http://flerovlab.jinr.ru/accullina-ii/

Study of neutron-rich systems ^{6}H, ^{7}H and 4n in ^{8}He+d interactions at ACCULINNA-2

FLNR JINR
Muzalevskii Ivan
for ACCULINNA-2 collaboration

DESYT-2025

History

^{6}H:

Y. Gurov, et al., EPJ A 32 (3) (2007) $^{9}Be(\pi^{-},pd)^{6}H$

^{7}H:

E. Yu. Nikolskii et al., PRC 81, 064606 (2010) $p(^{8}He,^{3}He)^{7}H$

Tetraneutron:

K. Kisamori et al. Phys. Rev. Lett. 116, 052501 (2016) $^{4}He(^{8}He,^{8}Be)$

M. Duer et al. Nature 606 (2022) 678 $p(^{8}He,p^{4}He)$

Prerequisites for successful experiment

- **Reliable channel identification**
- **suppression of background**
- **high energy resolution (~1 MeV)**
- **population by direct transfer (from ^8He core)**

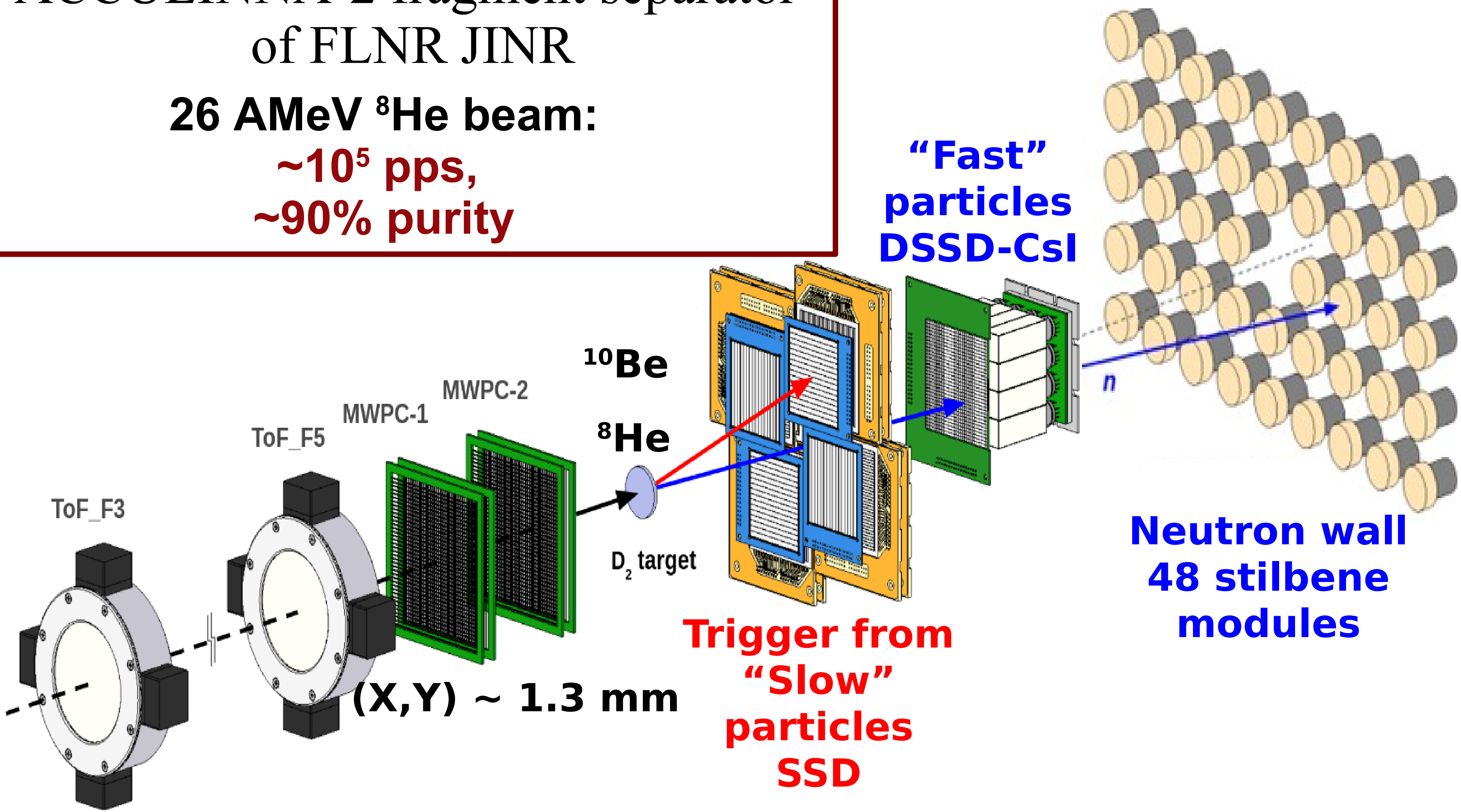
Detector setup

ACCULINNA-2 fragment separator of FLNR JINR

26 AMeV ^{8}He beam:

~10^5 pps,

~90% purity



ΔE ~ 0.2% (FWHM)

Reactions of interest

$^{2}H(^{8}He,^{3}He)^{7}H$, $^{7}H \rightarrow {}^{3}H + n+n+n+n$

$^{2}H(^{8}He,^{6}Li^{*})^{4}n$,

$^{6}Li^{*} \rightarrow {}^{3}H + {}^{3}He$, $^{4}n \rightarrow n+n+n+n$

- “Slow” ^{3}He & “Fast” ^{3}H

$^{2}H(^{8}He,^{6}Li)^{4}n$, $^{4}n \rightarrow n+n+n+n$

- “Slow” ^{6}Li(g.s.) & neutron

$^{2}H(^{8}He,^{4}He)^{6}H$, $^{6}H \rightarrow ?^{5}H? \rightarrow {}^{3}H + n+n+n$

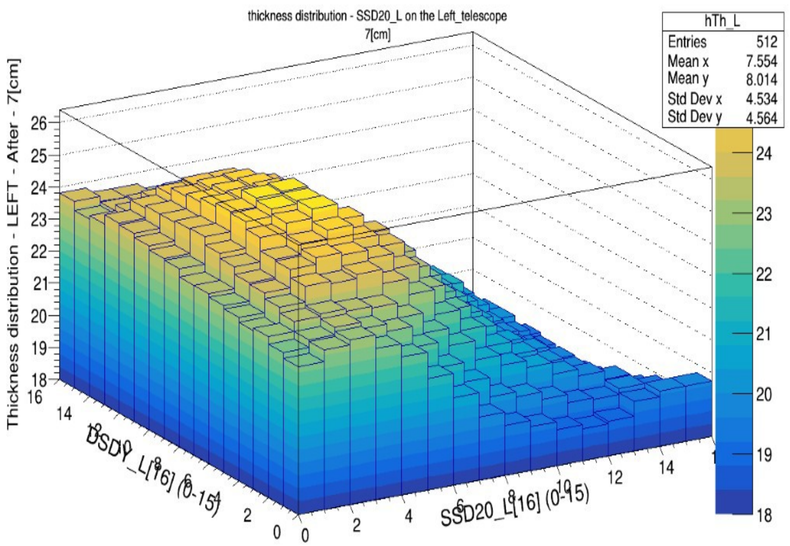
- “Slow” ^{4}He & “Fast” ^{3}H

Particle reconstruction

- Energy calibration:
  - SSDs – ^{226}Ra alpha source. FWHM(ΔE)~40 keV (<1%)
  - CsI – ^{3}H signals, experimental data. FWHM(ΔE)~200 keV (~1%)
  - Neutron wall – gamma parcitile ToF. FWHM(ΔE)~500 keV (~3%)
  - BeamDiagnostics (ToF plastics). FWHM(ΔE)~500 keV (<1%)

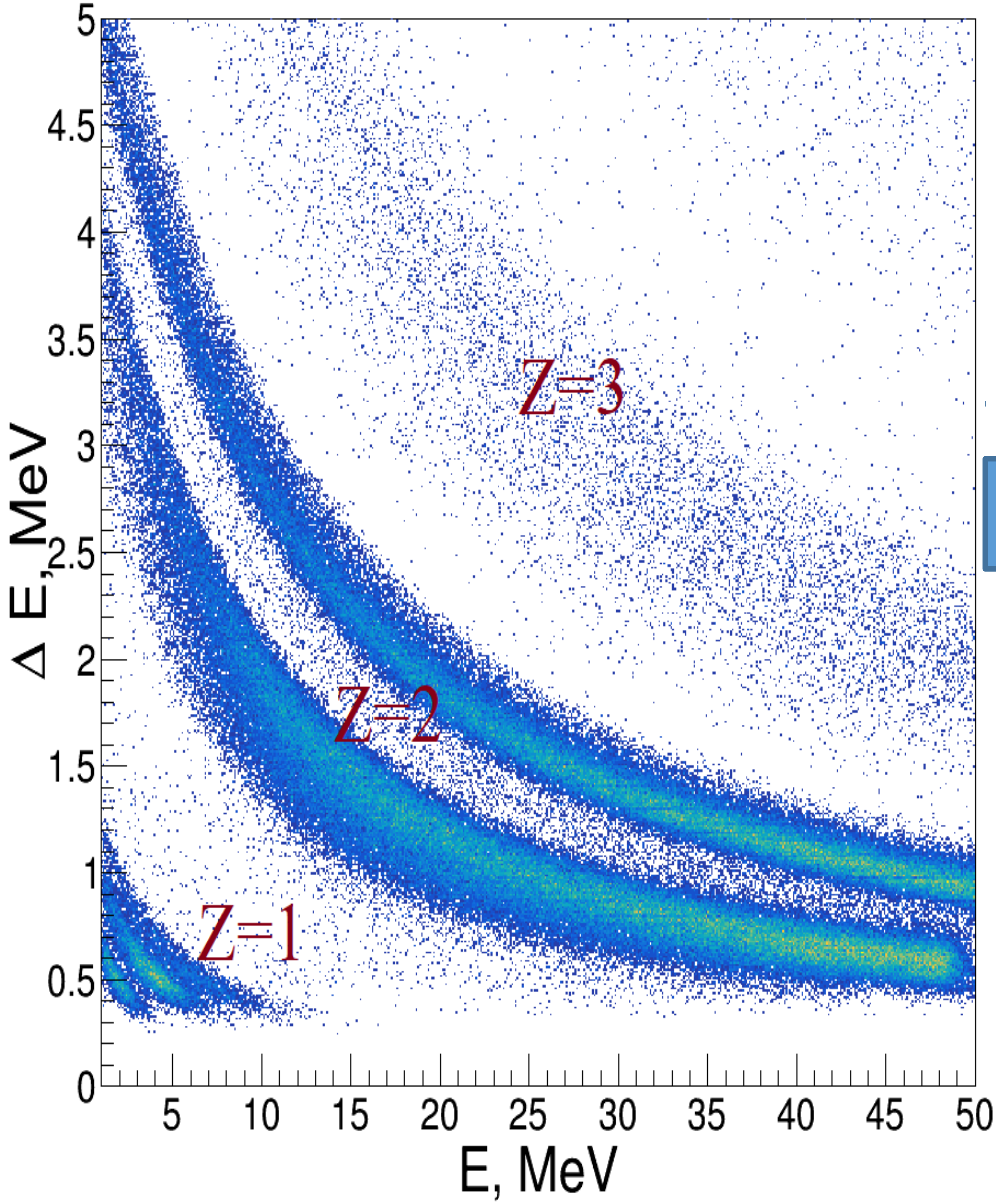
- 20-um SSD thickness inhomogeneity.

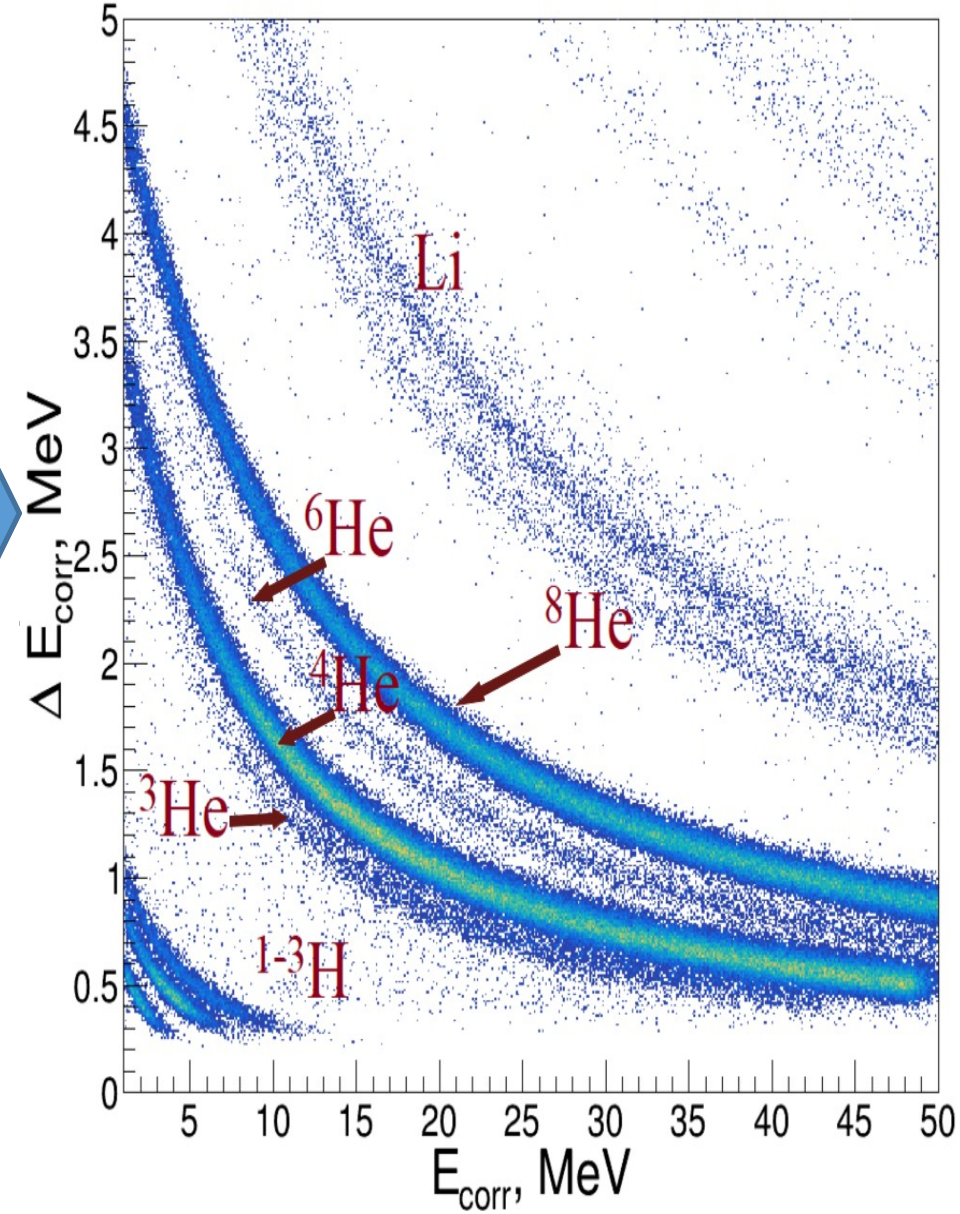
  ΔThickness up to 8 μm (30%)!
  Should be taken into account!



