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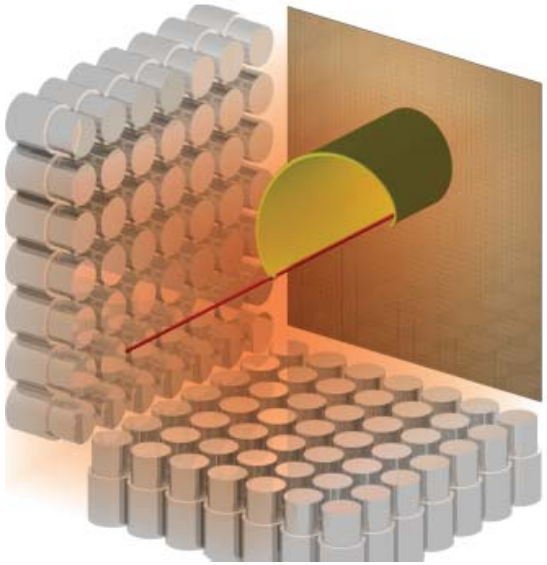
Coupling gamma-ray detection to an active target in a high magnetic field: the SpecMAT project for direct reaction studies

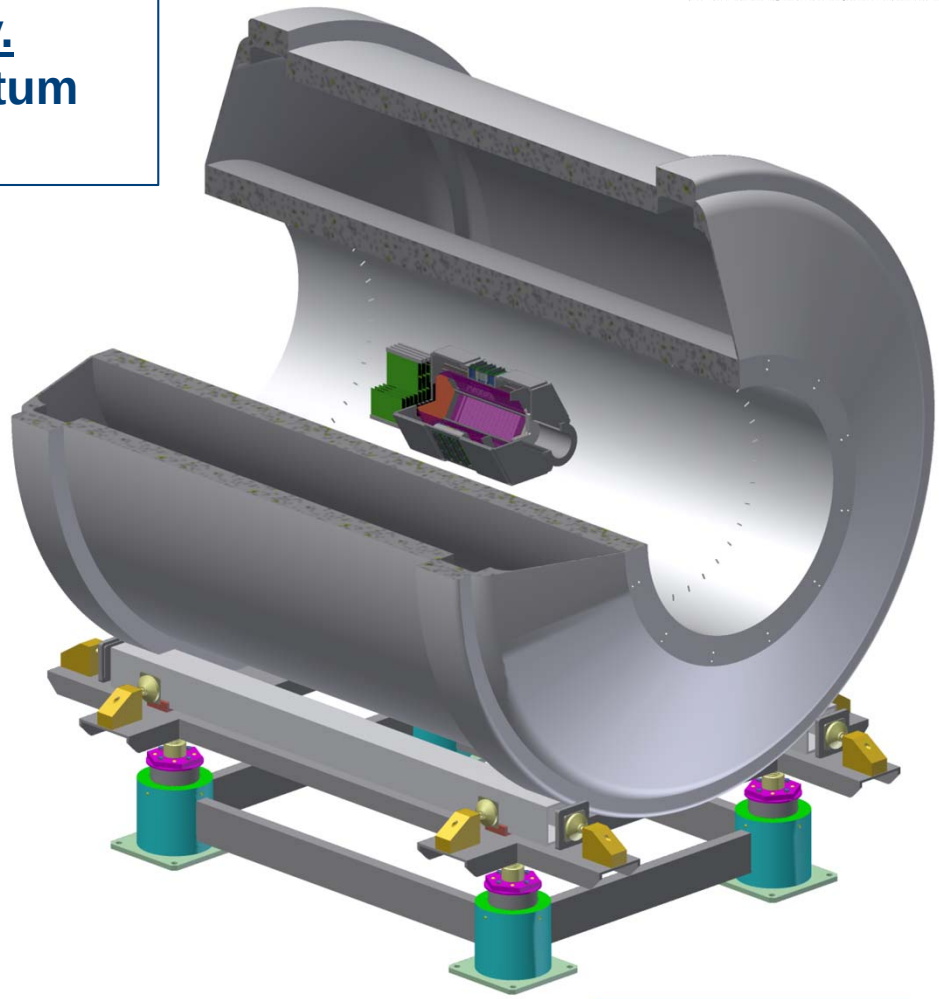
T. Marchi, IKS-KU Leuven

SpecMAT concept

European Research Council
Established by the European Commission

- **ACTIVE TARGET in high magnetic field.**
- **Surrounded by a gamma-ray array.**
- **Particle identification and momentum from traking.**





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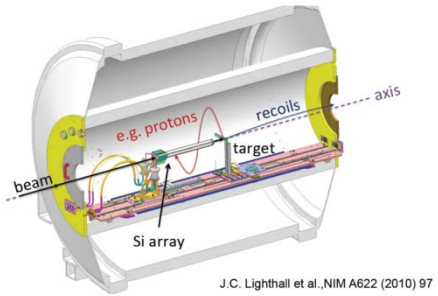
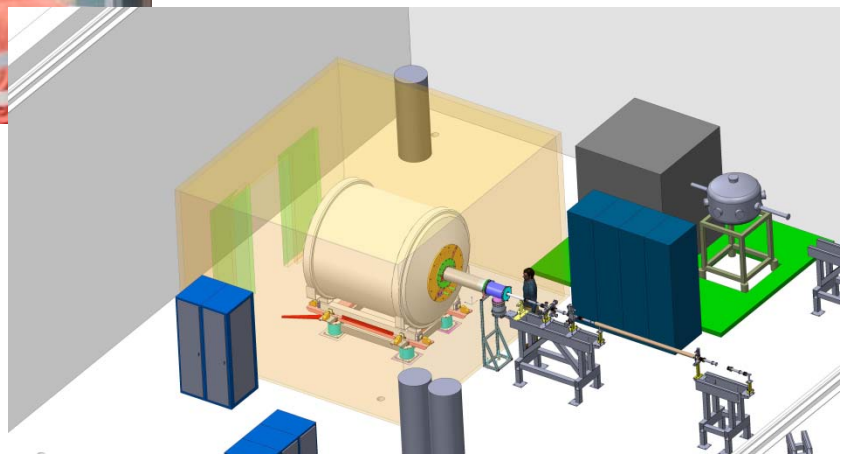
ISOL Solenoidal Spectrometer: a “shared” solenoid

Aarhus University (Denmark)
Louisiana State University (USA)
Argonne National Laboratory (USA)
University of Manchester (UK)
STFC Daresbury Laboratory (UK)
Oak Ridge National Laboratory (USA)
Technische Universität Darmstadt (Germany)
RIKEN Nishina Center (Japan)
University of Edinburgh (UK)
CEA Saclay (France)
ISOLDE (CERN)
U. De Santiago de Compostela (Spain)
University of Jyväskylä (Finland)
University of Surrey (UK)
Katholieke Universiteit Leuven (Belgium)
University of the West of Scotland (UK)
University of Liverpool (UK)
University of York (UK)
18 institutions from 10 countries (and growing...)



