Transfer reaction studies at HIE-ISOLDE

Freddy Flavigny

Outline

1. General context of transfer studies @ (HIE)-ISOLDE
2. MINIBALL + TREX: Performances and Highlights
3. Perspectives

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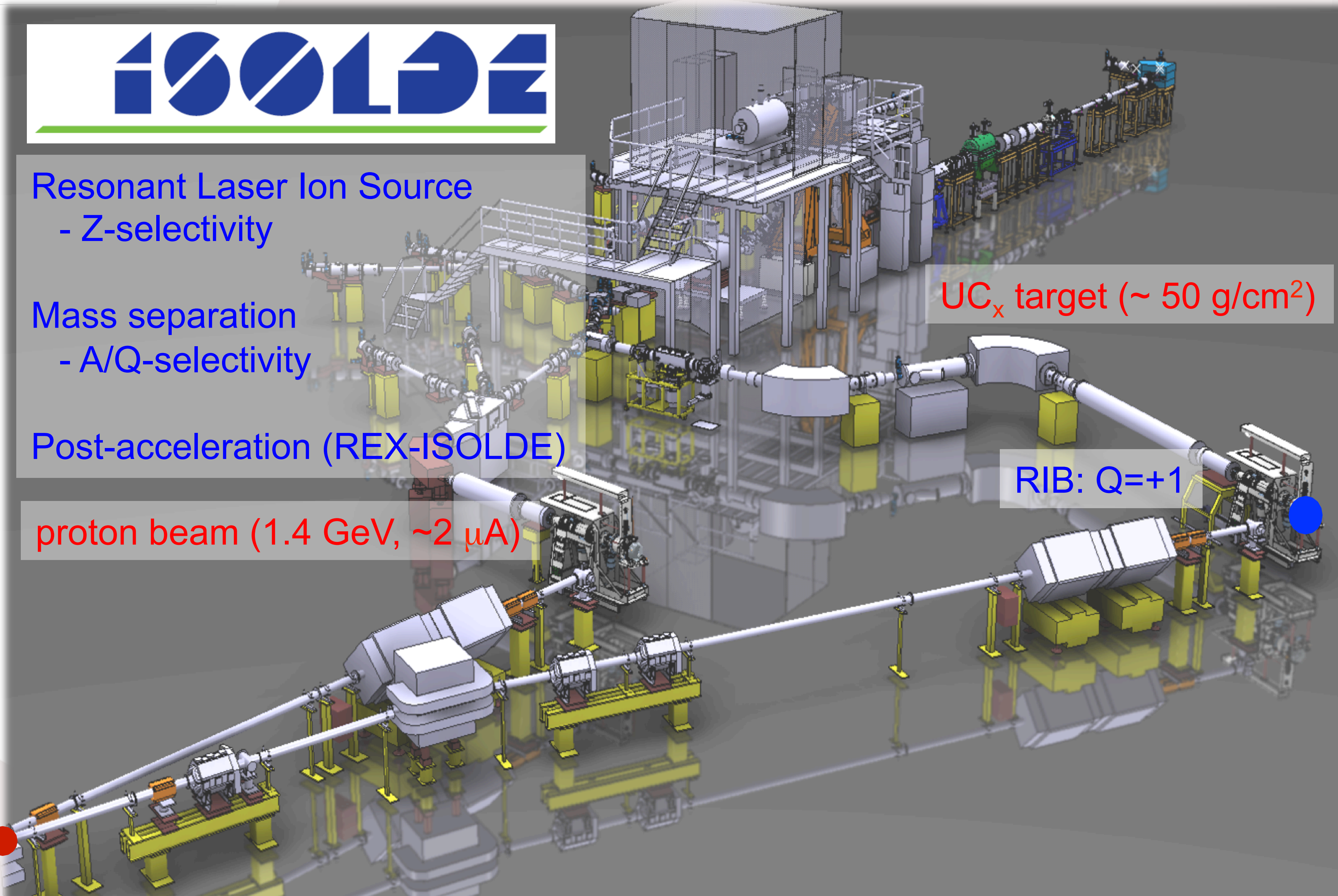
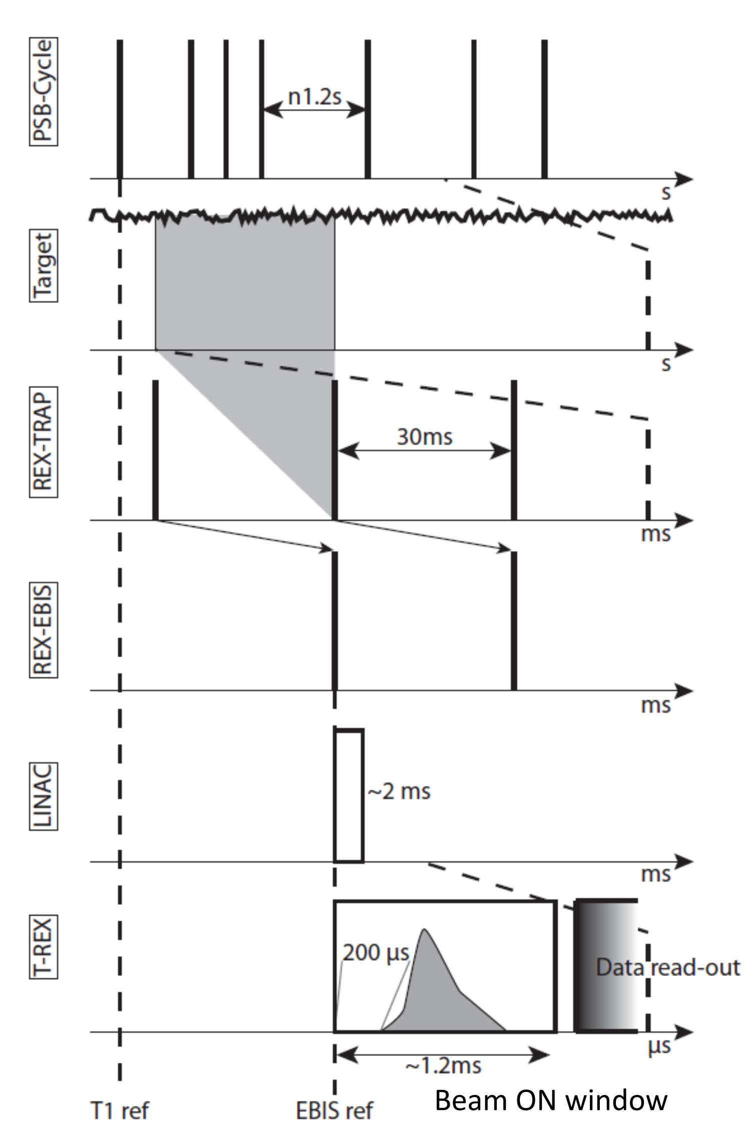
Introduction: ISOLDE