SSD identificatioin

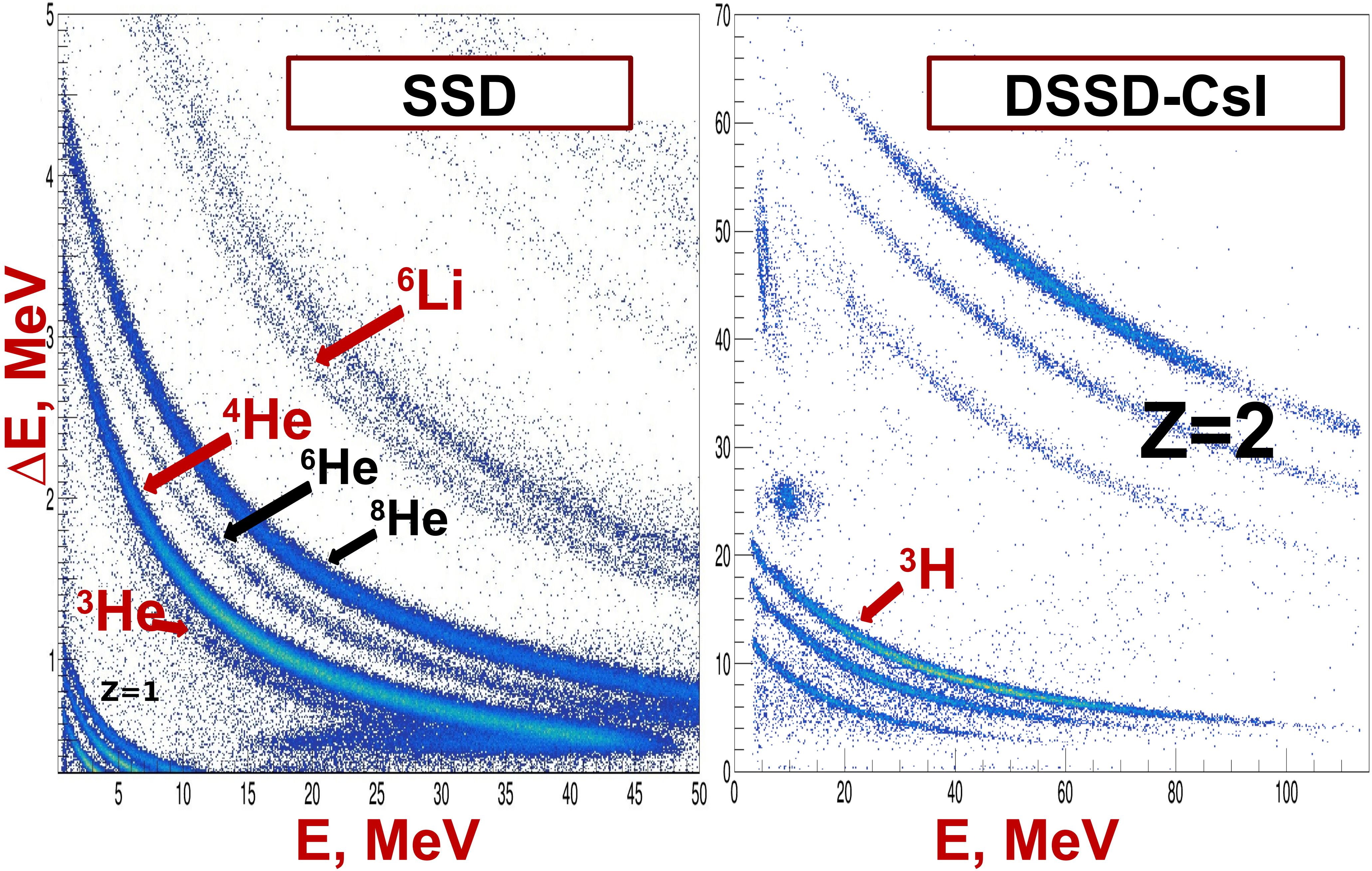
I. Muzalevski et al., Bull.Rus.Acad.Sci.: Phys., 84, 500 (2020)