J.C. Lighthall et al.,NIM A622 (2010) 97

Inner radius = 46 cm
Magnetic field: up to 4 T



Shipped from Canberra to Geneva ✓

Now:

- **Clean & perform vacuum tests**
- **Cool magnet**
- **Energise & verify field**
- **Implement Shielding**

Move to XT02 by end of January 2017

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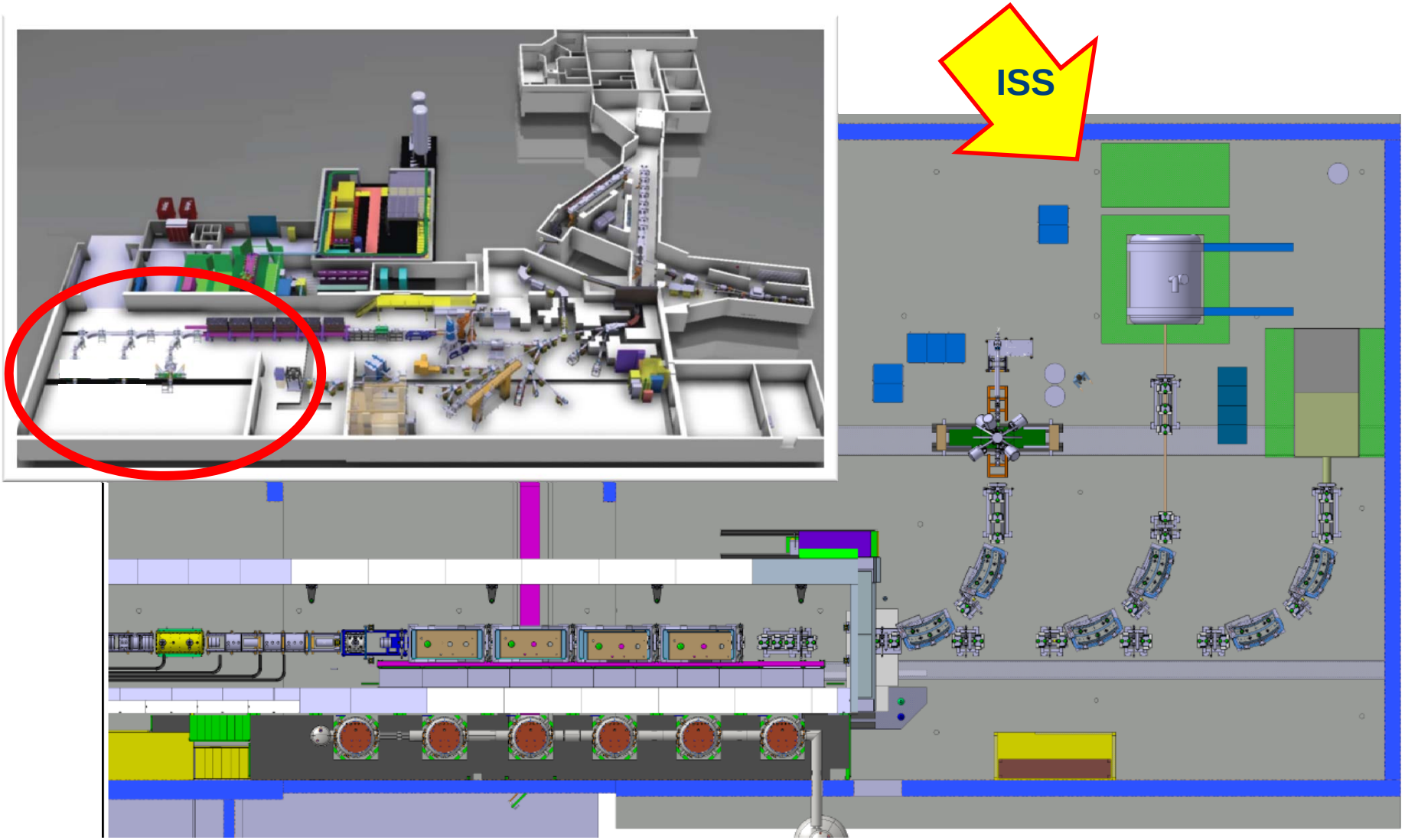
[R. Page at ISOLDE physics coordination meeting 2016]

SpecMAT at HIE-ISOLDE



[R. Page at ISOLDE physics coordination meeting 2016]