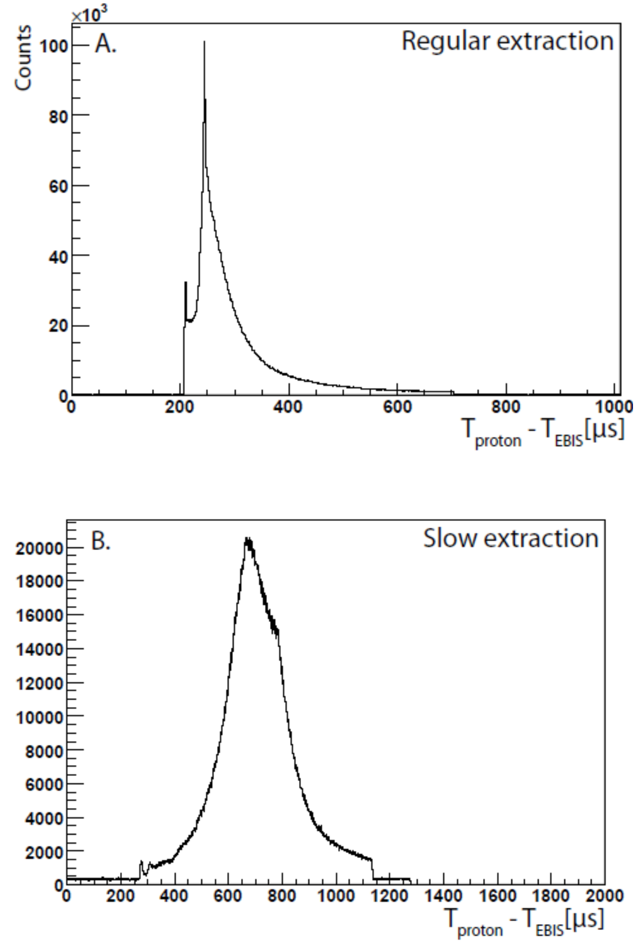


Time structure (ex: ^{66}Ni beam)



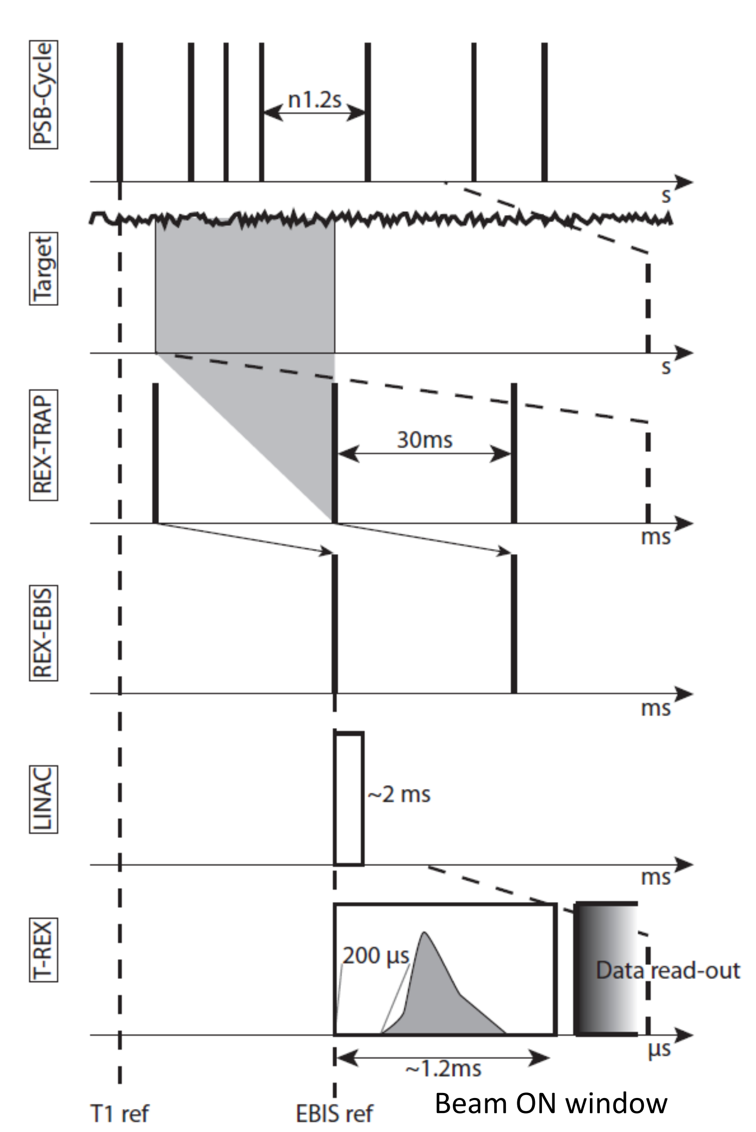
Trigger ACQ

REX EBIS release profile



Rate of detected particle at secondary target with respect to EBIS release time

Time structure (ex: ^{66}Ni beam)