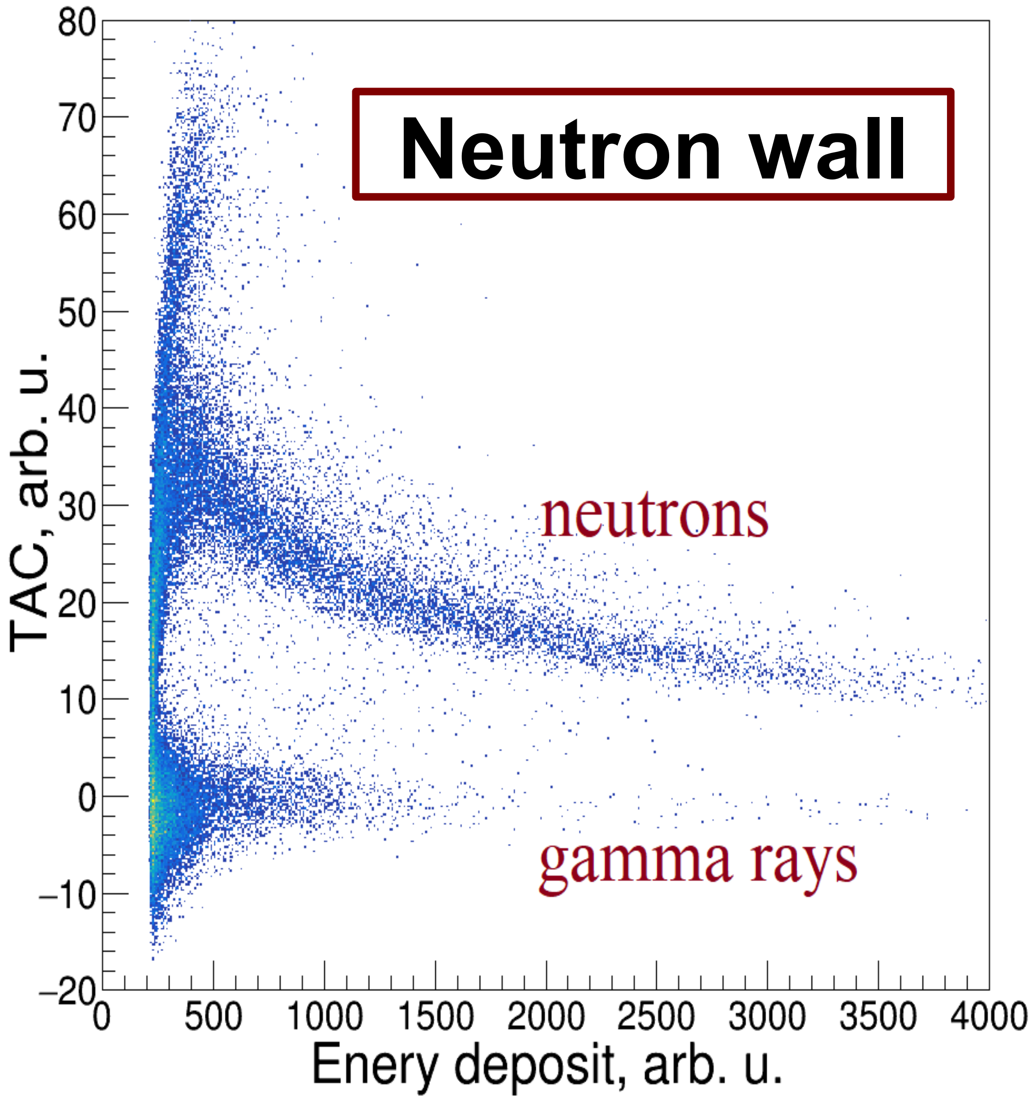


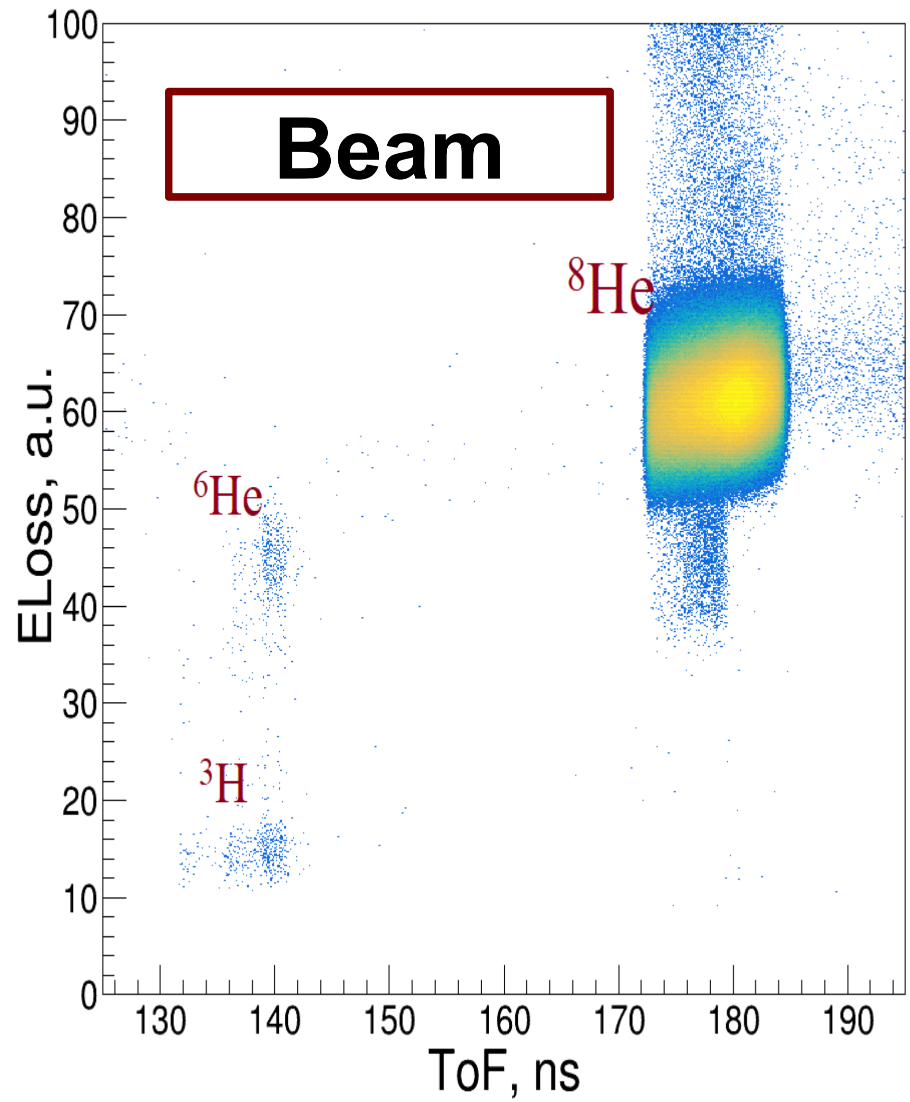
Particle identification

I. A. Muzalevskii et al., Bull. Russ. Acad. Sci. Phys., 84:500–504, 2020

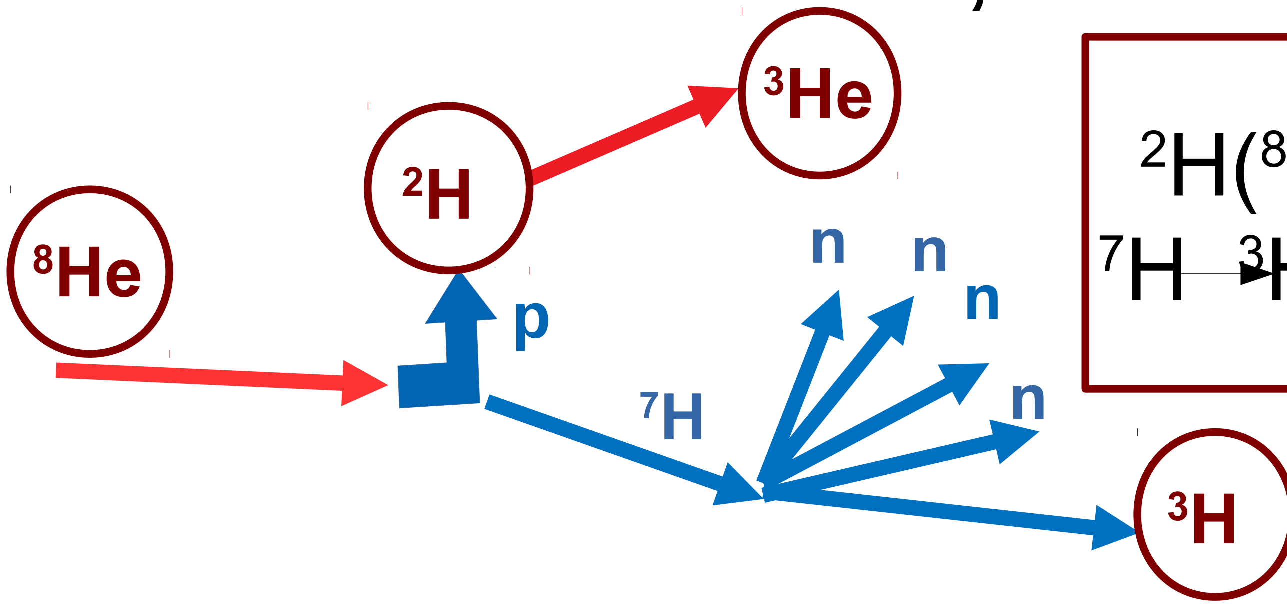


Particle identification



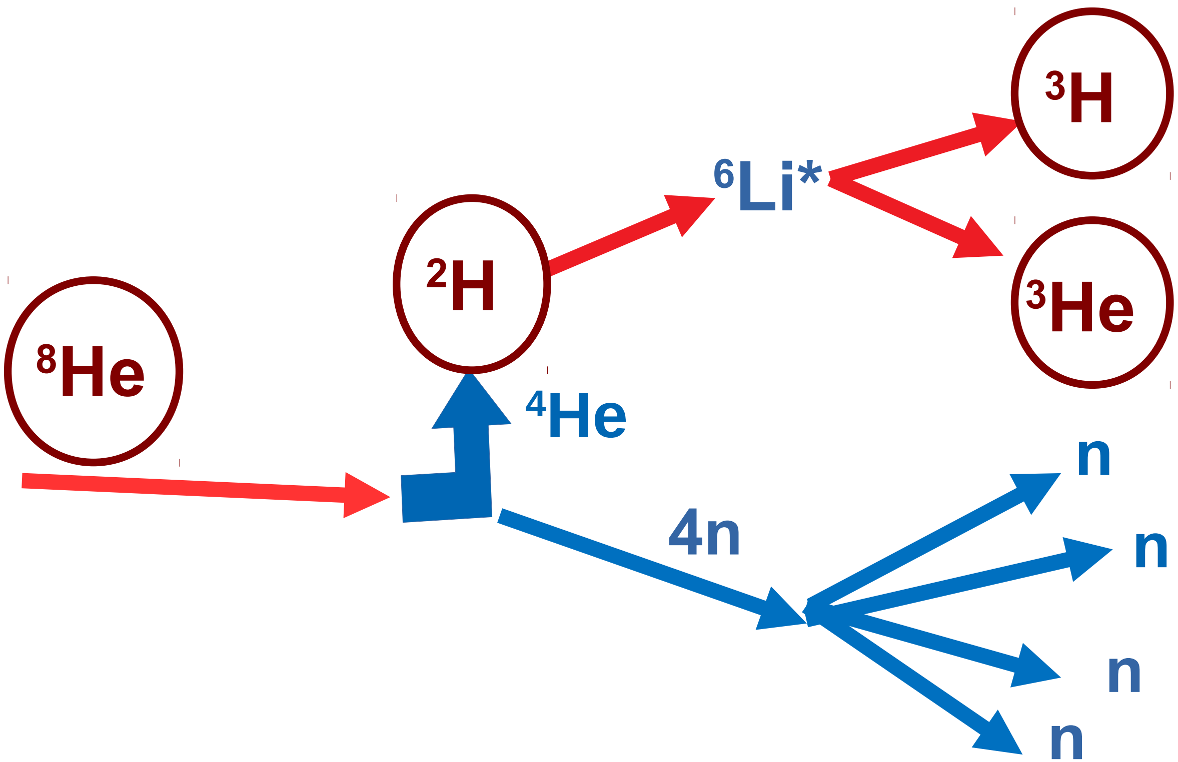


Sattelite channels; ^3He-^3H



$^2H(^8He,{}^3He)^7H$

$^7H \to {}^3H+n+n+n+n$

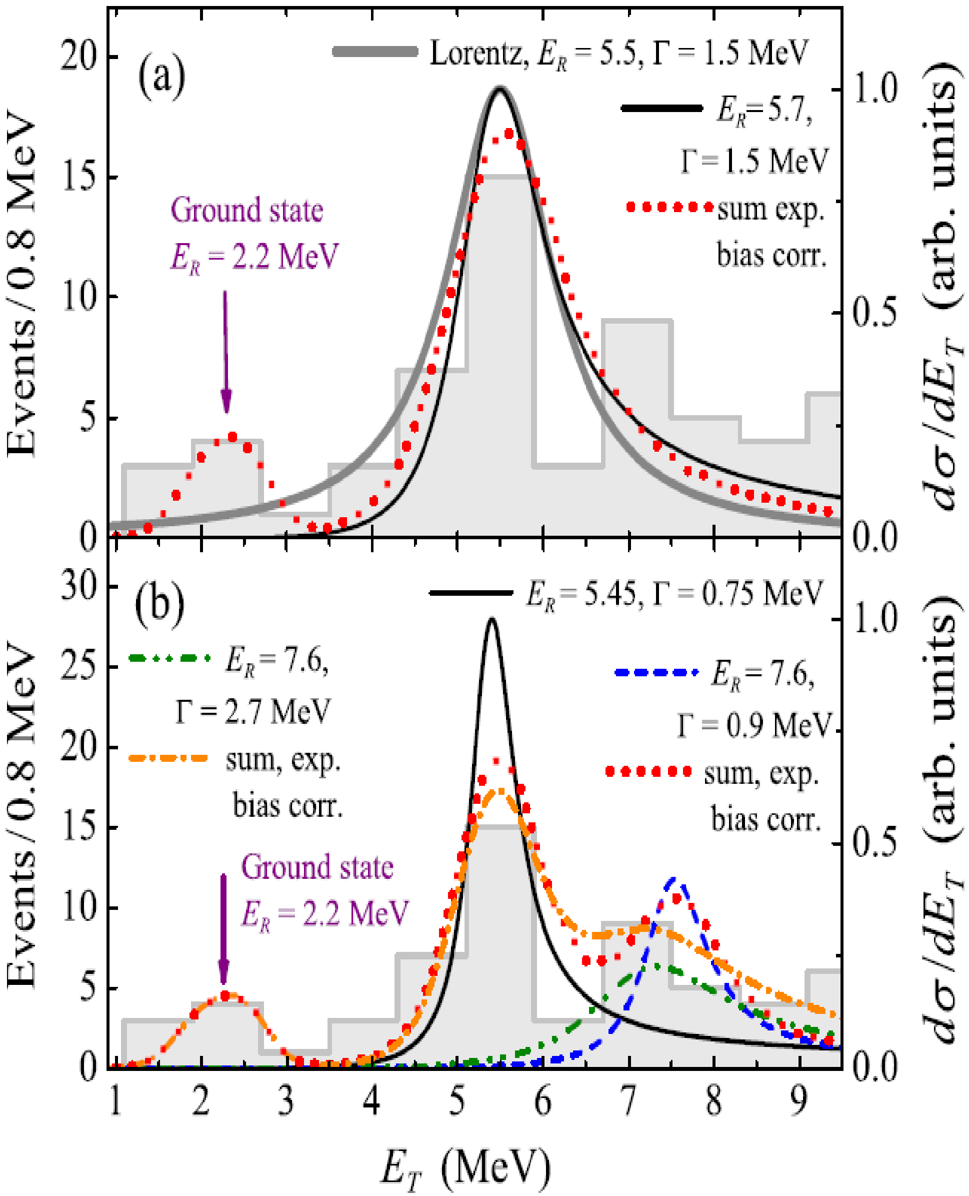


$^2H(^8He,{}^6Li^*)4n$

$^6Li^* \to {}^3He+{}^3H$

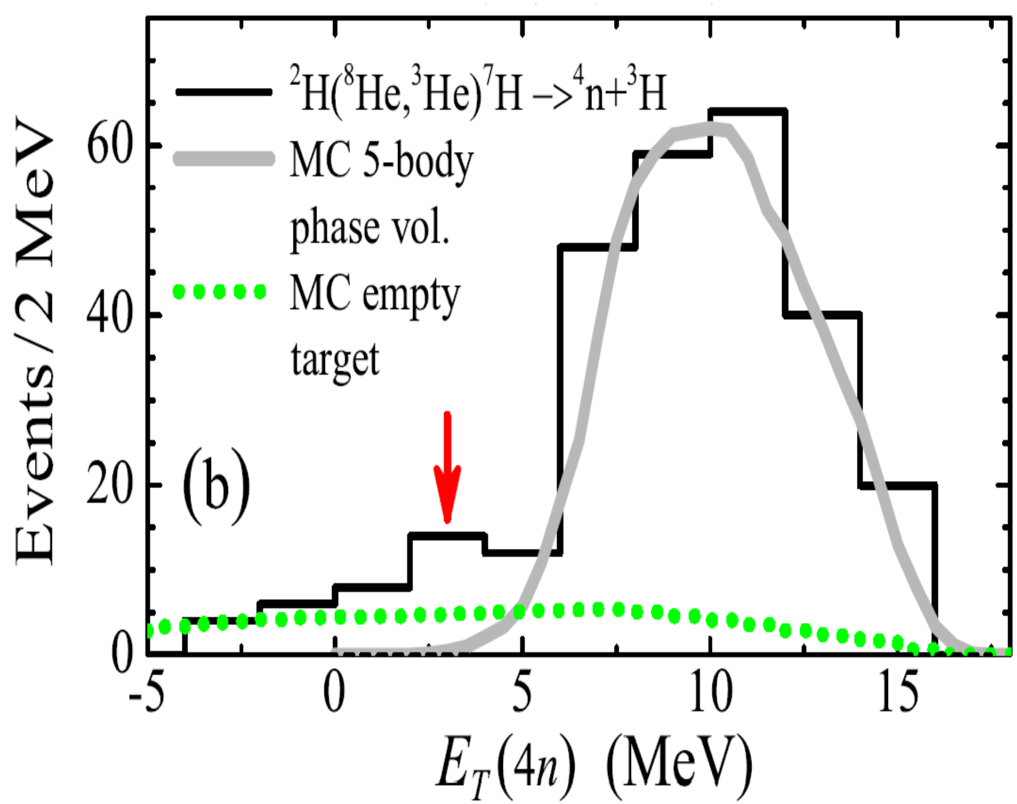
$^{2}H(^{8}He,^{3}He^{3}H)$ results

^{7}H states



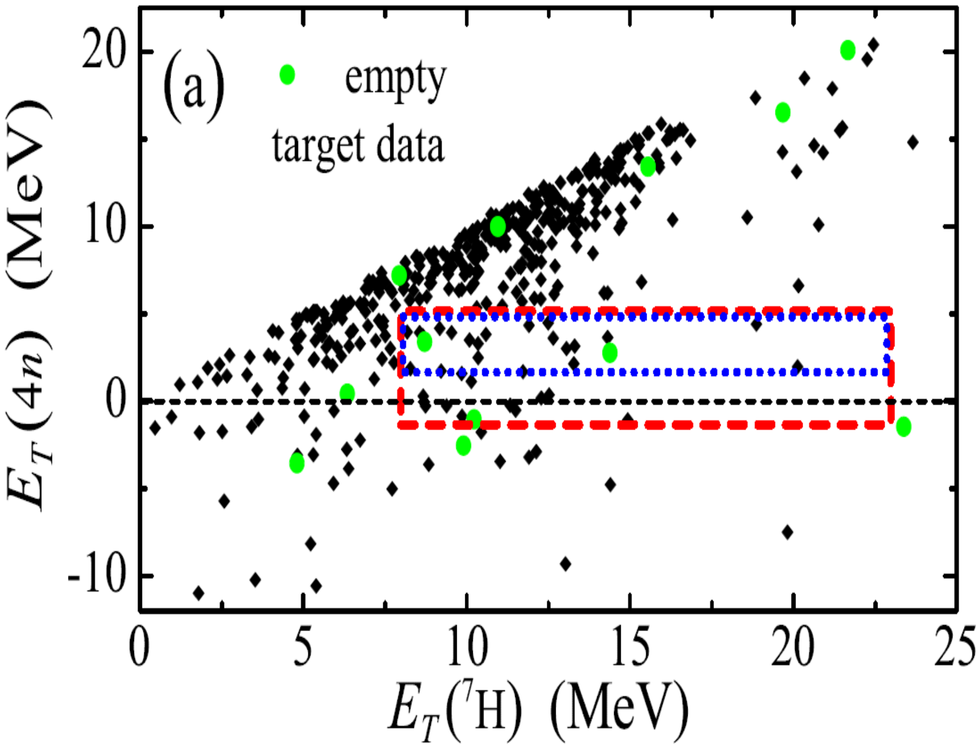
^{4}n MM from $^{3}He + {}^{3}H$

MM(^{7}H)>8 MeV

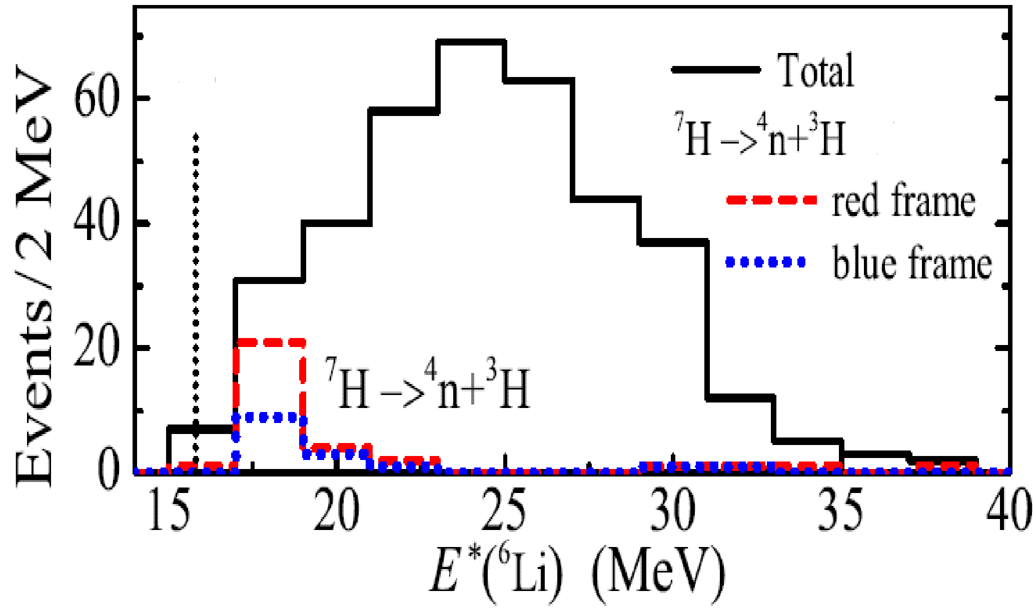


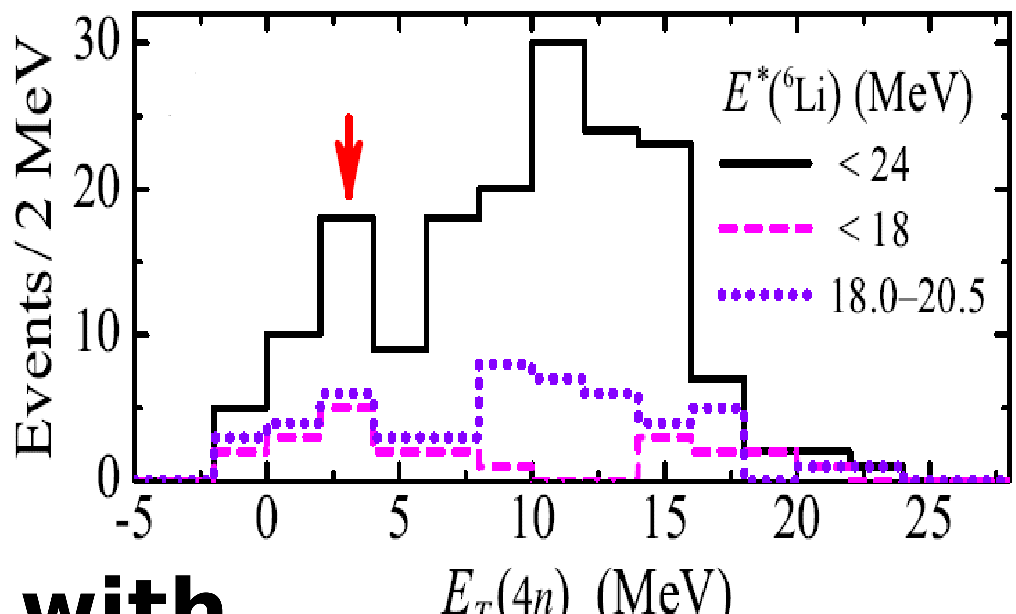