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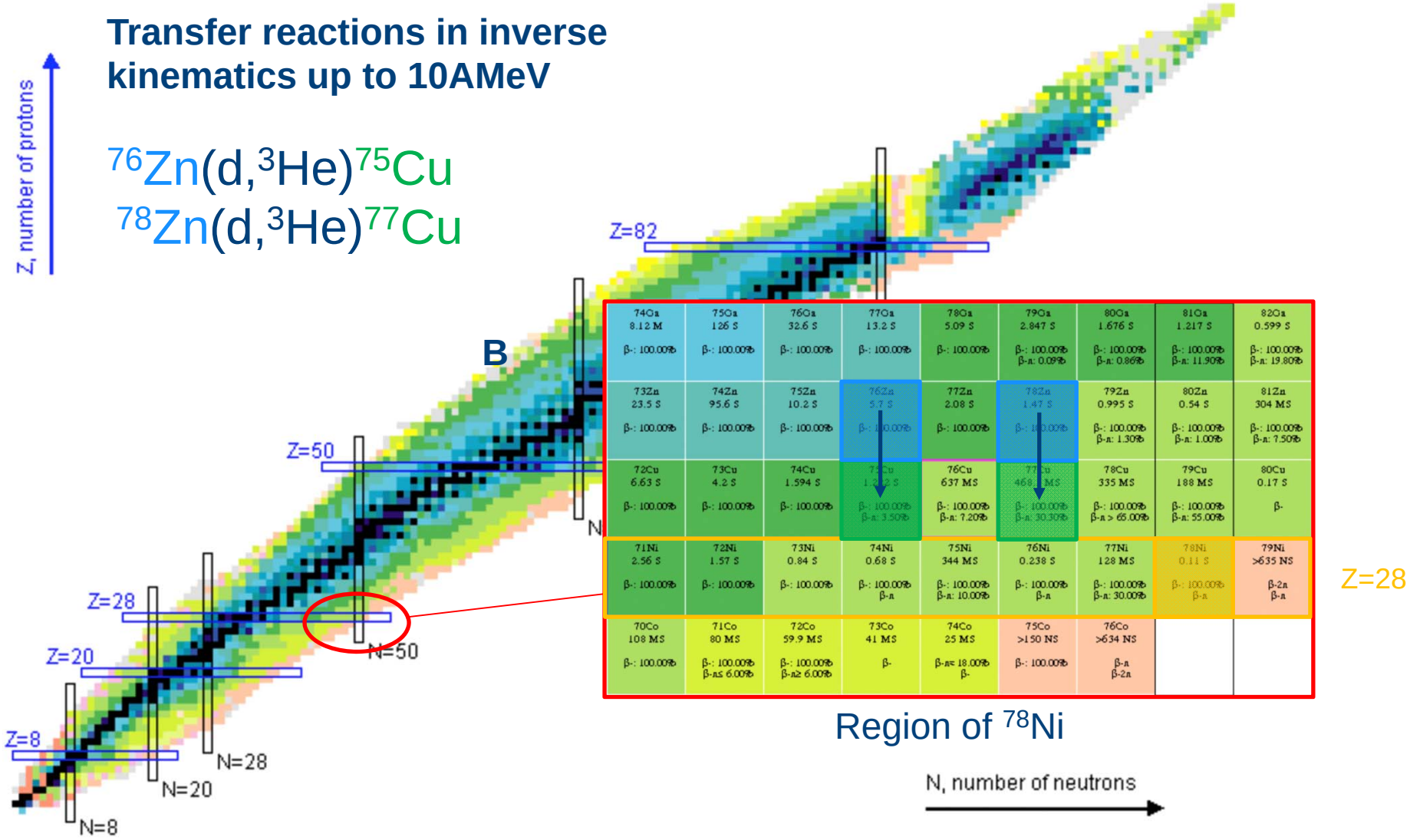
Example physic's case

Transfer reactions in inverse kinematics up to 10AMeV

$^{76}Zn(d,^{3}He)^{75}Cu$

$^{78}Zn(d,^{3}He)^{77}Cu$



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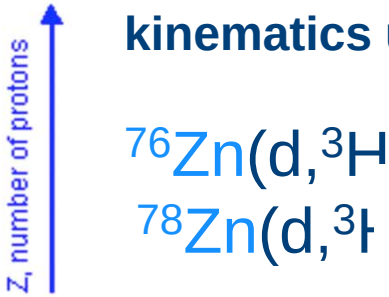
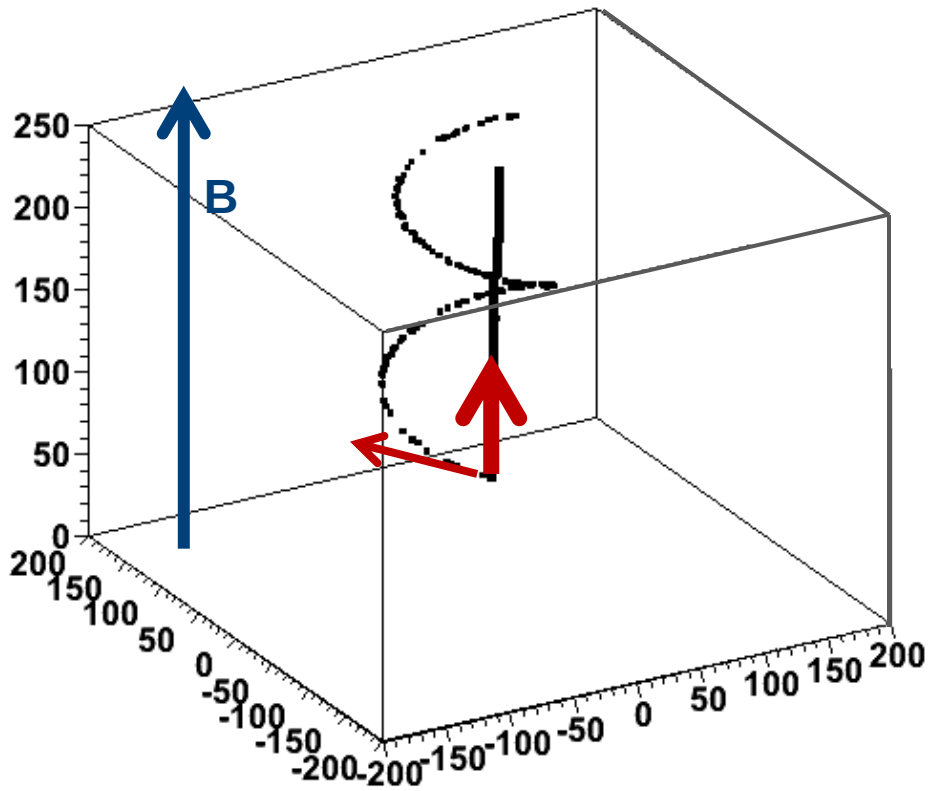
Example physic's case

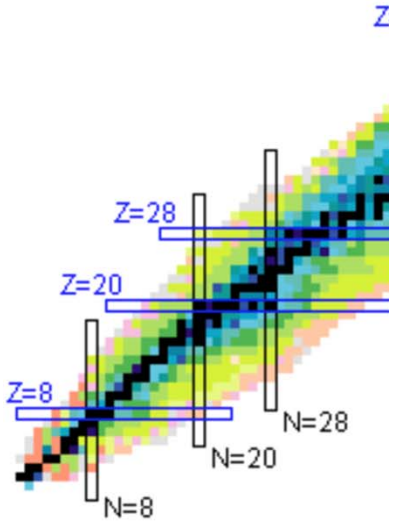
Transfer reactions in inverse kinematics up to 10AMeV

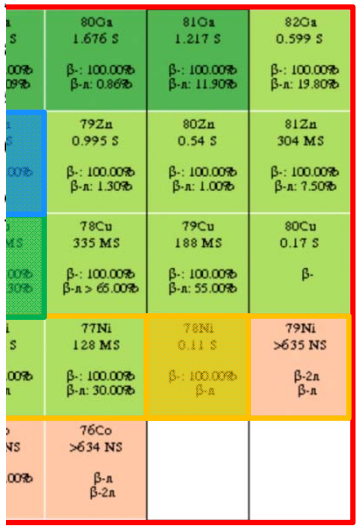
$^{76}Zn(d,^{3}He)^{75}Cu$

$^{78}Zn(d,^{3}H$









Z=28

Ni

neutrons

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SpecMAT - Implementation

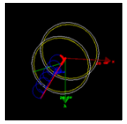
ACTIVE Target:

1. **Optimize detector design: chamber radius vs gamma-ray detection efficiency**
2. **Develop TRACKING software**
3. **Mechanical design**

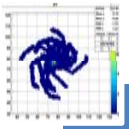
Scintillation detector array:

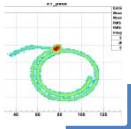
1. **Optimize geometry: efficiency**
2. **Doppler correction resolution**
3. **Test detectors and electronics in high magnetic field**

Ongoing work: gas chamber simulation



ACTARSim

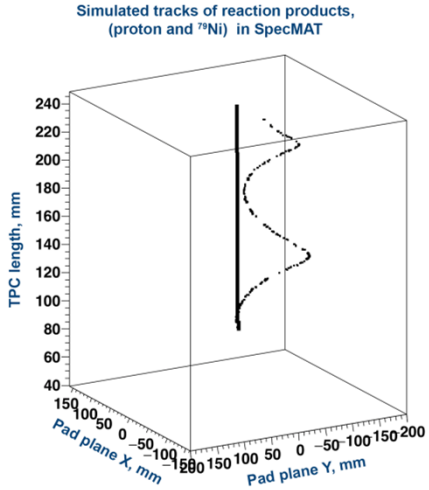


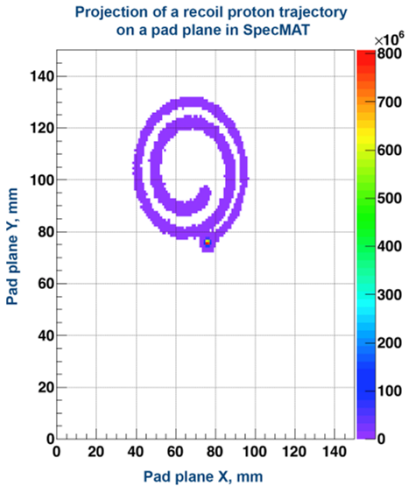


GEANT 4 simulation
- geometry
- physics
- Energy loss

Digitization macro
- El field
- Electron transport
- Electron amplification
- Electron collection

Analysis
- **TRACK reconstruction**
- Vertex identification
- Track finding
- Track fitting





Constraints	
B_{max}	4 T
Min pad size	~ 2 mm
Internal solenoid radius	~ 46 cm
fit up to 2”x2” scint + SiPM + electronics	
Gas pressure	1 – 2 atm

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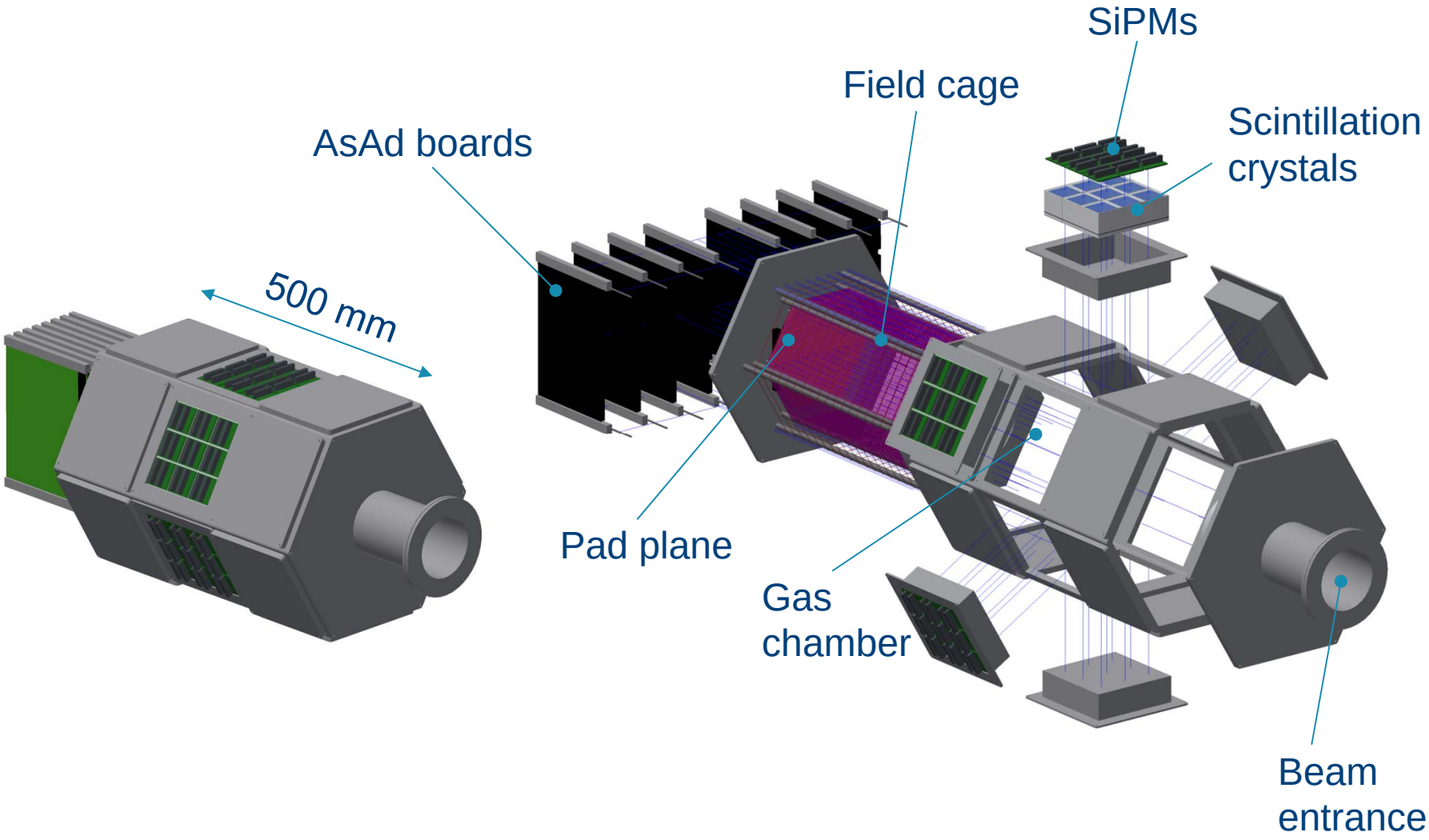
Preliminary Design study