Trigger ACQ

Example for ^{66}Ni beam:

BeamON width = 1.2 ms
REXEBIS-cycle = 33 Hz (Max 50Hz)

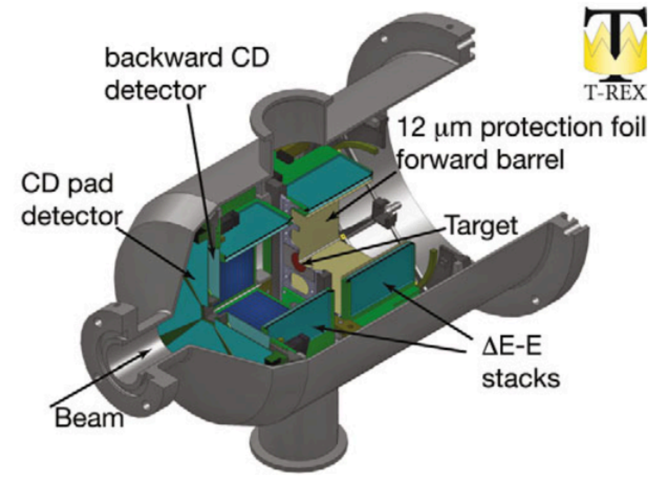
=>39.6 ms of beam /s (4%)

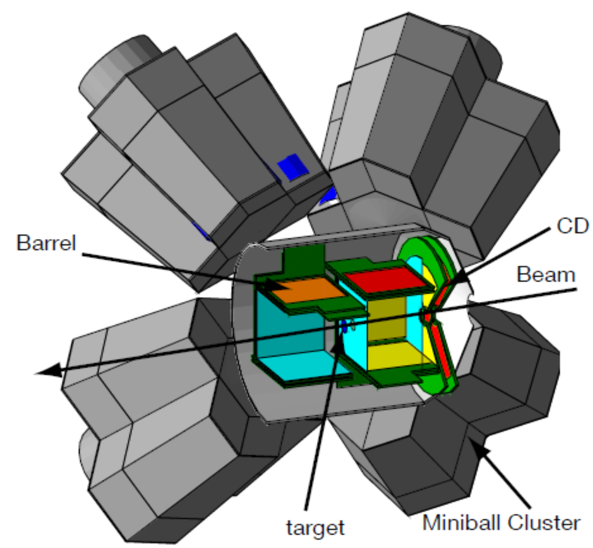
If integrated rate is 10^6 pps:

=> Instantaneous rate = $2.5*10^7$ pps

Existing Setups and Ongoing Projects

1. **TREX (+ MINIBALL)**
2. ACTAR-TPC
3. HELIOS
4. SPECMAT





V. Bildstein, EPJA ***48****, 85 (2012)*

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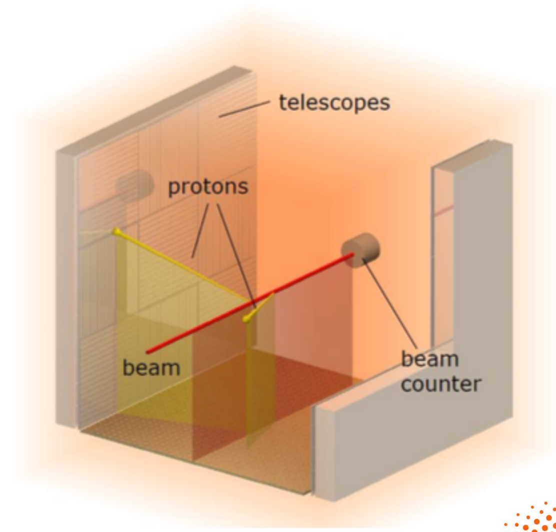
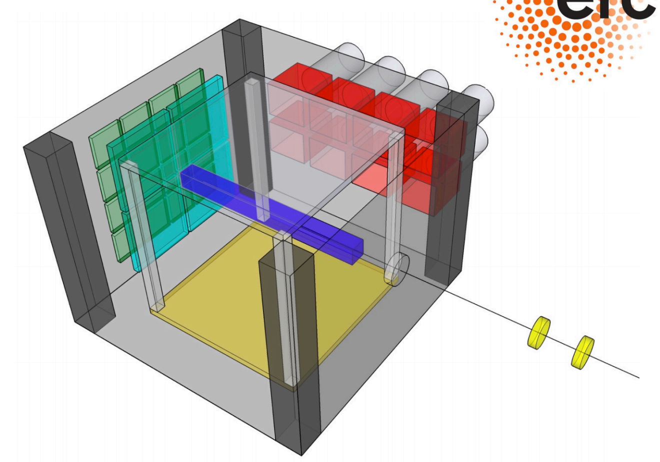
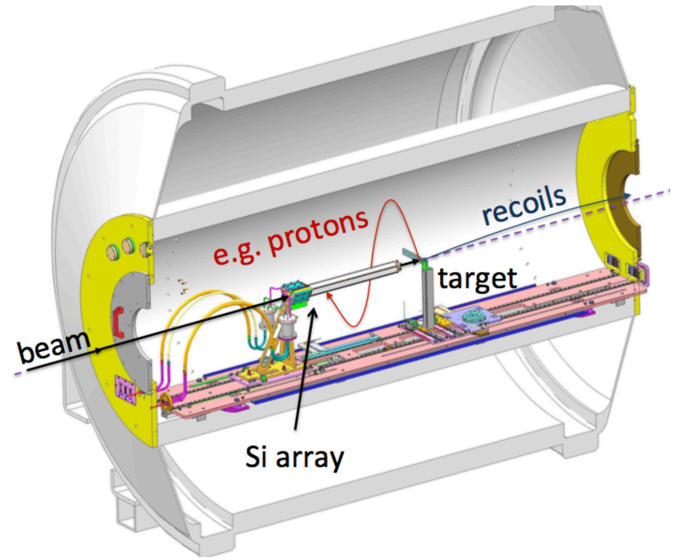


