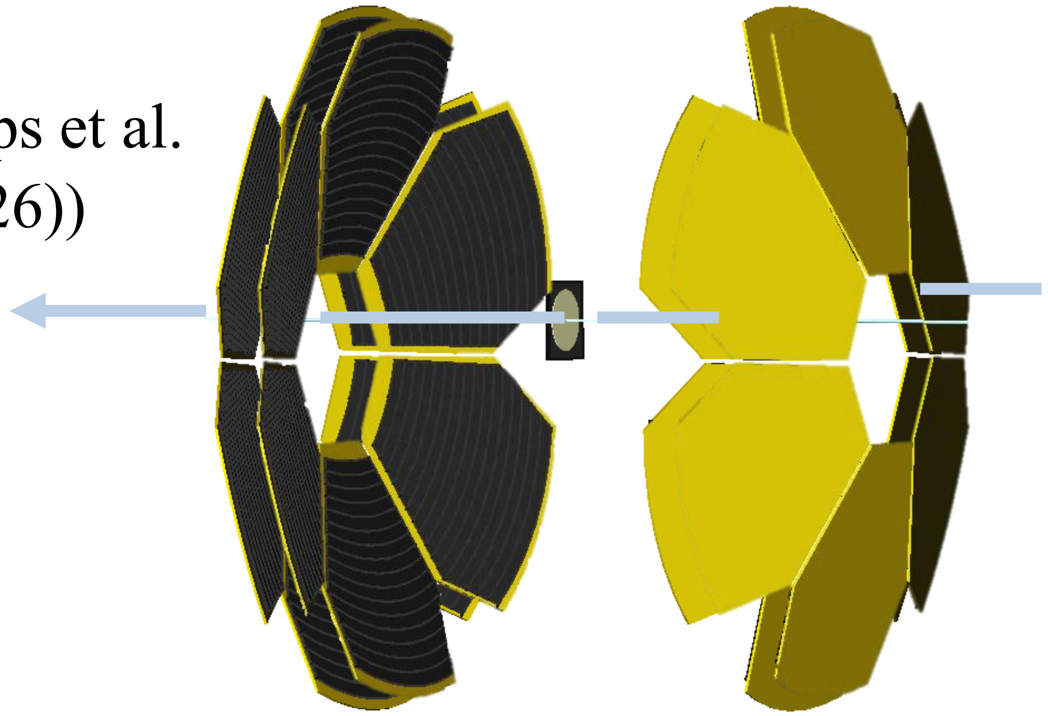


Photonuclear studies at HIγS

2023:

- $^{102}Pd(\gamma,p)$ and $^{102}Pd(\gamma,\alpha)$ - published (K.A. Chipps et al.
- Phys. Rev. C 114 (2026))
- $^{112}Sn(\gamma,p)$ and $^{112}Sn(\gamma,\alpha)$ - T. Petruse (Tuesday)





2026:

- $^{114}Sn(\gamma,p)$ and $^{114}Sn(\gamma,\alpha)$
- $^{117}Sn(\gamma,p)$ and $^{117}Sn(\gamma,\alpha)$
- $^{24}Mg(\gamma,\alpha)^{20}Ne$

Analysis in progress

Conclusions

- The $^{3}H(\alpha,\gamma)^{7}$Li reaction was studied directly in 1994 (Brune) and through the inverse reaction in 2017 (Munch).
- The preliminary results of this work were consistent with both previous measurements.
- The angular distributions reveal strong anisotropy at low energies
- The results of this work remain in agreement with the 2017 results, but no longer agree with the 1994 results.

Colaboration

- *Catalin Matei, D. Balabanski, Ioana Kuncser, T. Petruse, A. Pappalardo, H. Pai, Yi Xu (ELI-NP, Bucharest-Magurele, Romania)*
- *Steve Pain, Kelly Chipps, T. King, M Febbraro (ORNL – Oak Ridge, Tennessee, USA)*
- *M. Grinder, S. Balakrishnan, Heather Garland, Jolie Cizewski (Rutger University - New Brunswick, New Jersey, USA)*
- *H. Karwowski, R.V. Janssens, T. Psaltis, C. Marshall (University of Nord Carolina - Chapel Hill, Nord Carolina USA)*
- *C.R. Brune, A. Voinov (Ohio University, Athens, Ohio, USA)*
- *O. Tindle, C. Haverson, R. Smith (Shefield Hallam University, UK)*
- *M. La Cognata, G.L. Guardo, S. Palmerini, L. Sergi, D. Lattuada, R.G. Pizzone, G. Rapisarda, A. Tumino (INFN-Laboratori Nazionali del Sud, Catania, Italy)*
- *K.Y. Chae, Gyoungmo GU (Sungkyunkwan University, Suwon, Korea)*

NUCLEAR PHYSICS IN ASTROPHYSICS - CLUJ-NAPOCA

Thank you for attention!