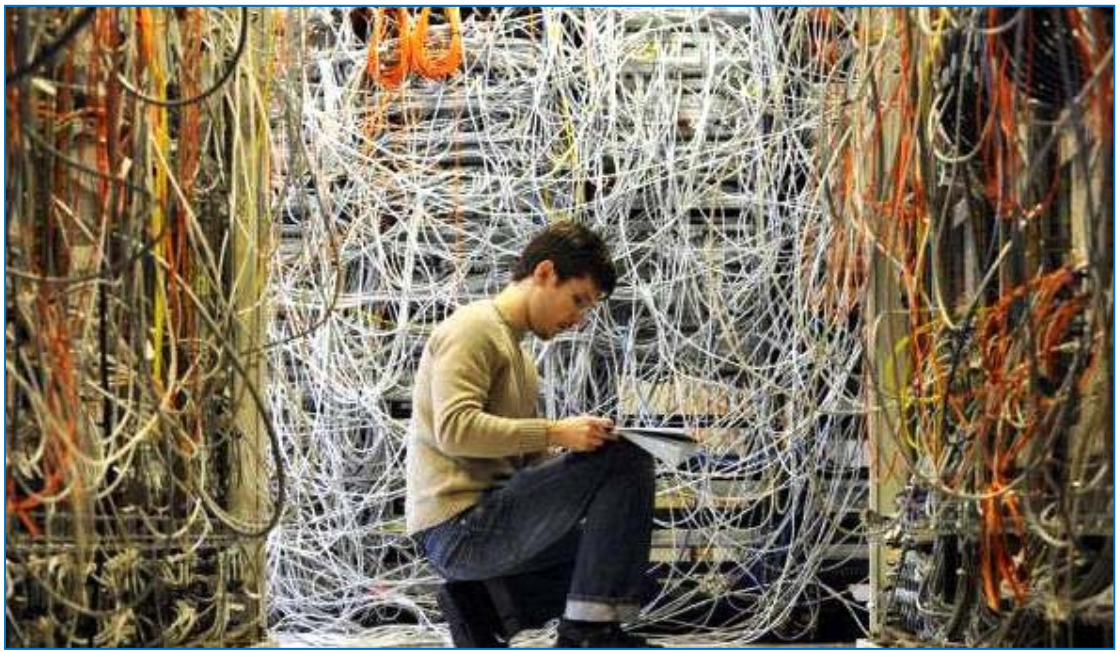


Courtesy of O. Poleshchuk

Readout electronics High channel numbers

ACTIVE TARGET and GET electronics:

- 2048 - ACTAR TPC Demonstrator, based at GANIL, Caen
- 10 024 – AT TPC Detector at NSCL, Michigan
- 16 284 – ACTAR TPC Detector



Point-to-point connections could lead to unpleasantness...

SpecMAT - Implementation

ACTIVE Target:

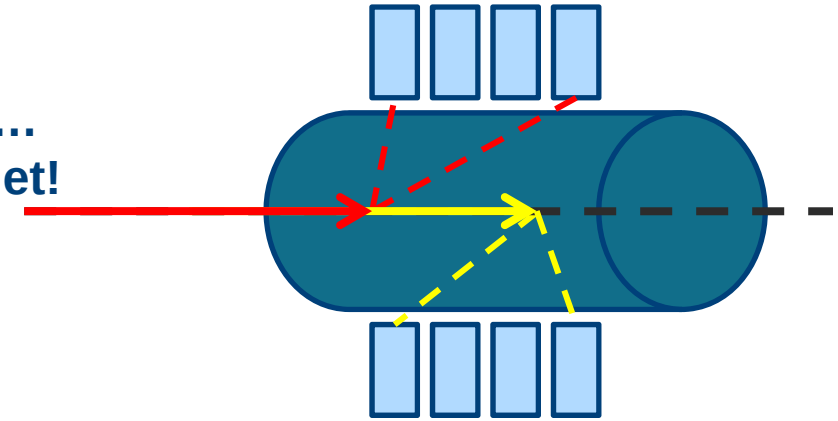
1. **Optimize detector design: chamber radius vs gamma-ray detection efficiency**
2. **Develop TRACKING software**
3. **Mechanical design**

Scintillation detector array:

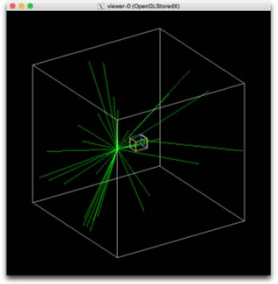
1. **Optimize geometry: efficiency**
2. **Doppler correction resolution**
3. **Test detectors and electronics in high magnetic field**

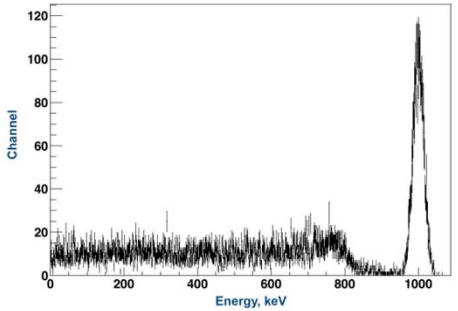
Requirements:
Resolution ~3% @ 662 keV → $LaBr_3$, $CeBr_3$, …
Maintain high efficiency … it's an active target!
Magnetic field: use of SiPM

Caveat: Interaction point is not fixed!