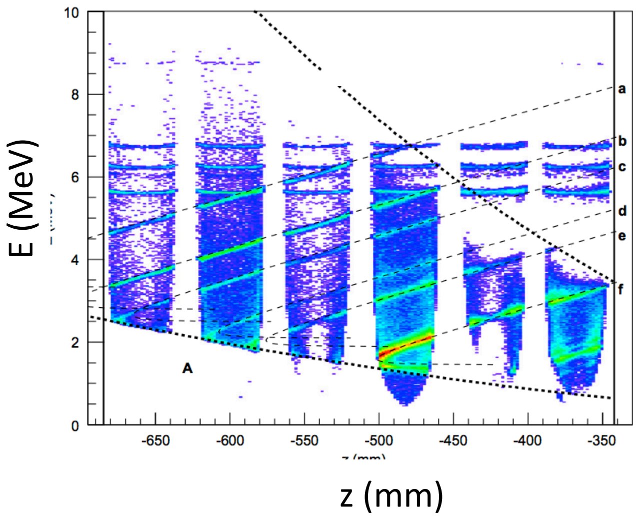


ERC grant, G. Grinyer (GANIL)

Existing Setups and Ongoing Projects

1. TREX (+ MINIBALL)
2. ACTAR-TPC
3. **HELIOS-like**
   (ISS coll., R. Page (U. Liverpool))
4. SPECMAT





J. C. Lightall, NIM A 622, 97 (2010)

Existing Setups and Ongoing Projects

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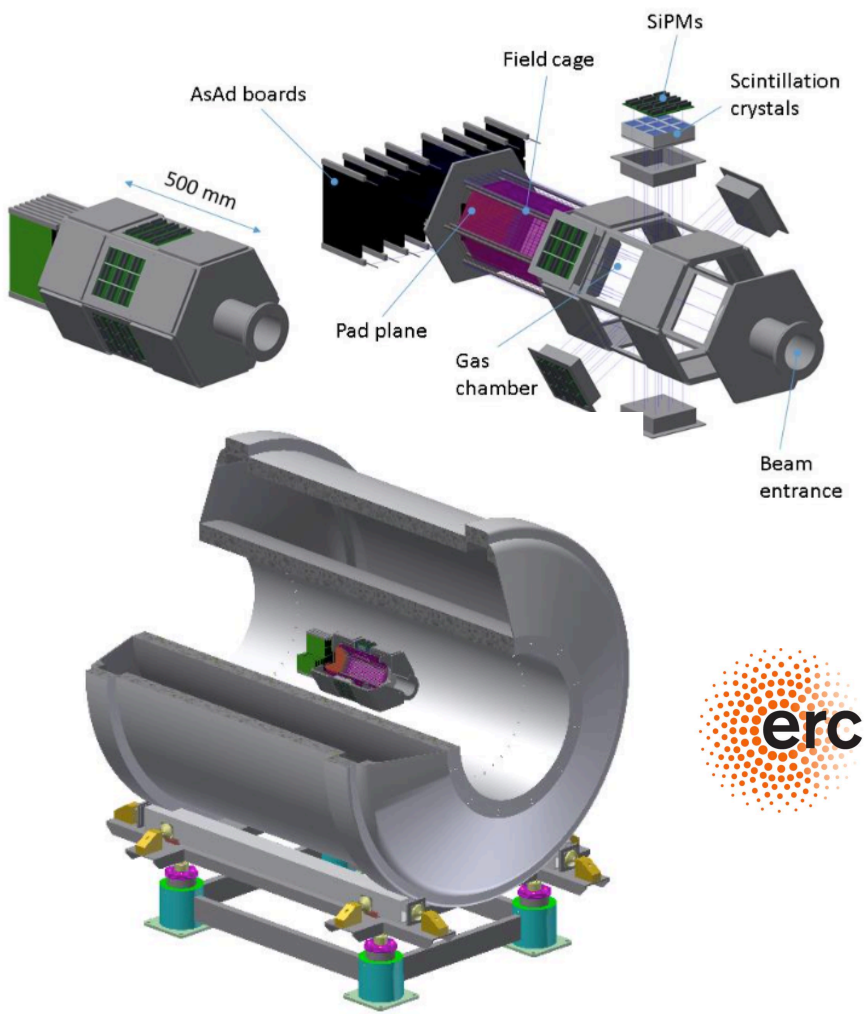
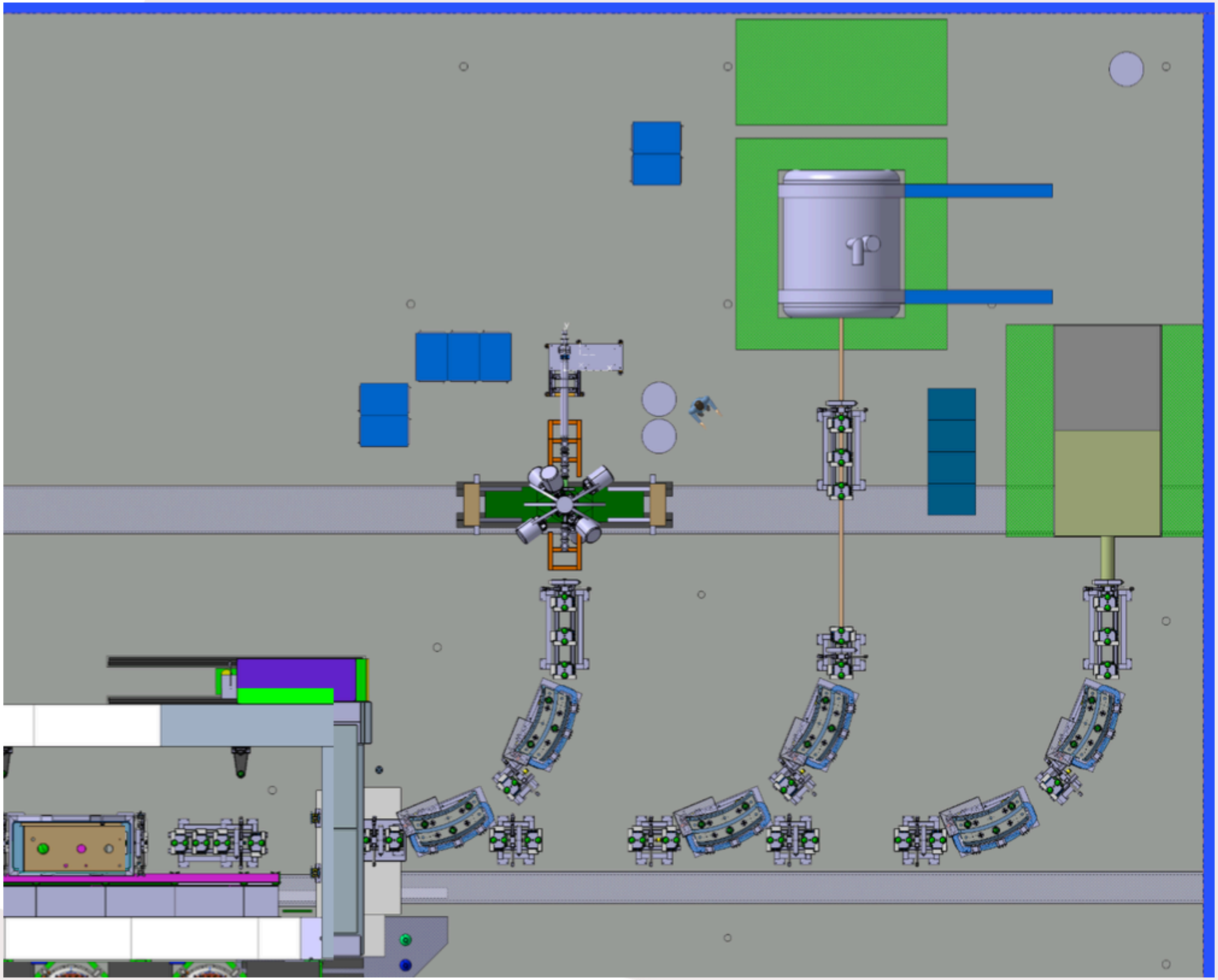