^{4}n peak at 3.2 MeV

^{7}H-^{4}n correlation



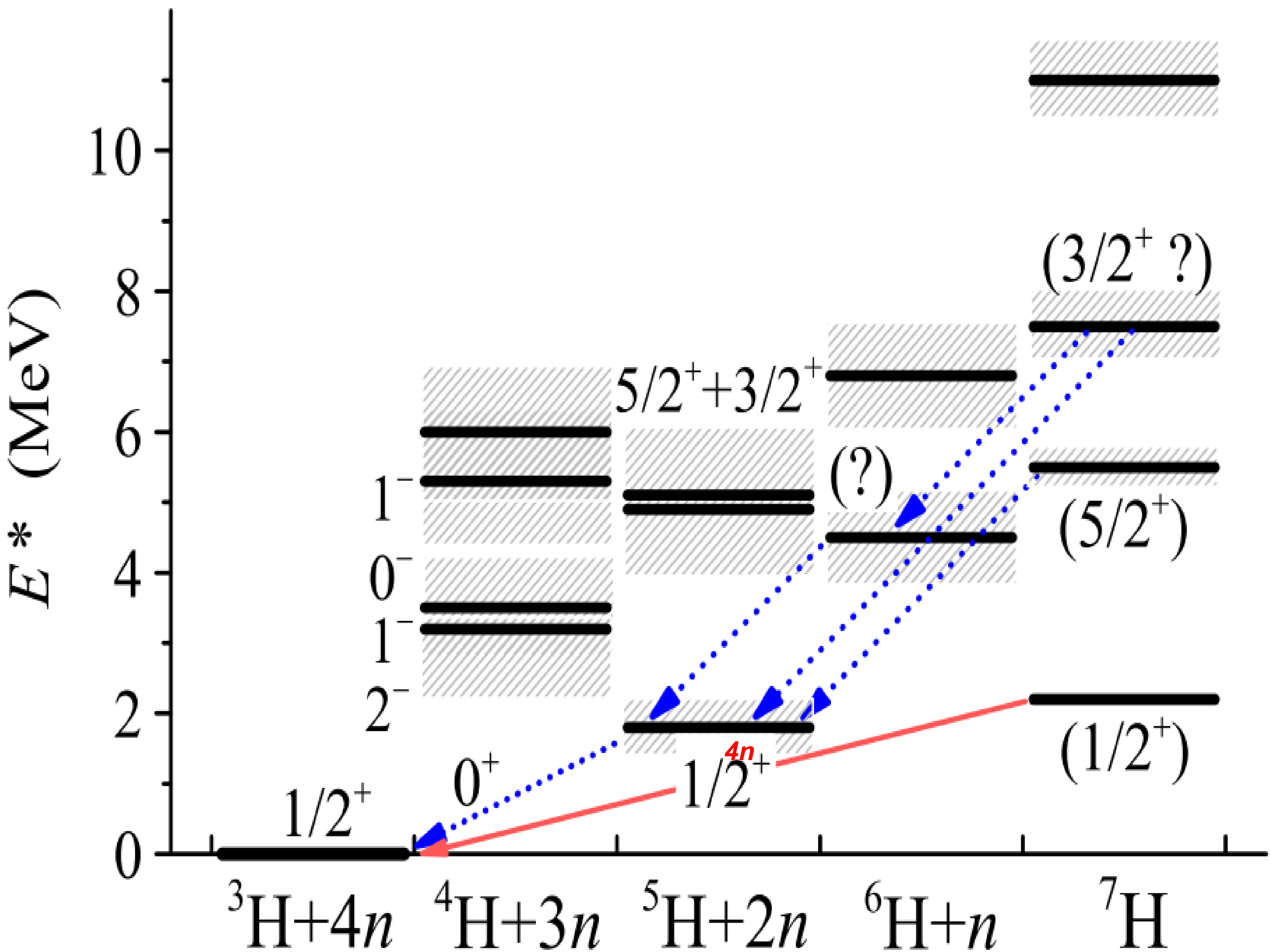
^{6}Li*-^{4}n correlation





Strong correlation with (2-)^{6}Li 18 MeV state

New information on hydrogen isotopes



ExpertRoot is a framework for **simulation** of detector`s response**, event reconstruction** and real **data analysis** of the experiments at the EXPERT and ACCULINNA-2

ExpertRoot is a FAIRRoot based framework:

- FAIRroot interface
- Special functionality for the EXPERT/ACCULINNA-2 setups
- uses Root framework for data storage and analysis and Geant4 as simulation engine

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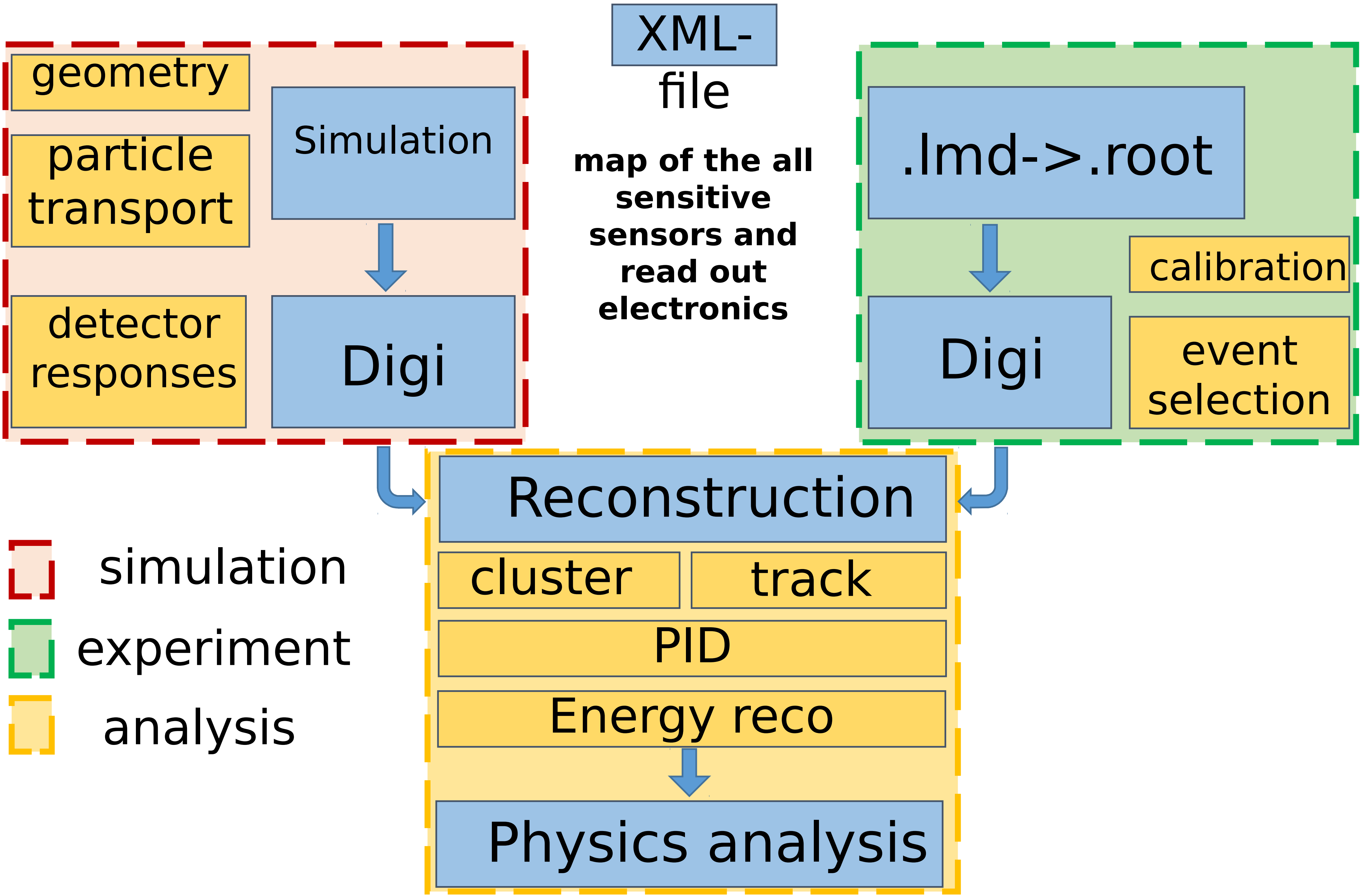
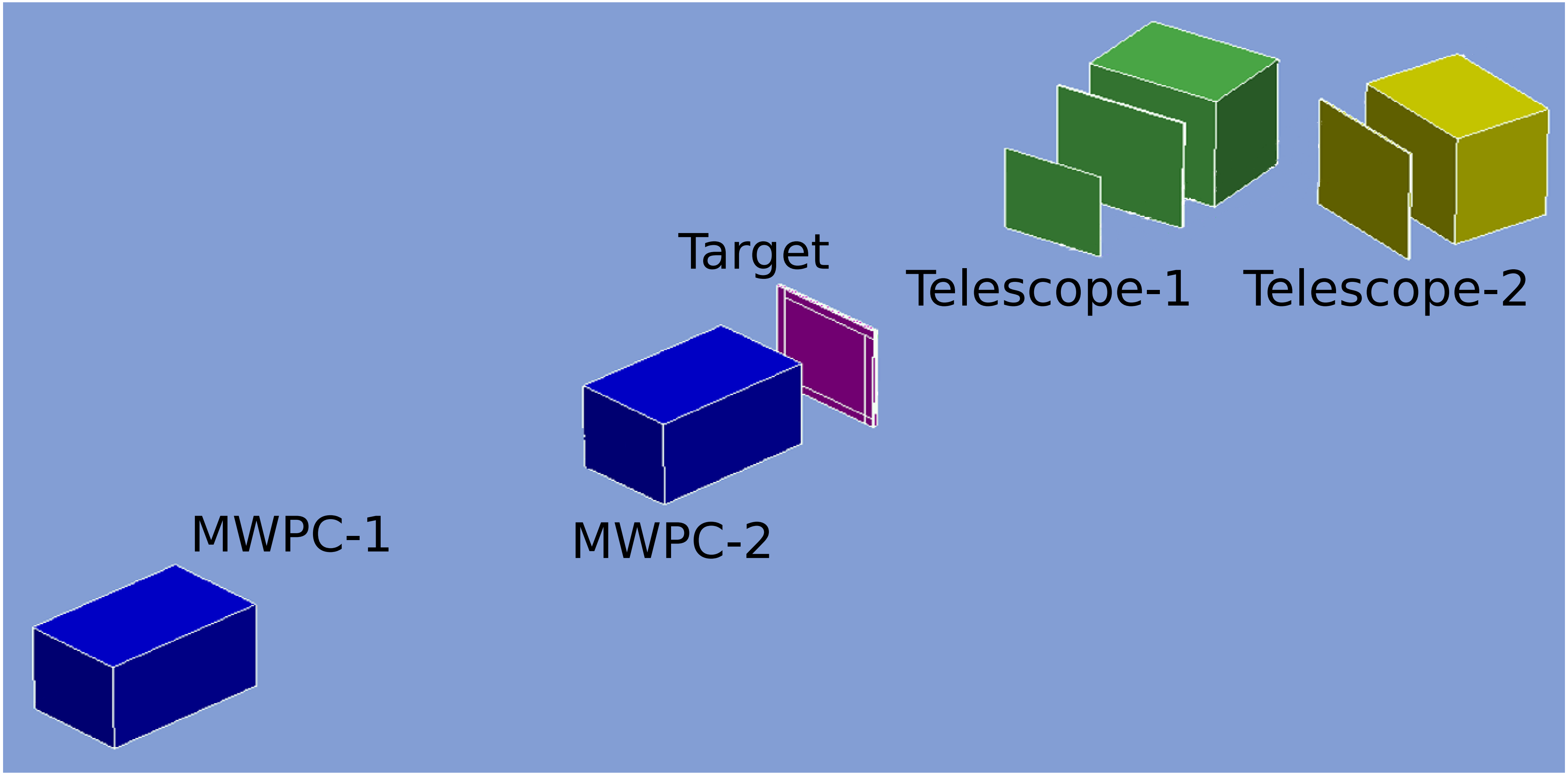
EXPERTRootTasks