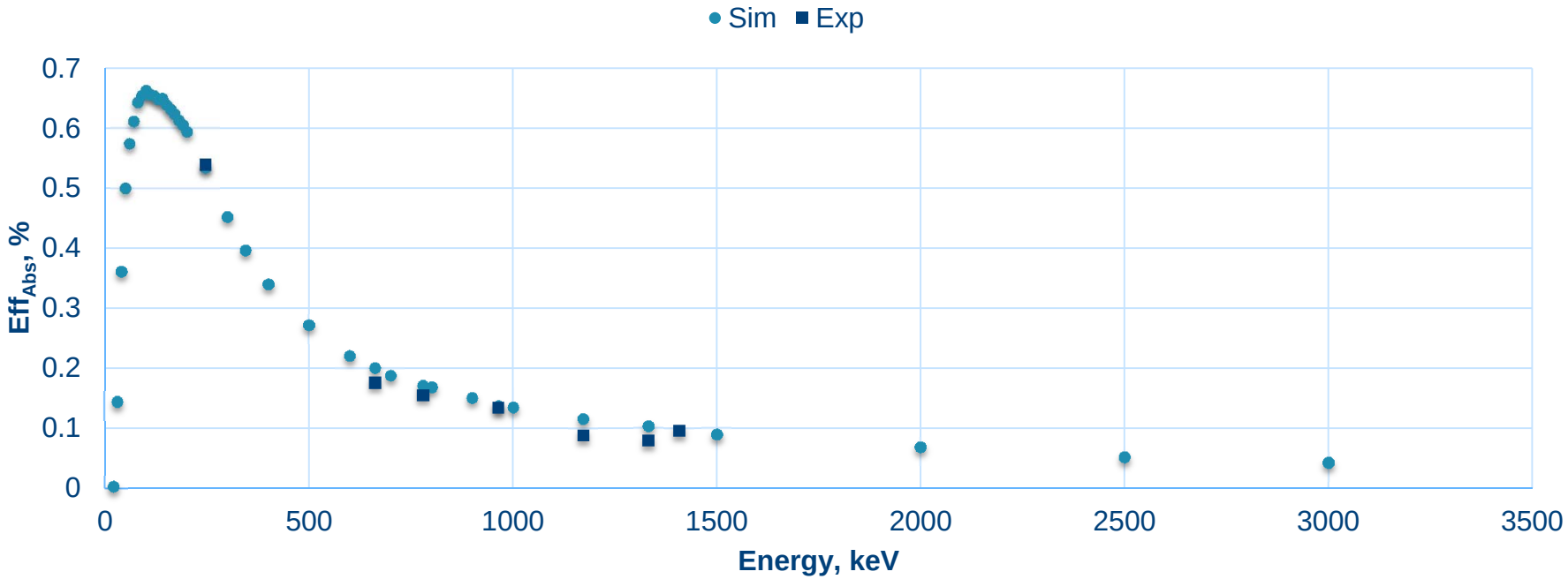


Simulations of scintillator array in GEANT4





1-Comparison of simulated and experimentally measured efficiency for one 1,5”x1,5”x1,5” $CeBr_3$ crystal at 120 mm



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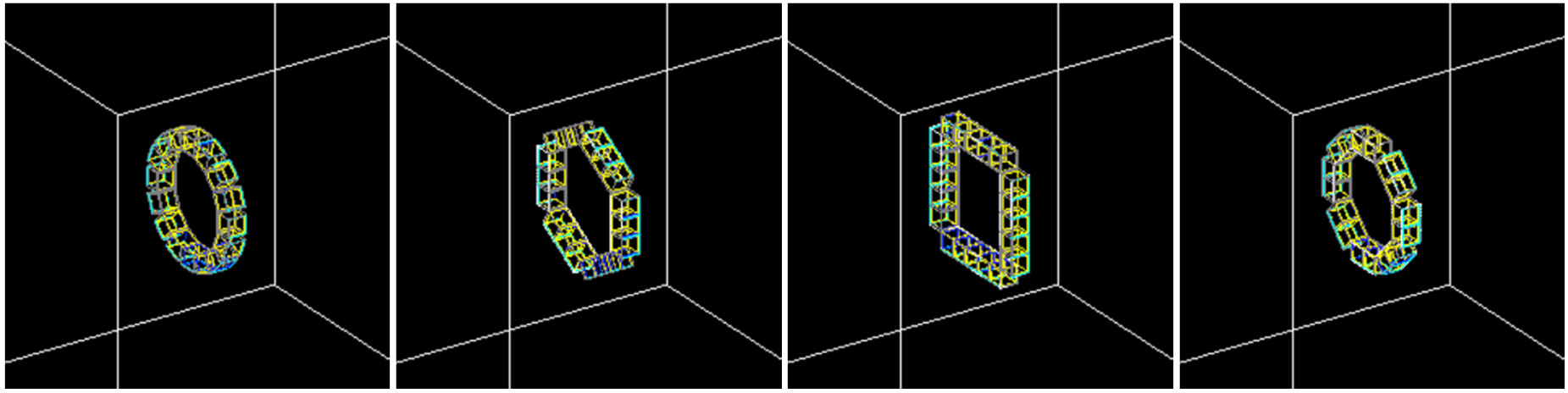
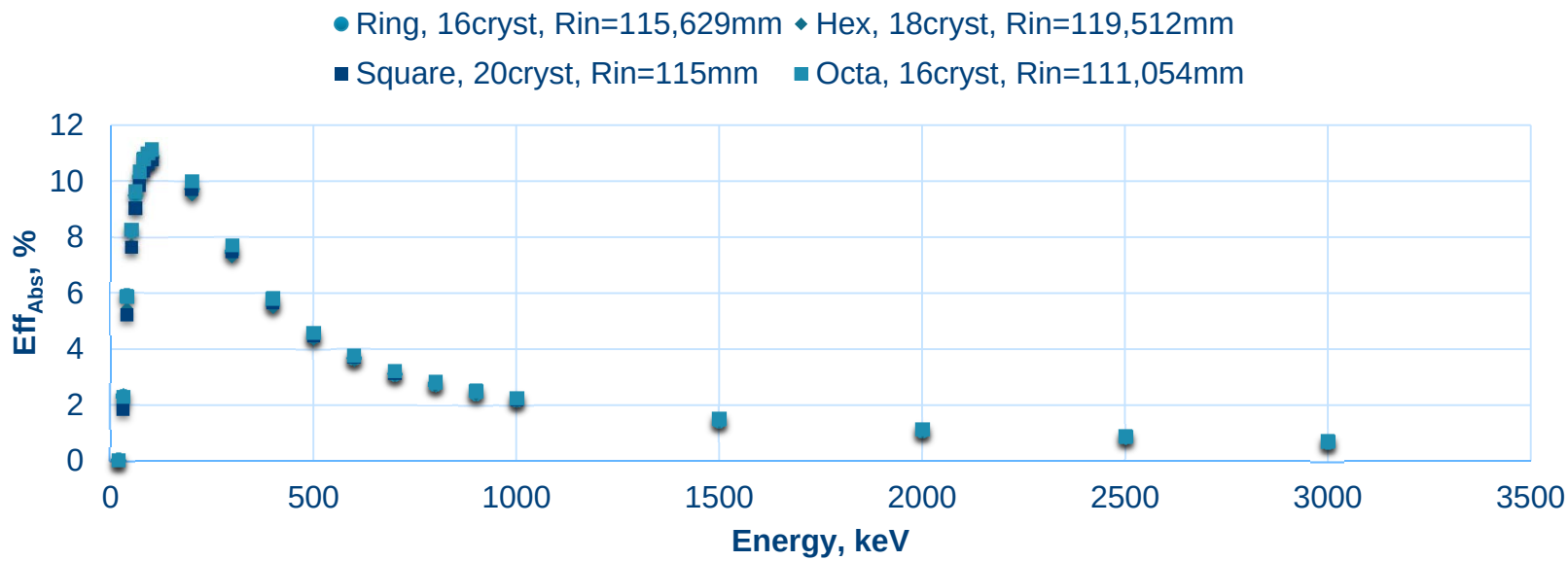
Simulation by O. Poleshchuk