ERC grant, R. Raabe (KU Leuven)

Layout of the Hall: 3 experimental lines



Completed transfer experiments (TREX)

Period: 2007-2012

Reaction	Analyzer
$^{30}Mg(d,p)$	V. Bildstein
$^{66}Ni(d,p)$	J. Diriken
$^{66}Ni(t,p)$	J. Eleseviers
$^{30}Mg(t,p)$	K. Wimmer
$^{44}Ar(t,p)$	K. Nowak
$^{78}Zn(d,p)$	R. Orlandi
$^{72}Zn(t,p)$	S. Hellgartner
$^{11}Be(d,p)$	J. Joanssen
$^{8}Li(d,p)$	O. Tengborn
$^{98}Rb(^{7}Li,t)$	S. Bottoni

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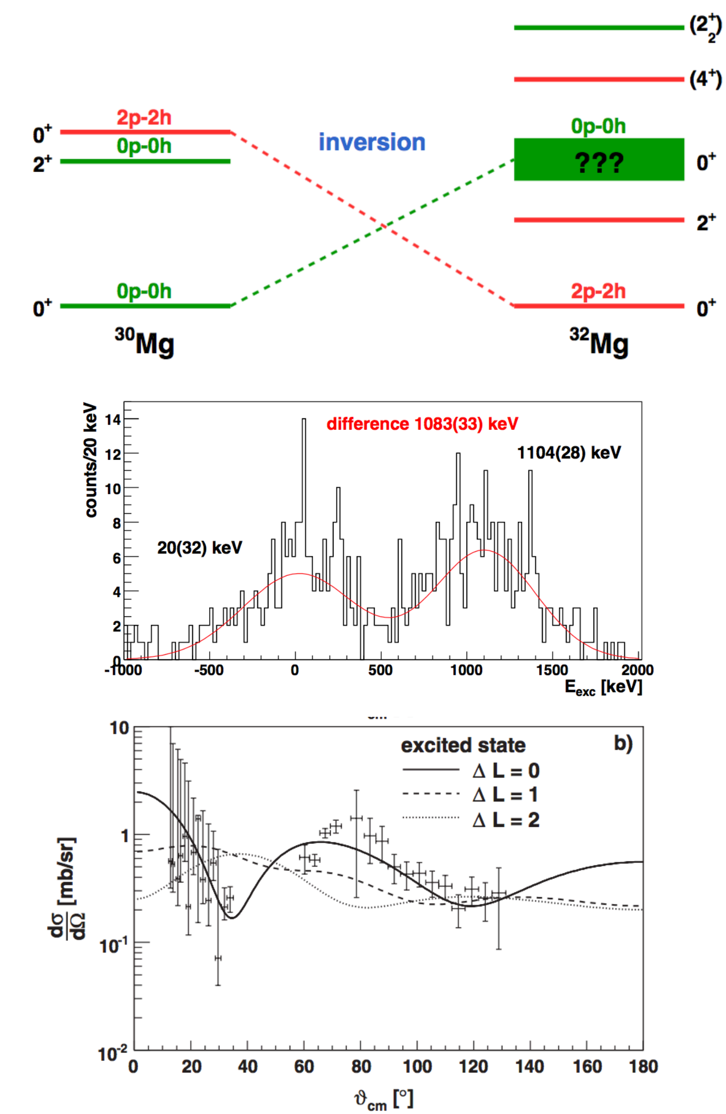
K. Wimmer, PRL ***105****, 252501 (2010)*