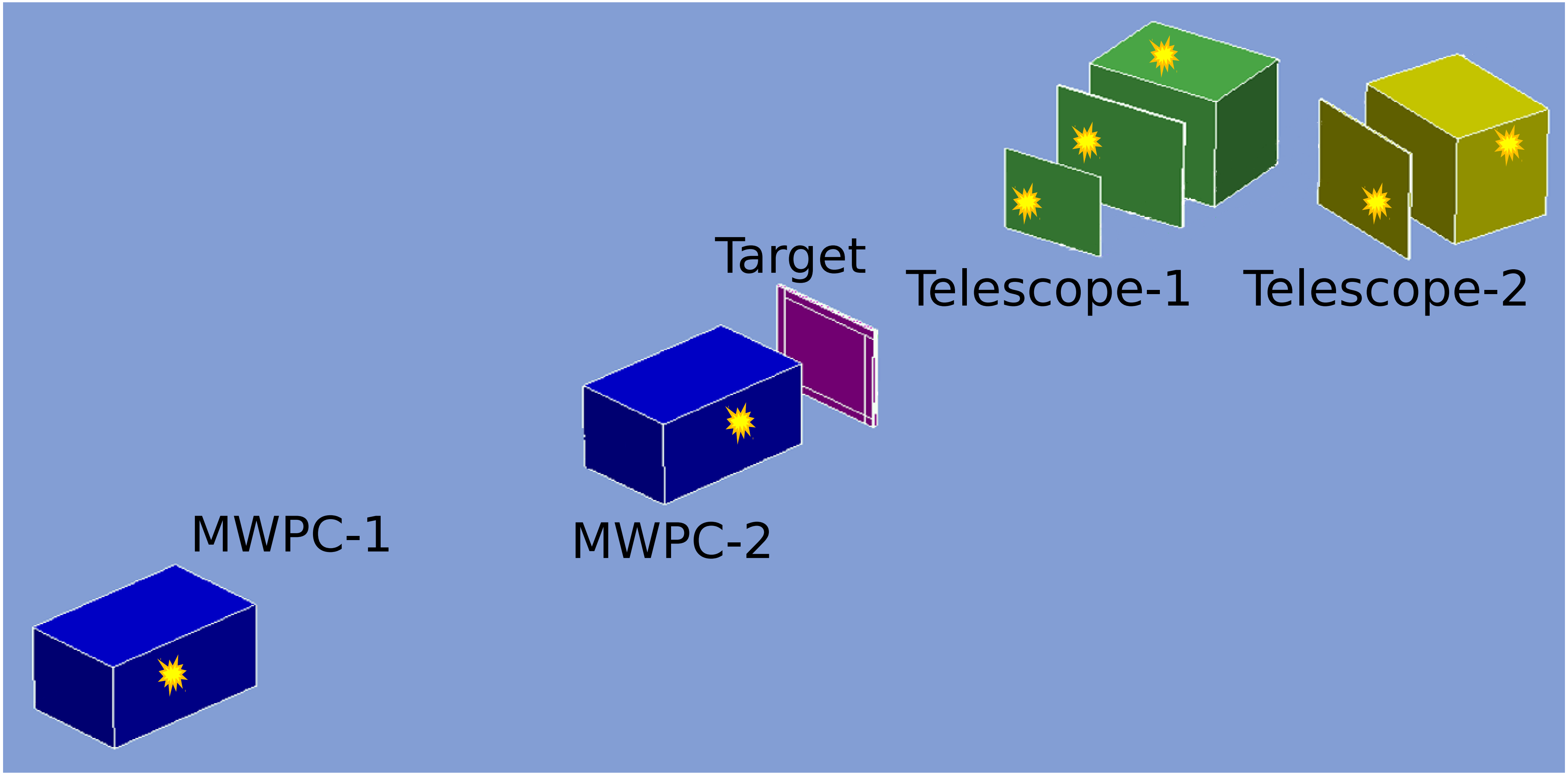


Simulation



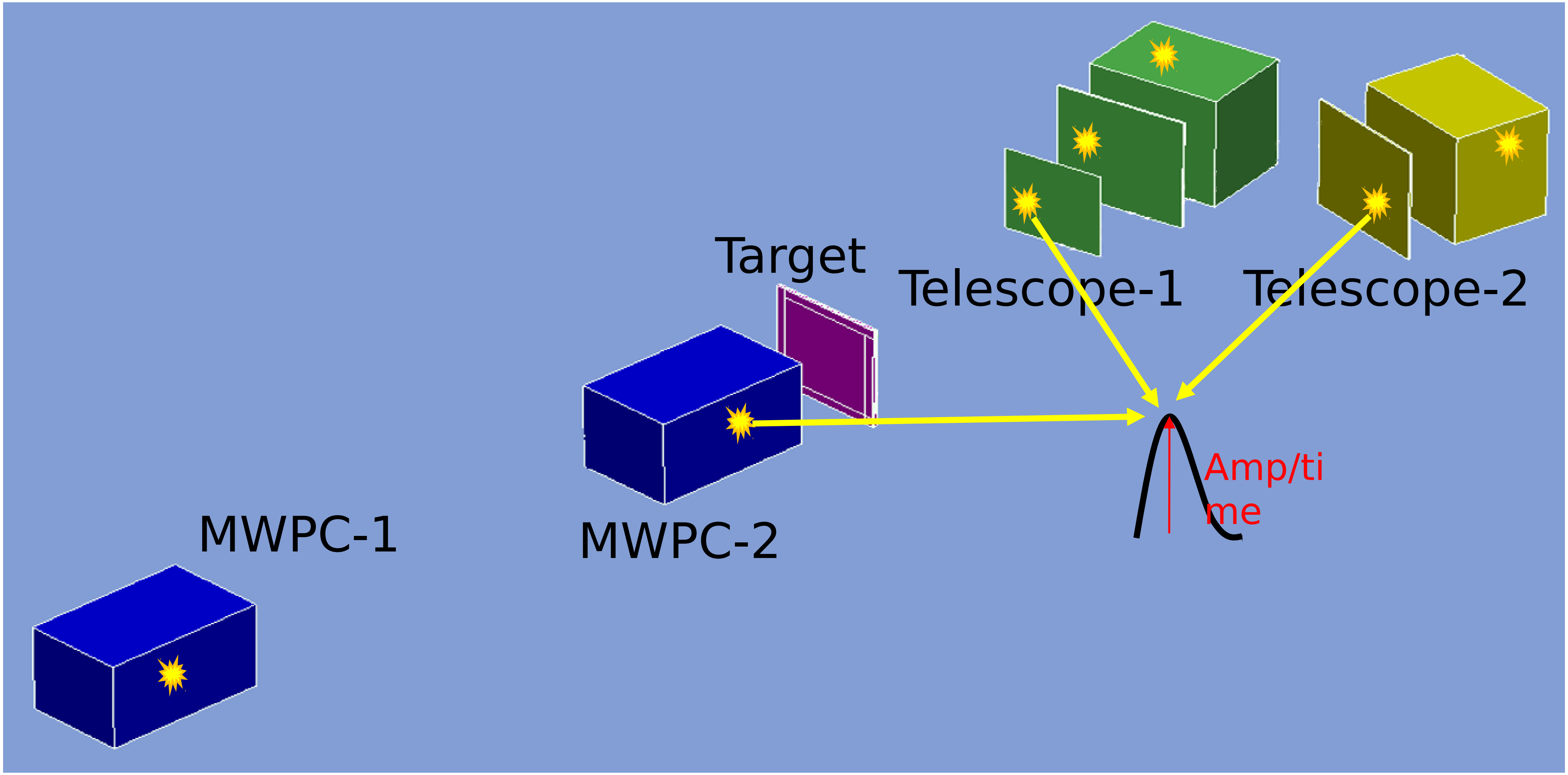
- **Geometry construction**

Simulation



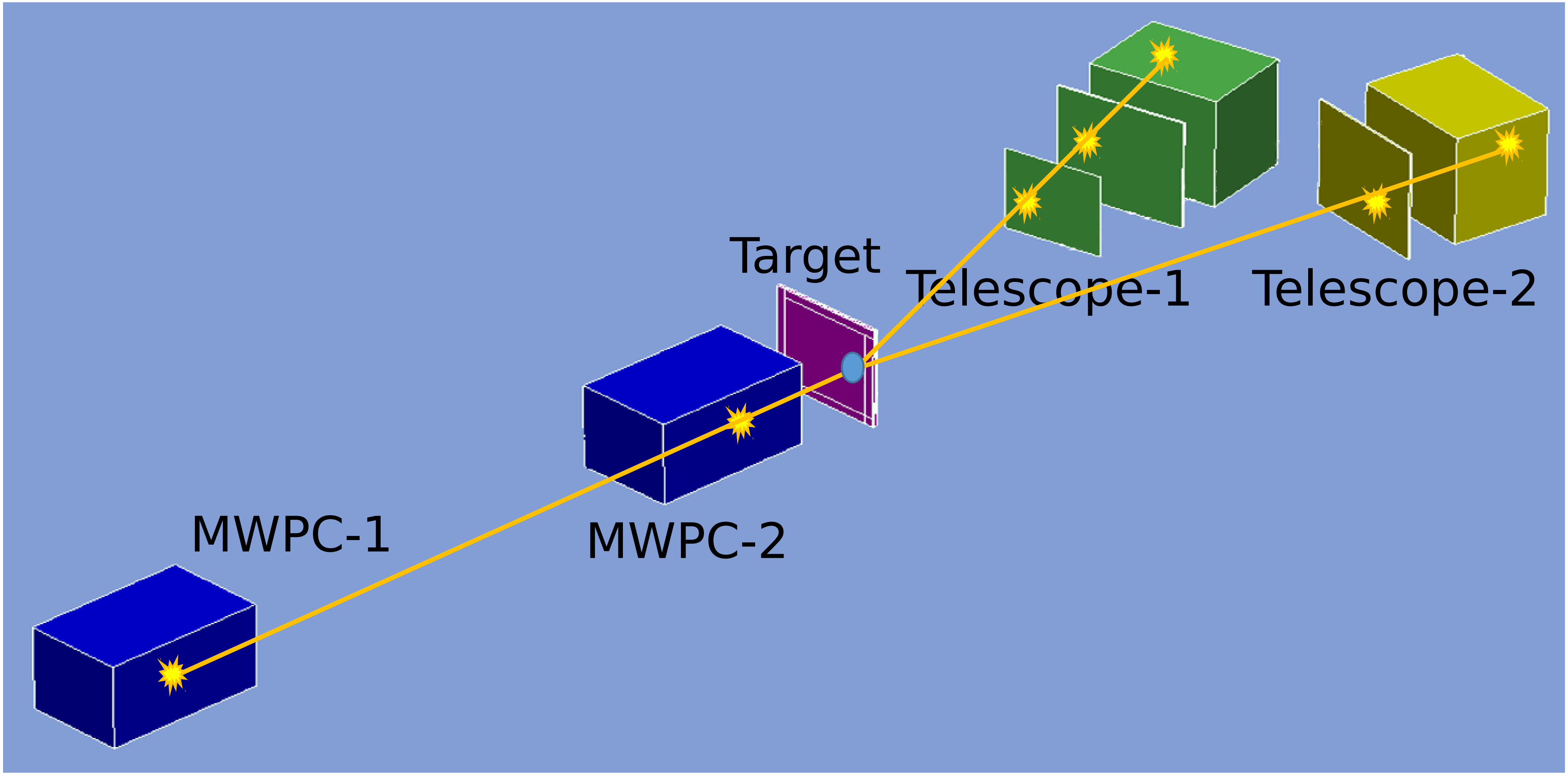
- Geometry construction
- **GEANT4 for the particle transport through the detector volumes**

Digi



- Geometry construction
- GEANT4 for the particle transport through the detector volumes
- **Energy losses transformation into the detectors' signals**
- **The format of the obtained data is the same for the experiment and simulation**

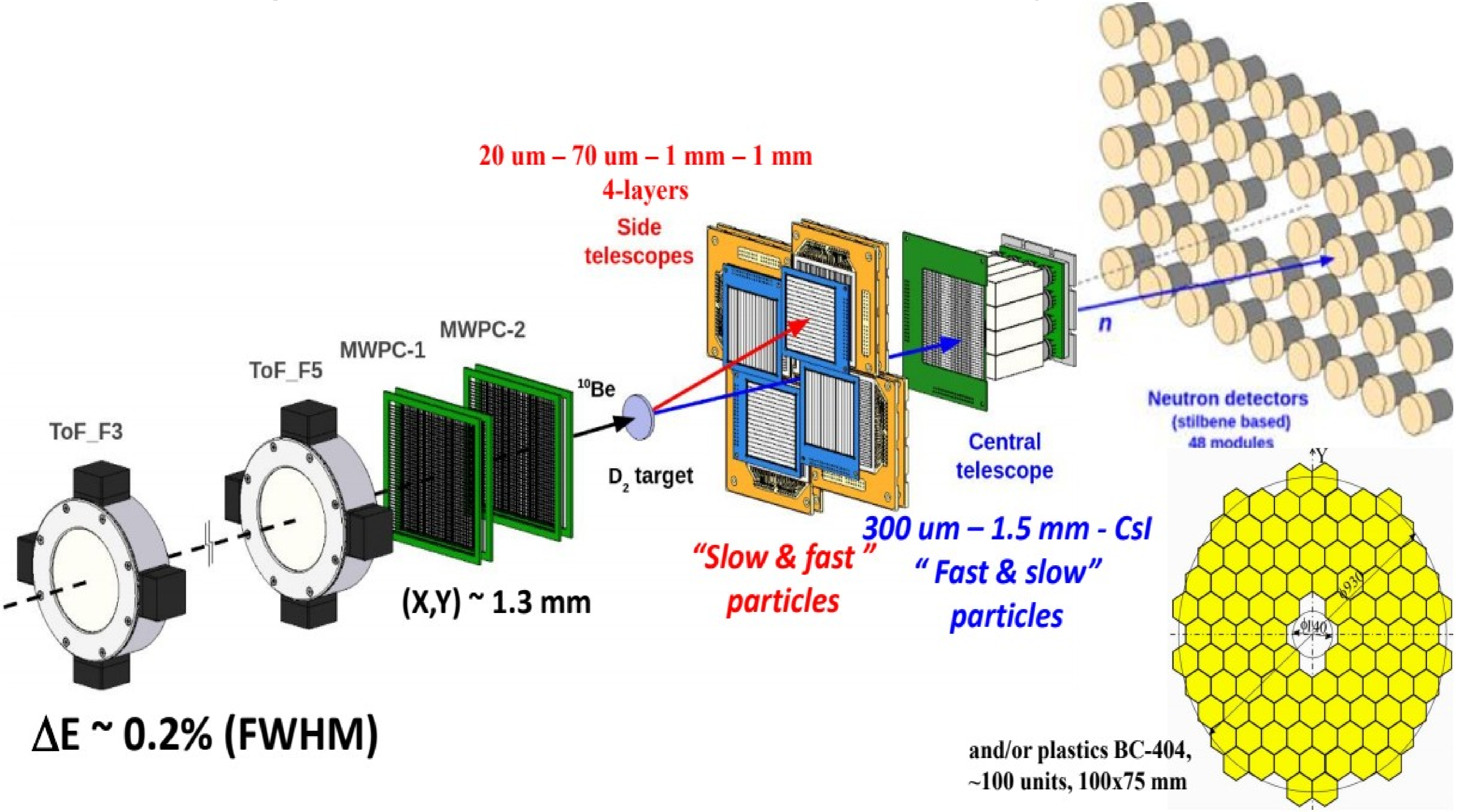
Reconstruction



- Geometry construction
- GEANT4 for the particle transport through the detector volumes
- Energy losses transformation into the detectors’ signals
- **Tracks reconstruction, considering the clusterization**