Comparison of Eff_{Abs} for different array shapes of 1,5”x1,5”x1,5” $CeBr_3$ crystals



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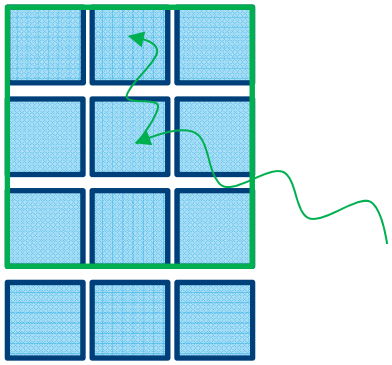
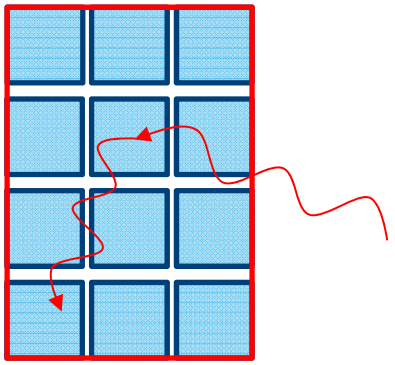
Simulation by O. Poleshchuk

Realistic scale

also considering AddBack

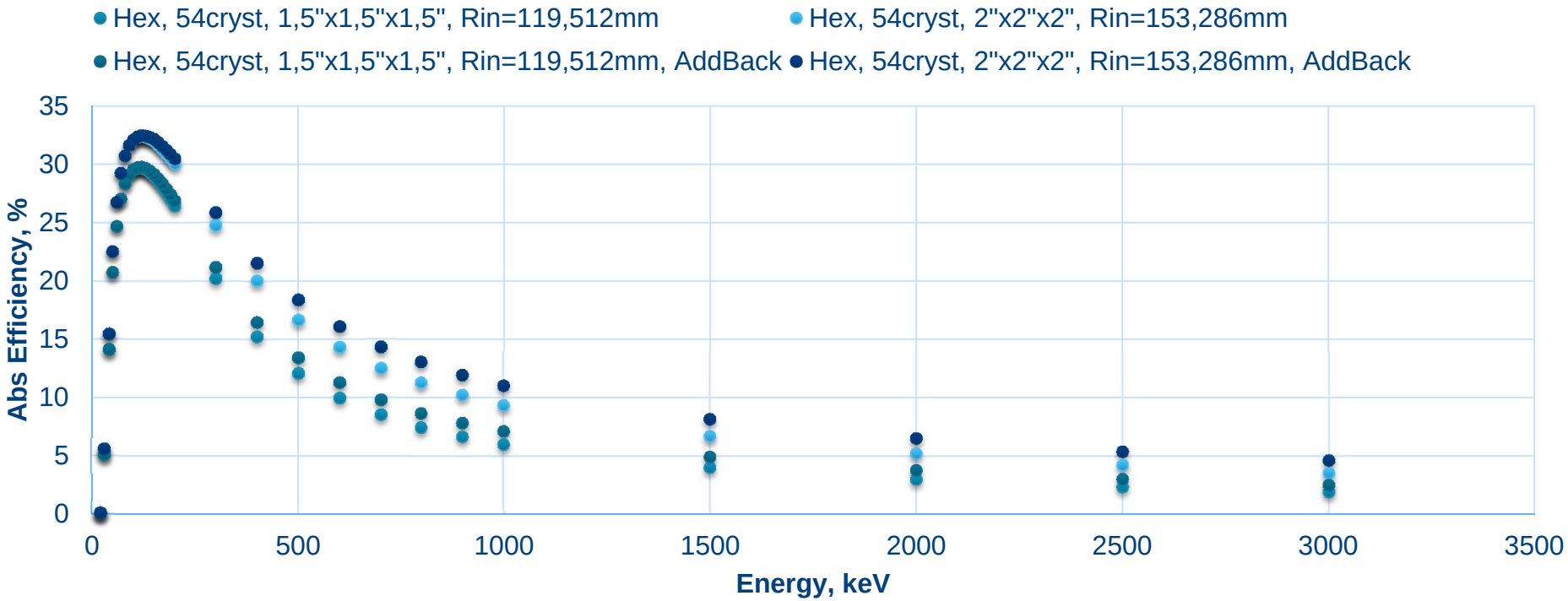


$E_{AddBack} = E_1 + E_2$



E_1, E_2

Total efficiency for $CeBr_3$ detector array (with and without AddBack)



Next step: merge Scintillation Detector's simulation and ActarSim

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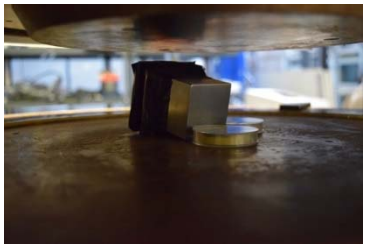
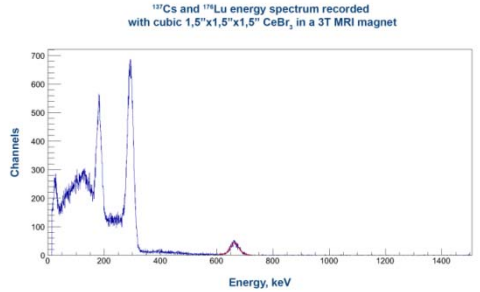
Simulation by O. Poleshchuk

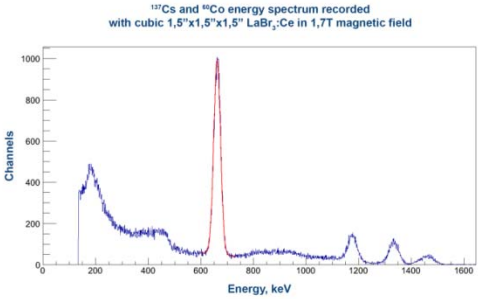
Resolution in 1.7 T and 3.0 T magnetic fields