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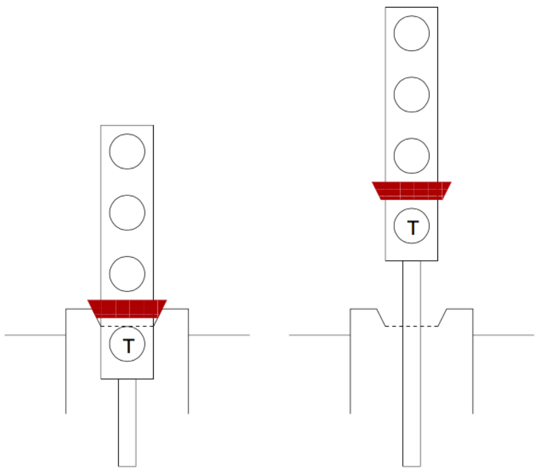
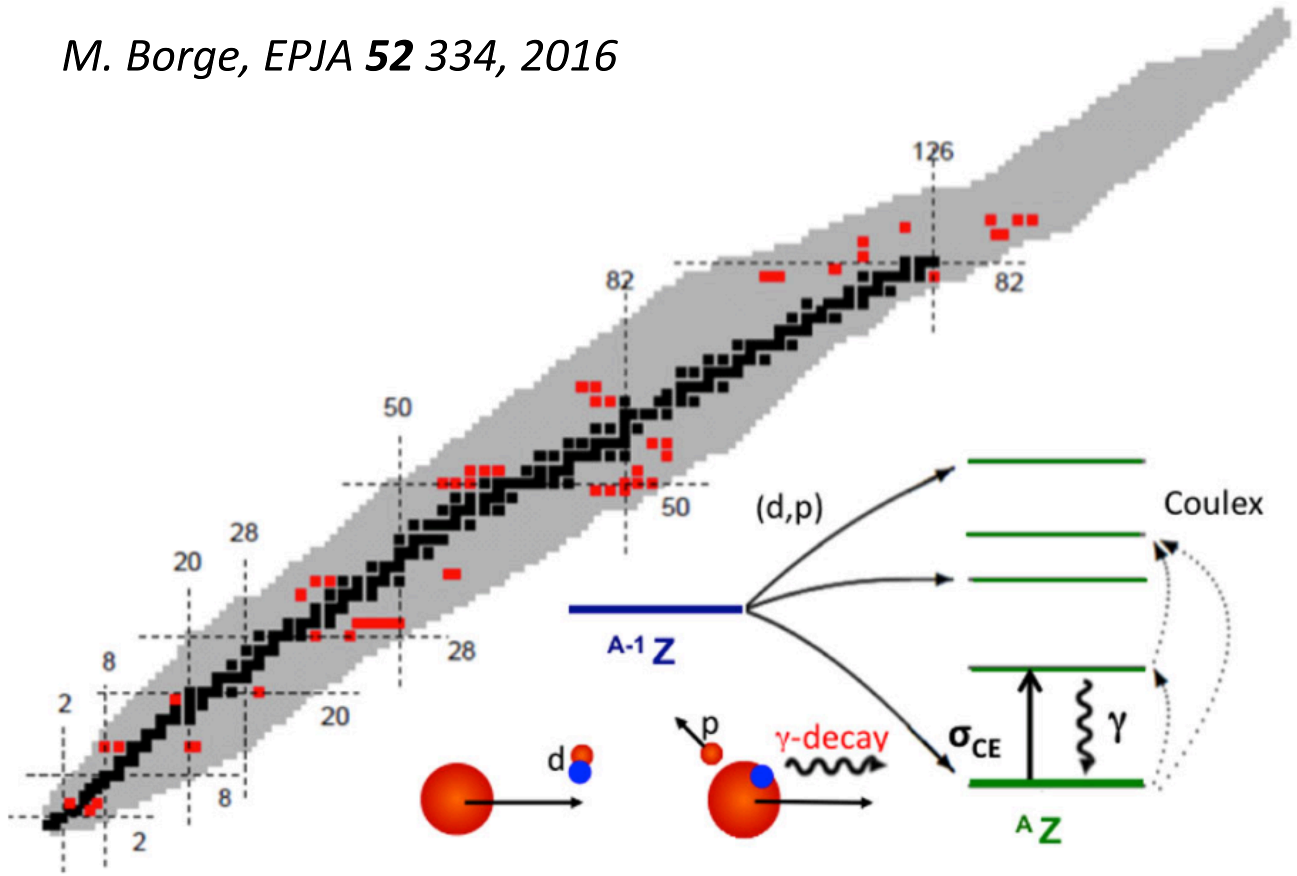
*K. Wimmer, PRL**105**, 252501 (2010)*

Target:
- ^{3}H loaded Ti foil: 10 GBq
- Tot. Thick: 500 μg/cm2
- Ratio 3H/Ti: 1/3
- Eff. Thick: 40 μg/cm2



HIE-ISOLDE: Future Transfer and Coulex experiments

*M. Borge, EPJA **52** 334, 2016*



http://isolde.web.cern.ch/active-experiments.