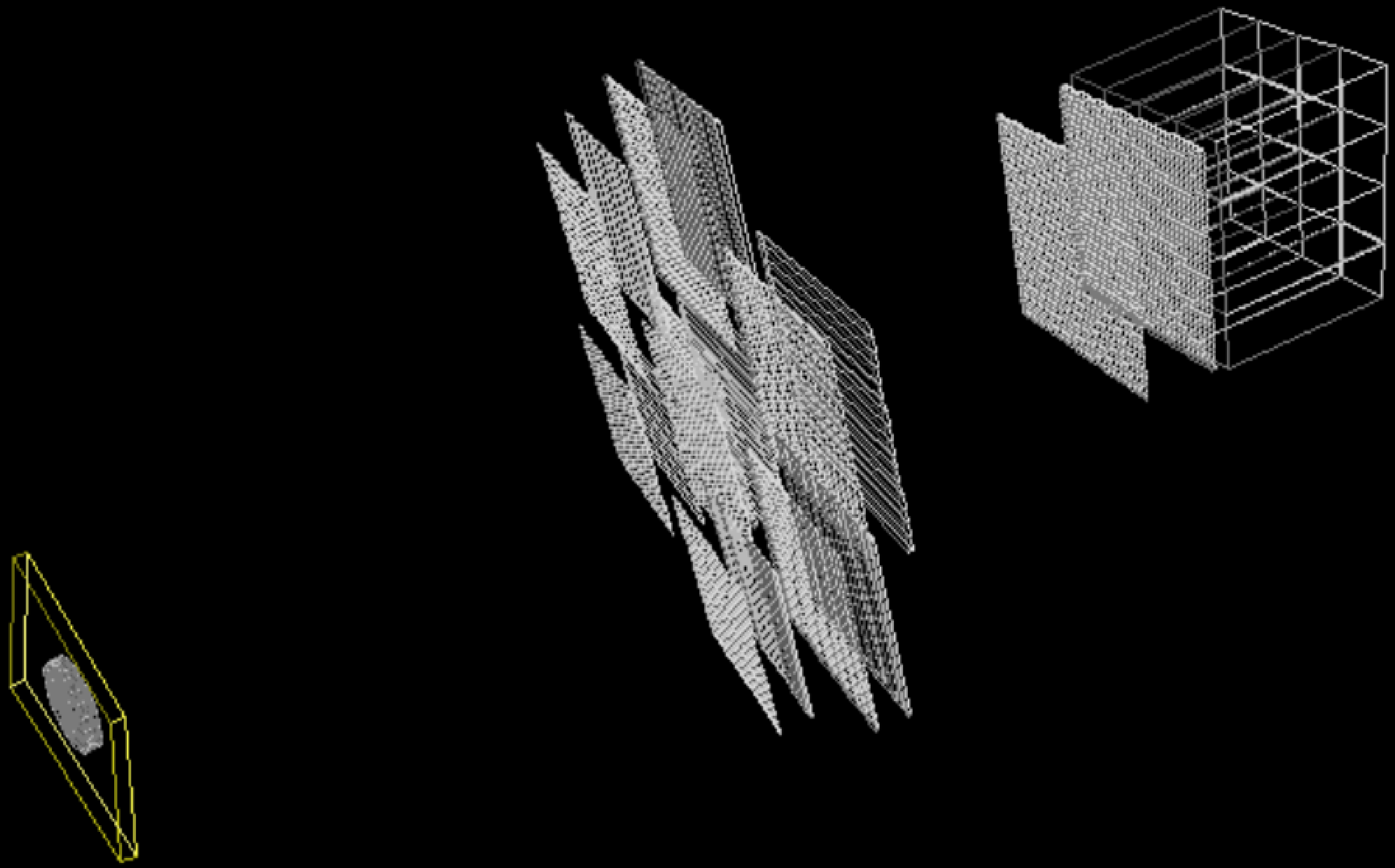
New detector setup

Expected statistics to be increased by >4 factor.



MM resolution in old setup/new setup:

- ^{7}H 1.2 MeV → 0.9 MeV
- 4n 1.8 MeV → 1.4 MeV



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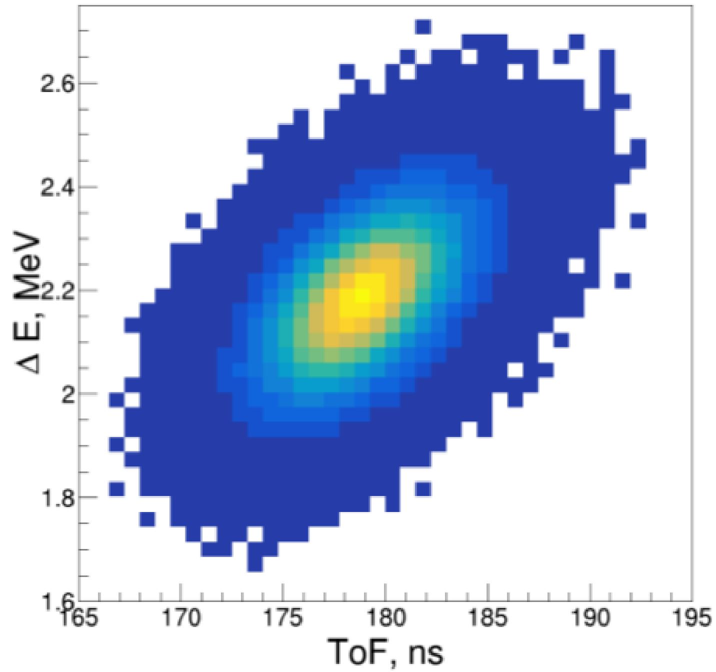
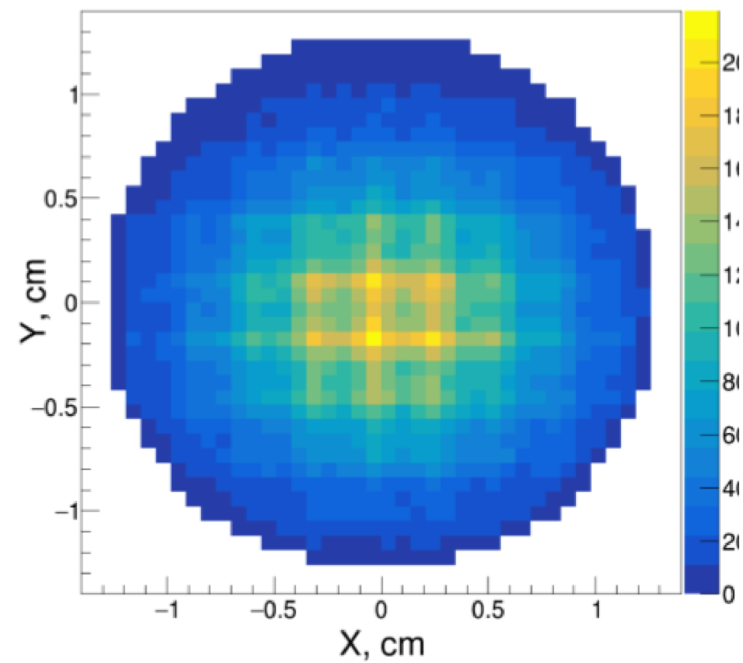
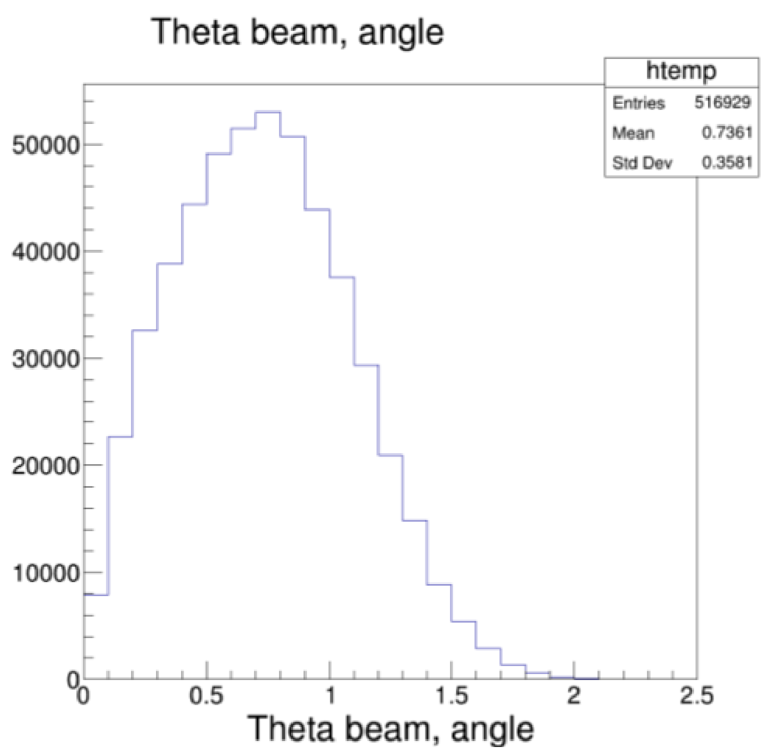
1. *Bezbakh et al., Evidence for the first excited state of ^{7}**H**, Phys. Rev. Lett. **124** (2020) 022502.*
2. *Muzalevskii et al., Resonant states in ^{7}**H**: Experimental studies of the ^{2}H(^{8}He,^{3}He) reaction, Phys. Rev. C **103** (2021) 044313.*
3. *Nikolskii et al., ^{6}**H** states studied in the ^{2}H(^{8}He,^{4}He) reaction and evidence of an extremely correlated character of the ^{5}H ground state, Phys. Rev. C **105** (2022) 064605.*
4. *Nikolskii et al., Study of proton and deuteron pickup reactions **^{2}H(d,^{3}He)^{9}Li** and **^{2}H(d,^{4}He)^{8}Li** with 44 AMeV ^{10}Be radioactive beam at ACCULINNA-2 fragment separator, Physics of Atomic Nuclei, Vol. **87** №1 (2024) 1-8.*
5. *Muzalevskii et al., Population of tetraneutron continuum in reaction of on deuterium, Phys. Rev. C **111** (2025) 014612.*