Comparison of detectors resolution

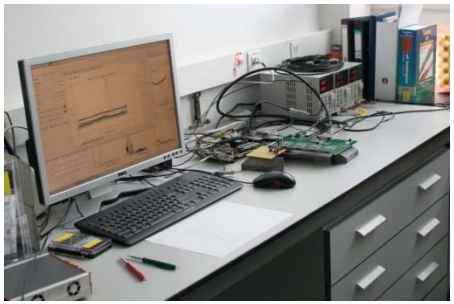
	Magnetic Field, T	Electronics	Resolution at 662 keV, %
$LaBr_3$:Ce + SiPMs	0	Analog	4,47±0,05
$LaBr_3$:Ce + SiPMs	1,7	Analog	4,58±0,03
$LaBr_3$:Ce + SiPMs	0	GET	5,16±0,03
$LaBr_3$:Ce + SiPMs	1,7	GET	5,23±0,04
$CeBr_3$ + SiPMs	0	Analog	5,67±0,02
$CeBr_3$ + SiPMs	3	Analog	5,31±0,11*
$CeBr_3$ + SiPMs	0	GET	5,86±0,02



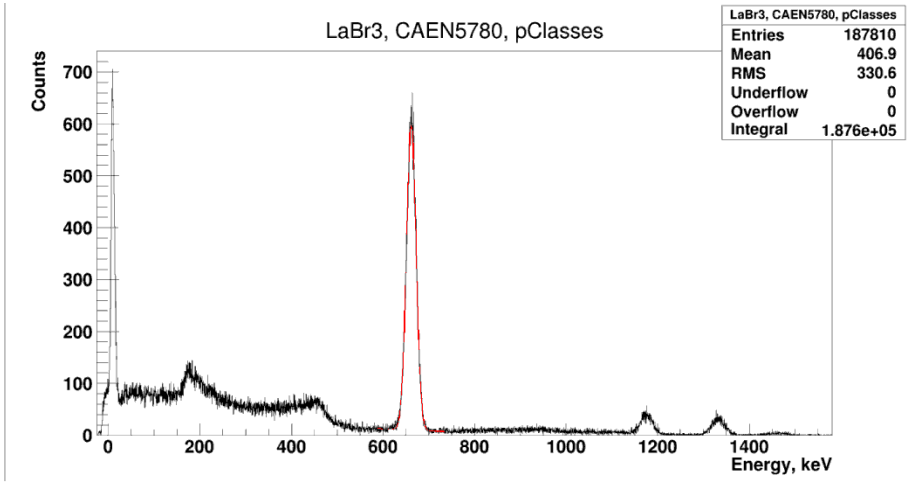


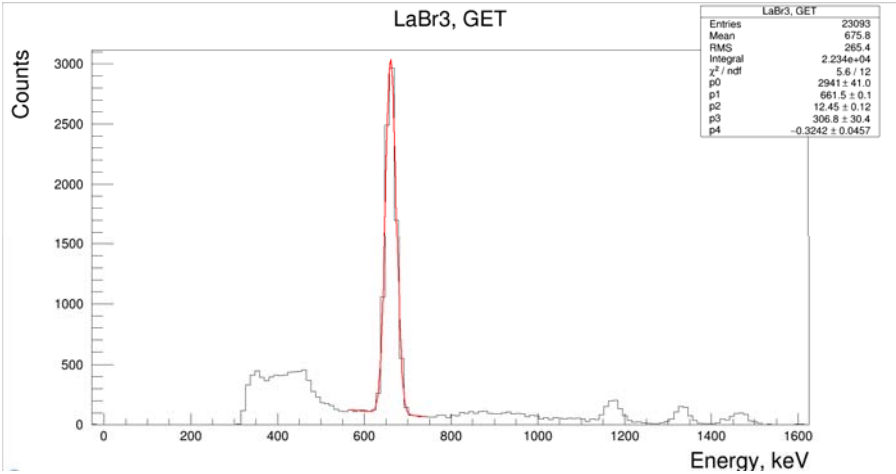
*preliminary result

Latest results at IKS



- ✓ **Improved SiPM-crystal optical coupling**
- ✓ **Installed reduced GET system**





CAEN DT5780
and custom analysis software.
Resolution: 3.7% at 662 keV

With GET
Using shaper: 4.1% at 662 keV
No shaper: 4.4% at 662 keV

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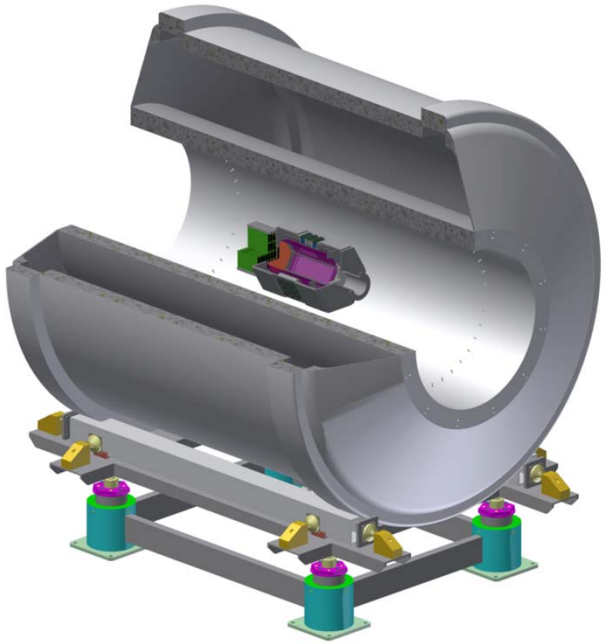
Summary and outlook

- ✓ SpecMAT is an ACTIVE target for transfer reactions in inverse kinematics surrounded by gamma-ray scintillators.
- ✓ Test of the scintillation detectors up to 3T magnetic field show promising results.



Work in progress:

- o Optimization of the reaction chamber design
- o Simulation od the gamma-ray detectors array
- o Definition of the electronics setup

Collaboration

IKS, KU Leuven:

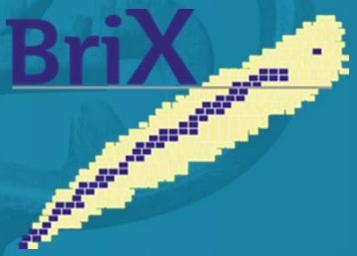
R. Raabe
O. Poleshchuk
S. Ceruti
F. Renzi
T. Marchi
H. De Witte

J.A. Swartz

GANIL:

G. F. Grinyer
A. Laffoley

and the ACTAR TPC and GET collaborations



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