Accepted experiments (31) + LOIs

Accepted for 4-5.5 MeV/u:

Reaction	SpokePersons	I(pps)	Contaminant
$^{17}N(d,p)$	A. Matta, W .Catford	$1*10^4$	
$^{68}Ni(d,p)$	L. Gaffney, F. Flavigny	$2*10^5$	^{68}Ga
$^{9}Li(t,p)^{11}Li$	K. Riisager, D. Mucher	$1*10^6$	
$^{80}Zn(d,p)$	R. Orlandi, R. Raabe	$2\text{-}8*10^3$	^{80}Ga
$^{70}Ni(d,p)$	J. Valiente Dobon	$1*10^4$	^{70}Ga
$^{7}Be(d,p)$	D. Gupta	$1*10^7$	
$^{20}Mg+p\text{->}^{21}Al$	B. Fernandez	50	^{20}Na
$^{11}Be(t,p)$	J.G. Johansen	$5*10^6$	
$^{132}Sn(^{7}Li,t)$	S. Leoni, B. Fornal	$8*10^5$	

+ about 15 Coulomb Excitation experiments

Letters of Intent (2010)

Reaction	SpokePersons
^{100}Sn region	J. Cederkall
^{184}Hg region	P. Van Duppen
^{132}Sn region	Th. Kroll
$^{50-52}Ca$ region	S. Freeman
GASPARD	W. Catford, D. Beaumel

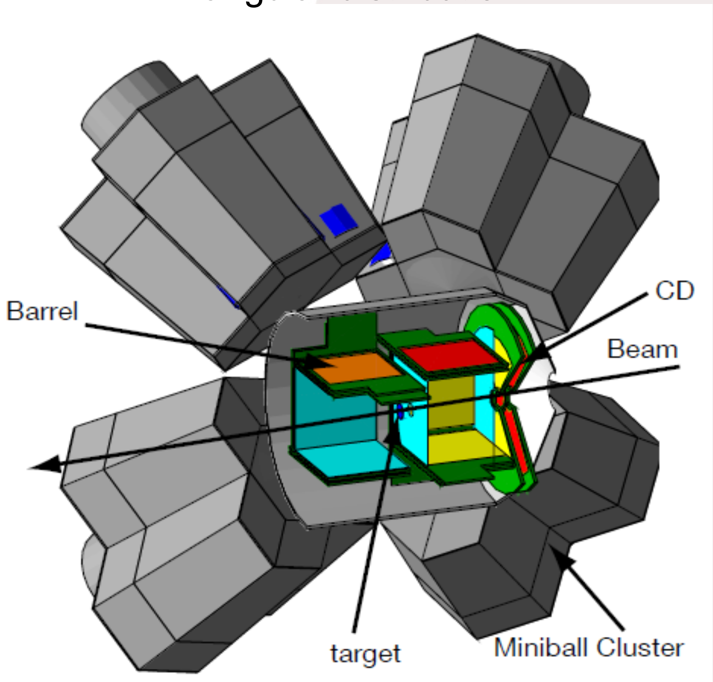
1. General context of transfer studies @ (HIE)-ISOLDE

2. **MINIBALL + TREX: Performances and Highlights**

3. Perspectives

Setup for Transfer: TREX + Miniball

- T-REX:
  - identification
  - energy
  - angular distribution

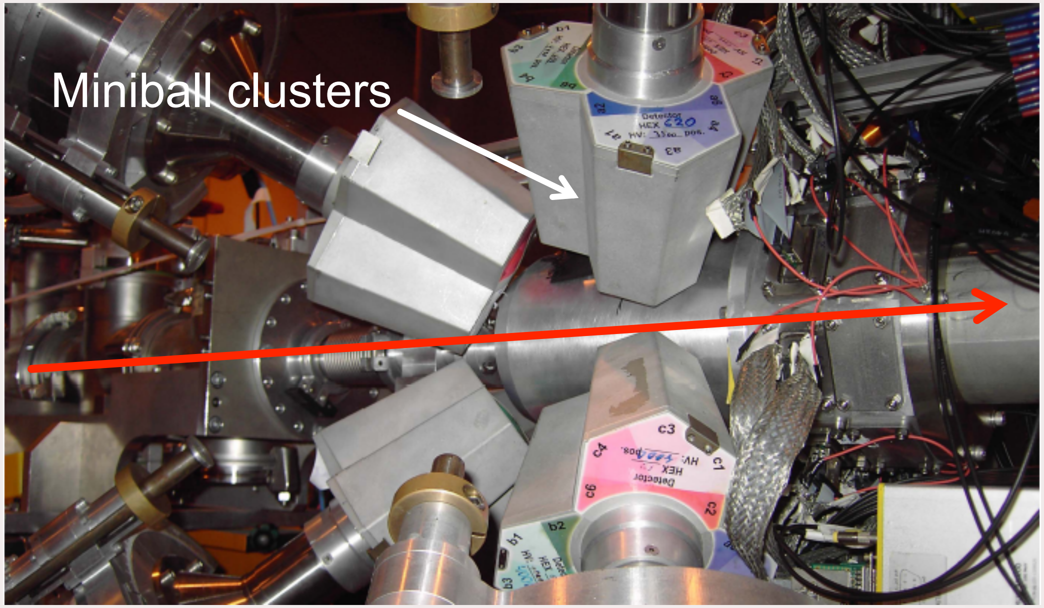


- 8 ΔE-E_{rest} barrel detectors (140/1000 um)
- 2 ΔE-E_{rest} CD detectors (140/500 and 500,1500 um)
- Covered θ_{lab} range:

  28° to 78° and 102 to 152° (Barrel)

  and 152 to 172° (Bw CD)

- gamma detection in Miniball:
  - energy
  - angular distribution (Doppler correction)