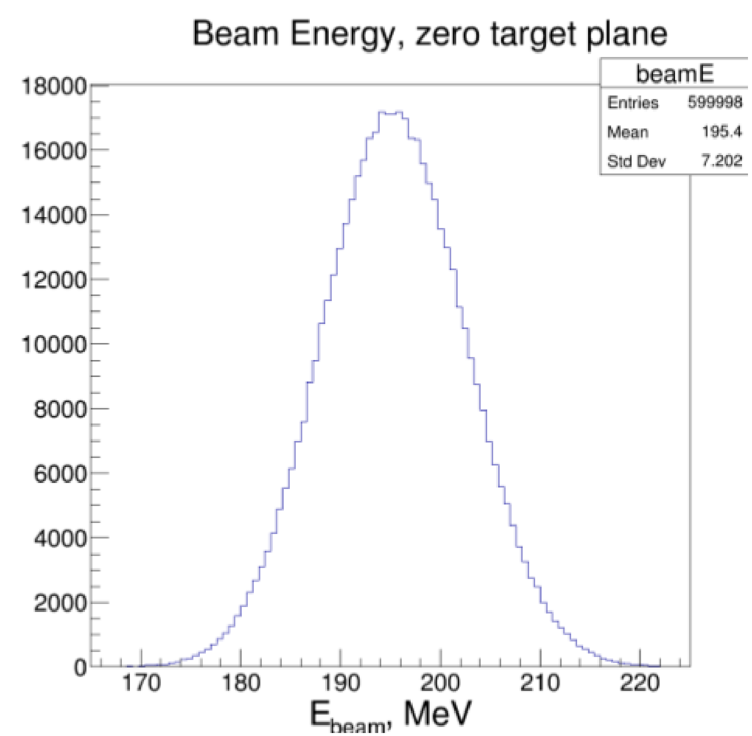
Thanks for attention

Beam simulation

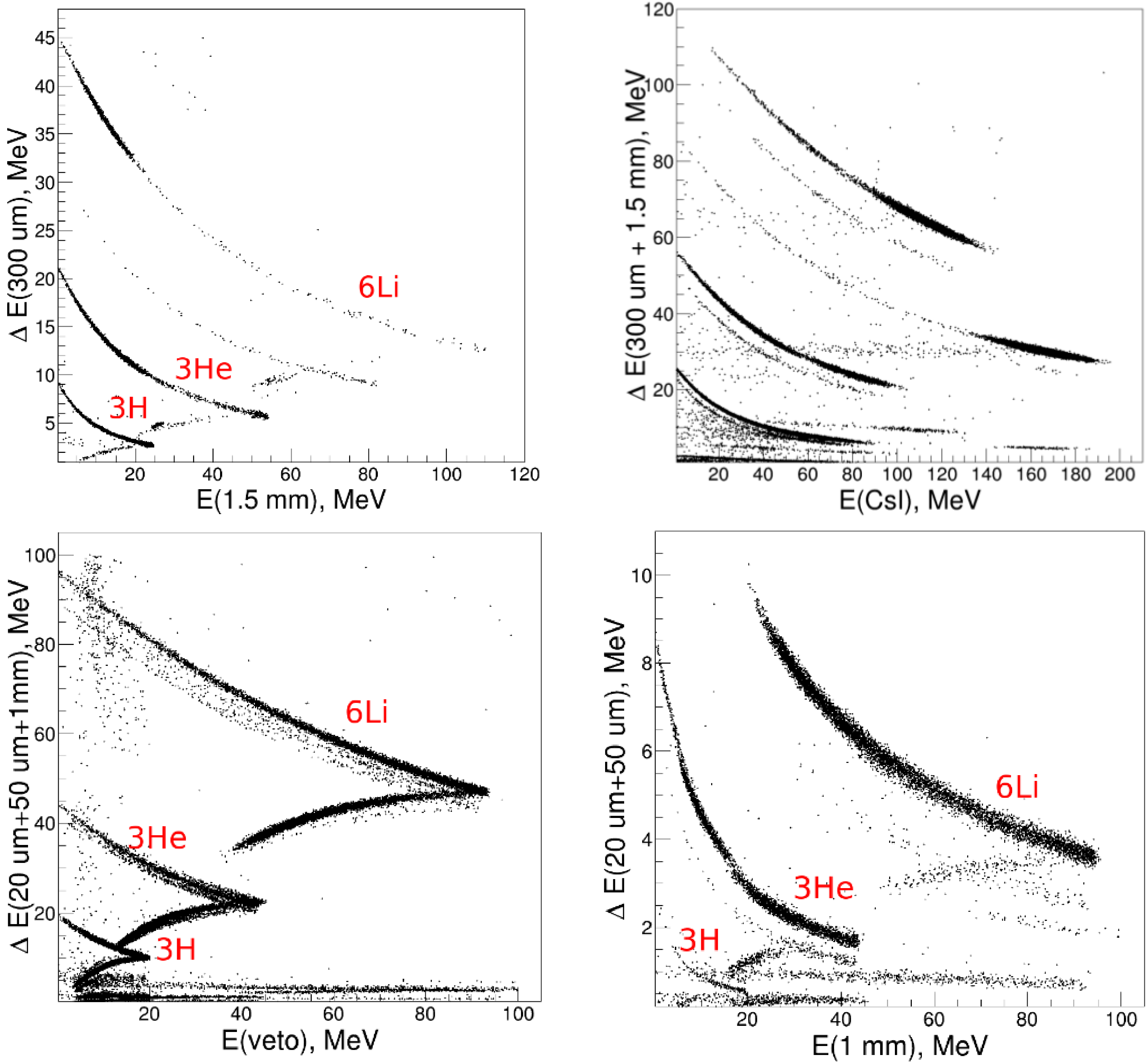




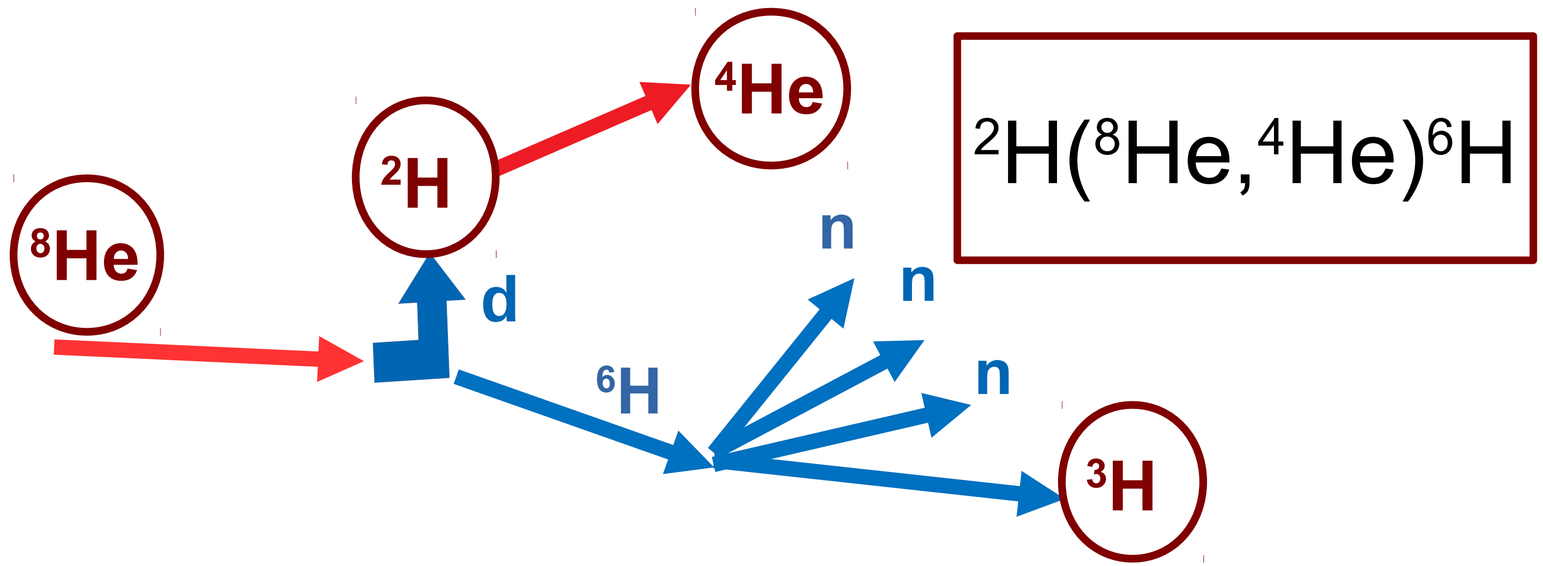


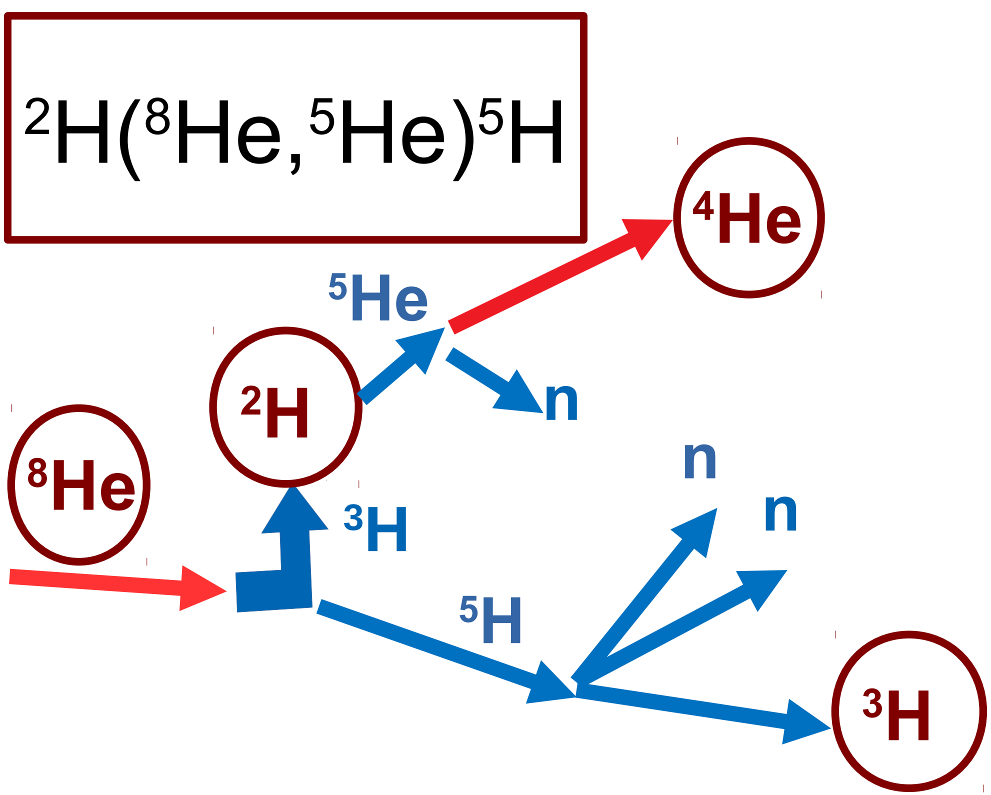


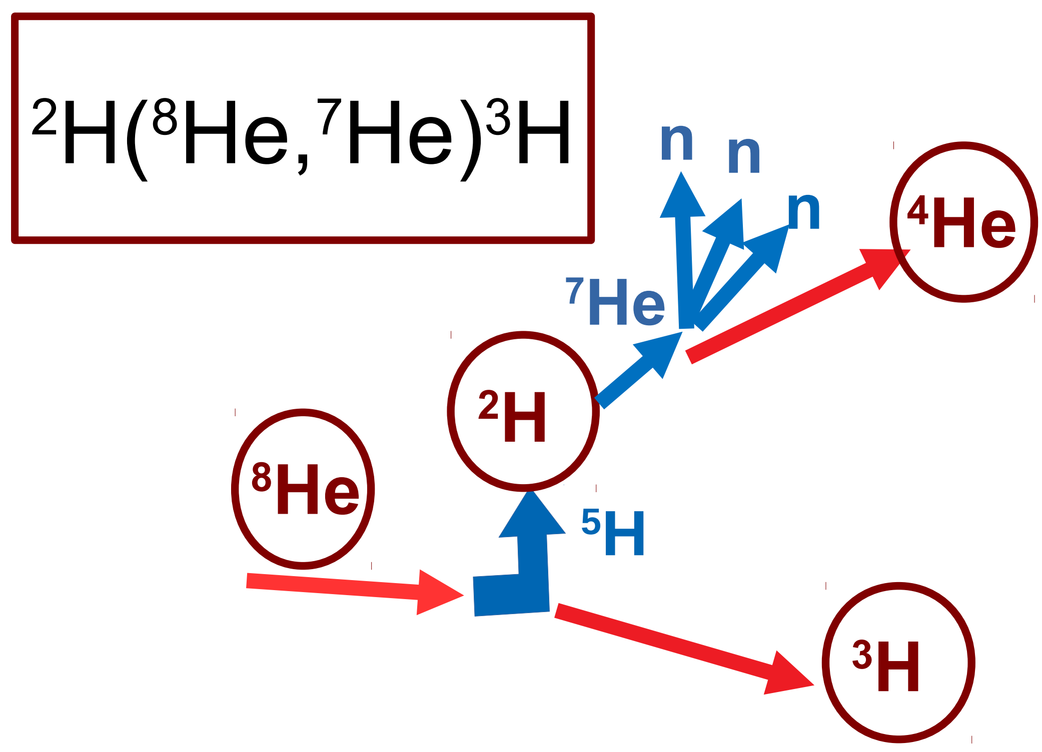
Particle identification



Sattelite channels; ^{4}He-^{3}H





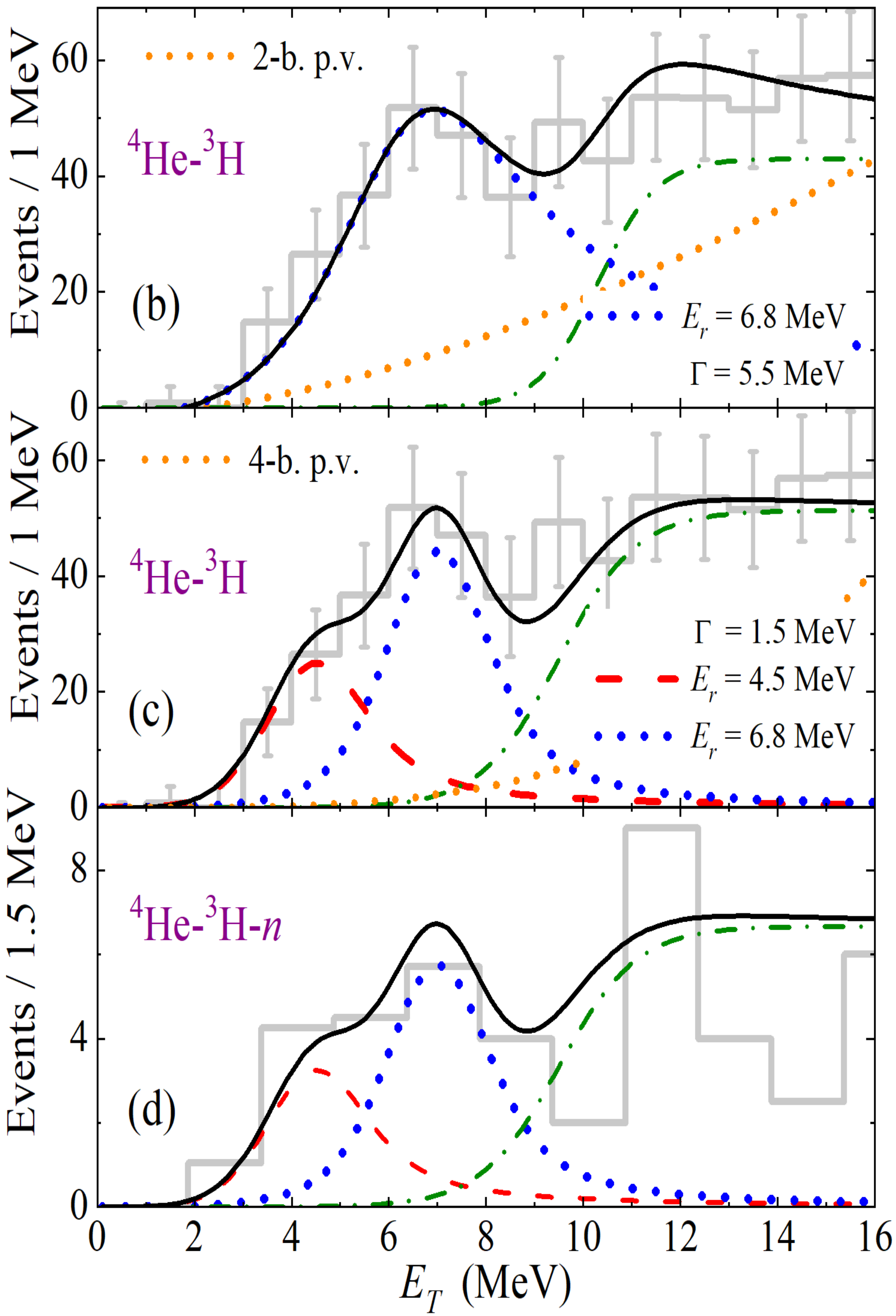


^6H results

NO states below 3.5 MeV ($d\sigma/d\Omega$ < 5 μb/sr)

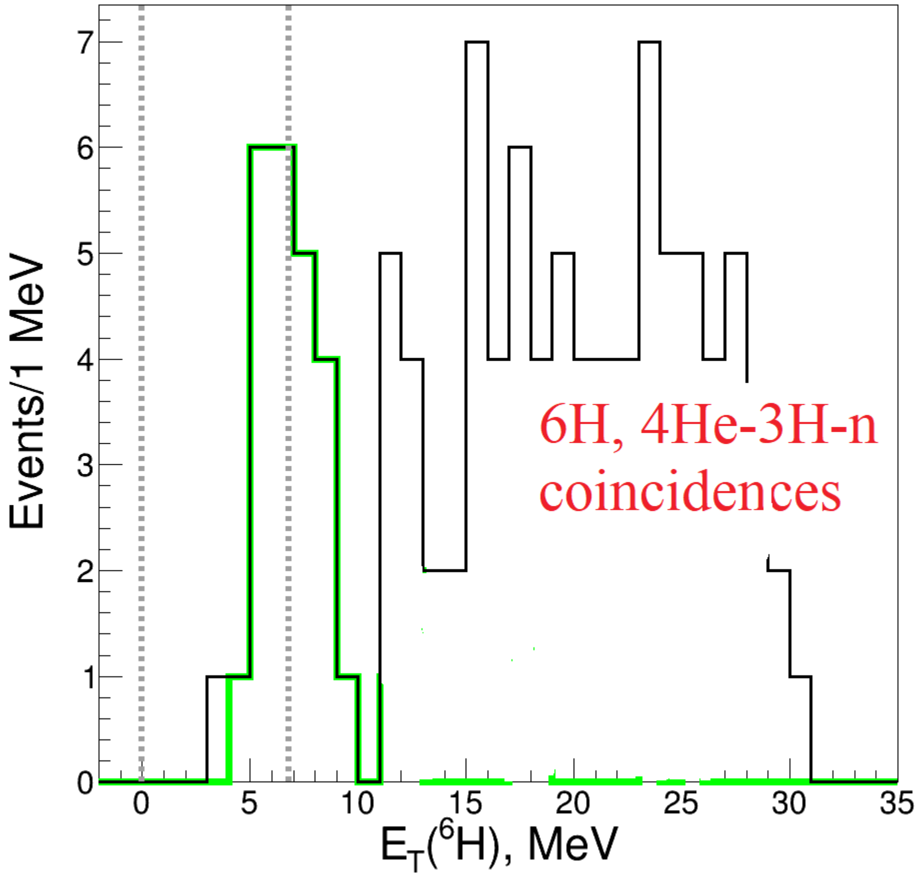
Peak at 4-8 MeV (~190 μb/sr):

- 4.5 MeV ground state
- 6.8 MeV excited state

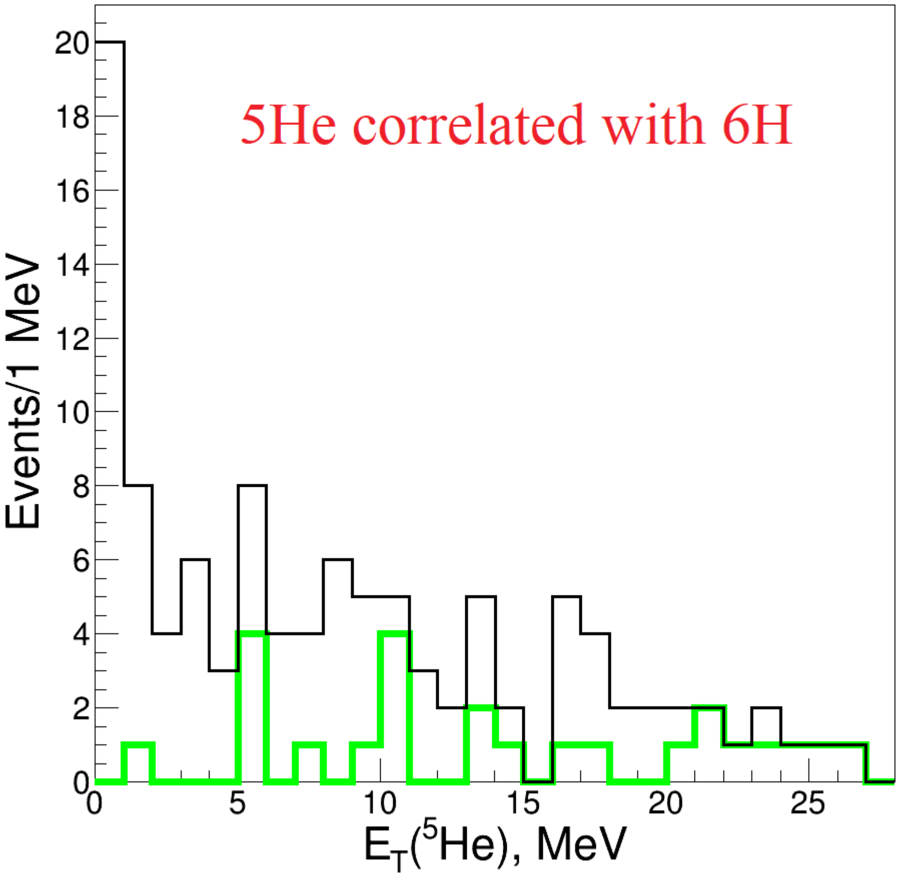


$^{2}H(^{8}He,^{5}He)^{5}H$ correlation with $^{2}H(^{8}He,^{4}He)^{6}H$

^{6}H spectrum

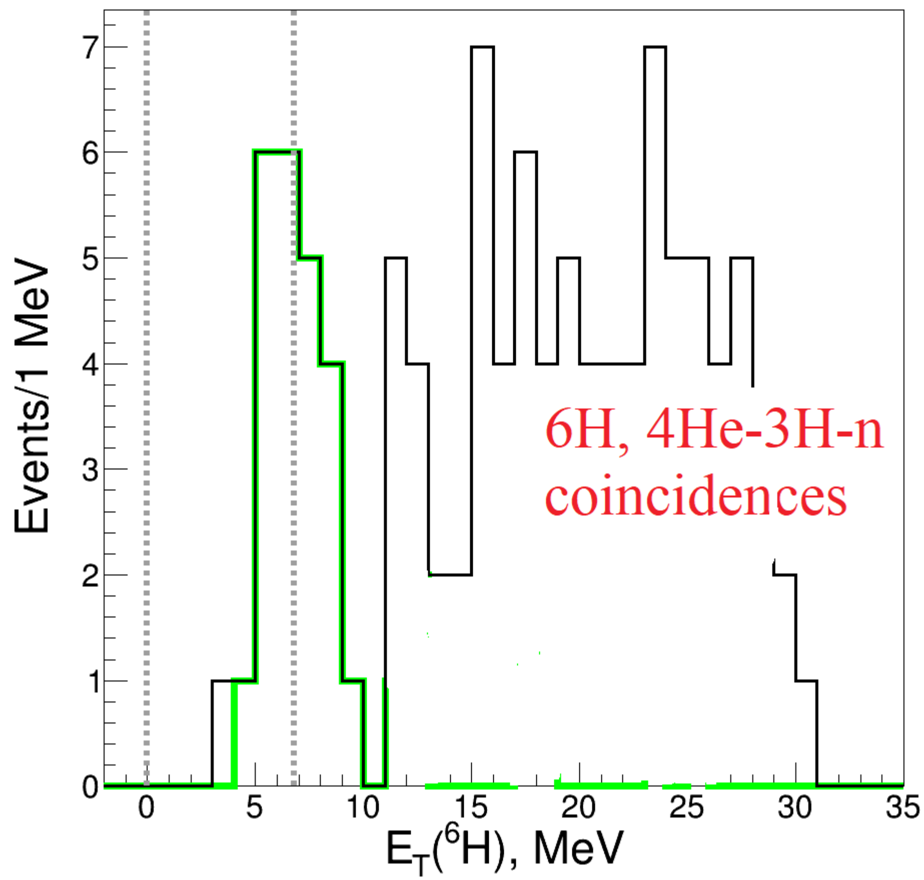


^{5}He spectrum

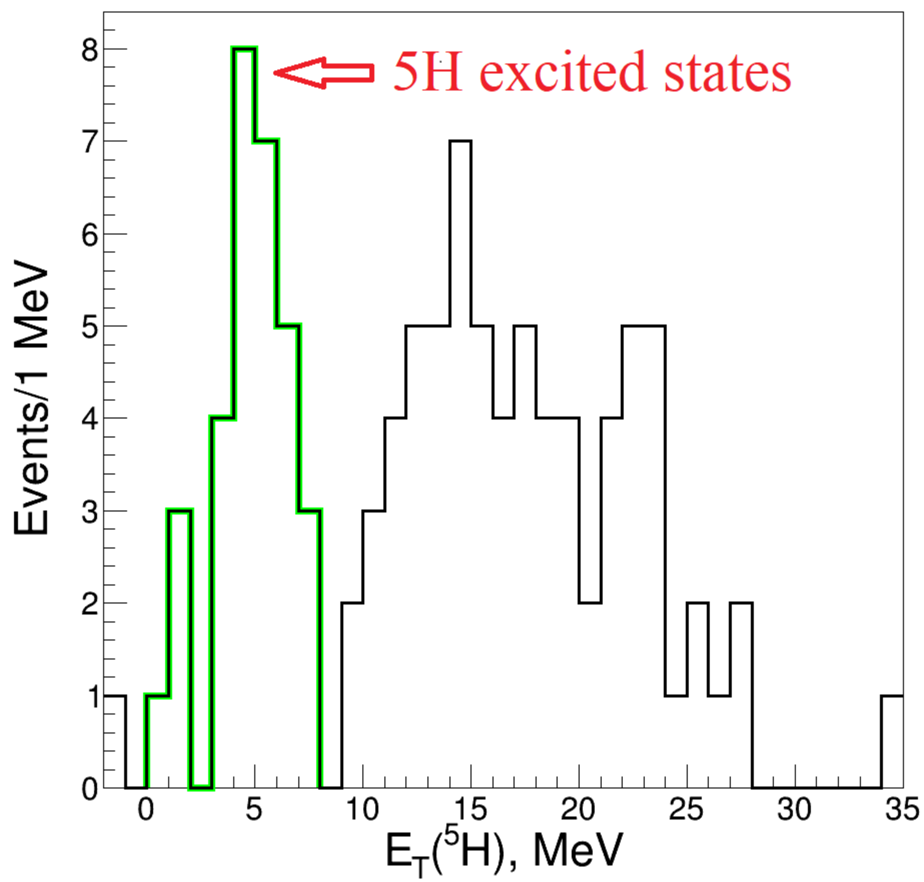


^5H correlation with $^2H(^8He,^4He)^6H$; $^6H \rightarrow {}^5H+n$

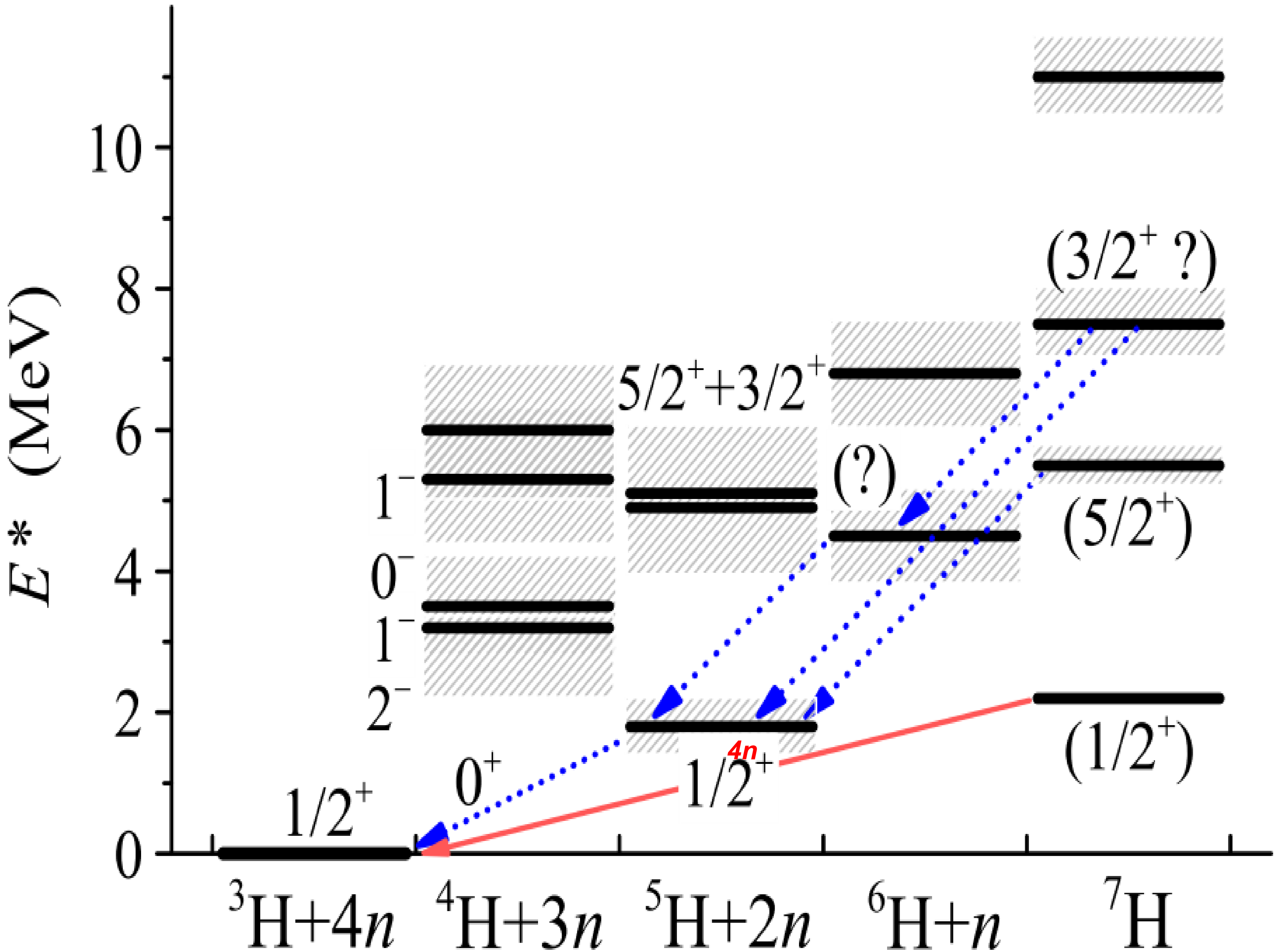
^6H spectrum



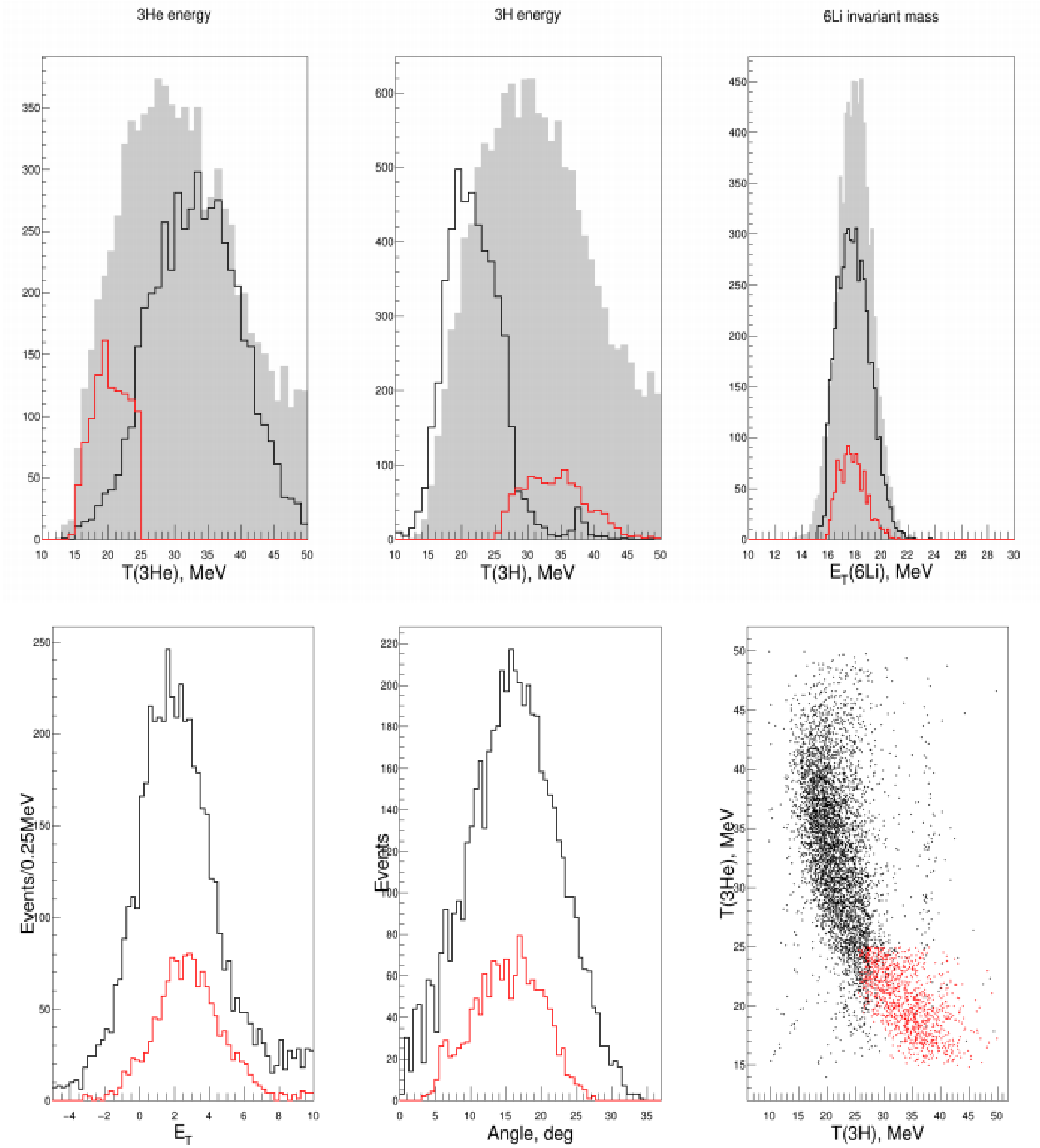
^5H spectrum



New information on hydrogen isotopes



New detector setup simulations of $^{2}H(^{8}He,^{3}He^{3}H)^{4}n$



Red – old setup

Black – new setup