- 8 Miniball triple (HPGe) clusters
- Each crystal: 6-fold segmented

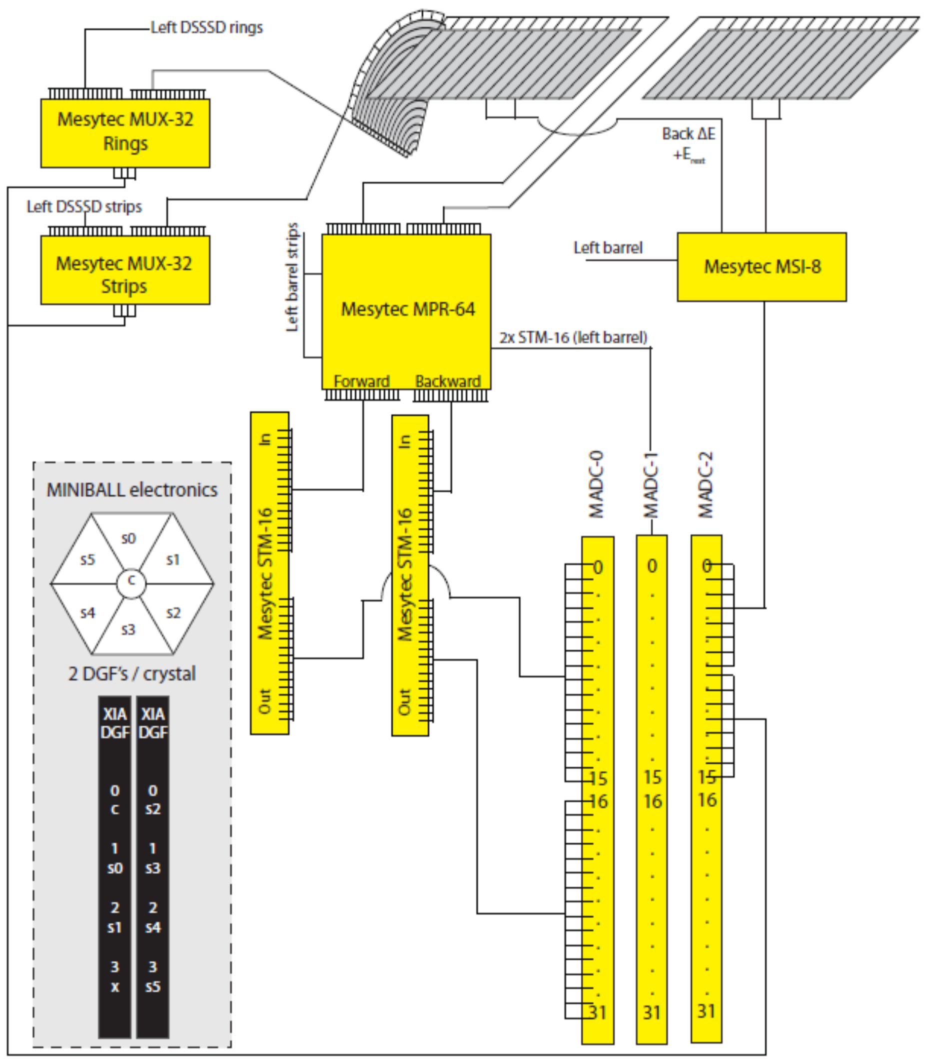
- Reaction chamber:

  Diameter: 140 mm

  Thickness:2mm Al

Miniball: Warr EPJ49 (2013)   T-REX: Bildstein EPJ48 (2012)

Electronics



MiniBall: Digital electronic (DGFs)

- DGF: Digital Gamma finder (CAMAC stdrd)
  - Amplifier (gain+offset)
  - 2 DGFs per crystal – 48 DGFs -168 ch.
- ADC : 40 MHz – 16 bit sampling
- Timestamp + Buffer until read out

TREX: Analog electronic (Mesytec)

- CD signals multiplexed (MUX32)
  - From 32 to 4= 2*(Energy+Position) signals
  - 2 events over thresh. max per 30ns
- 2 Trigger groups (Top-Left, Bottom-Right)
- MADCs + buffer + read-out
- Timestamp sync. with DGF master clock

TREX: Resolutions

Angular resolution

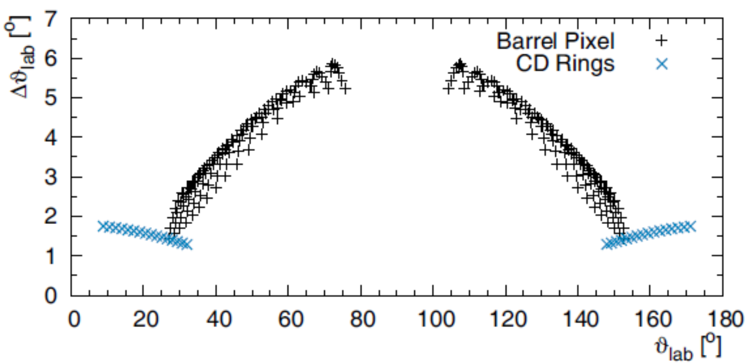
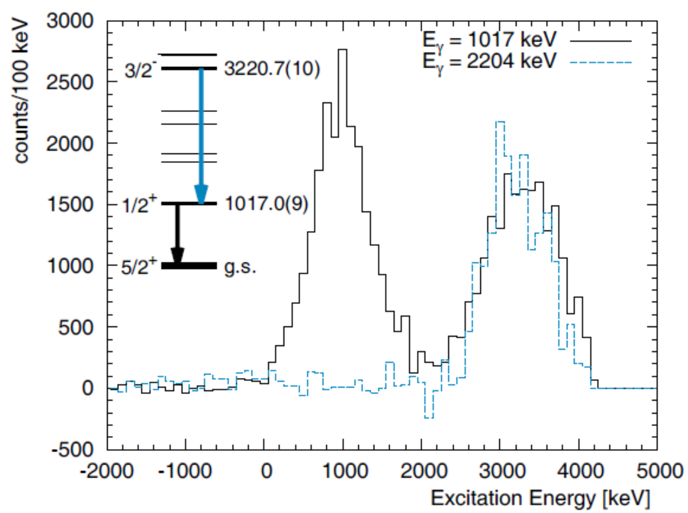


Fig. 6. Polar resolution achievable with T-REX if the strips are divided in the analysis into 16 bins along their length.

Excitation Energy



Geant4 Simulations

$^{22}Ne(d,p)^{23}Ne$ @ 2.85 MeV/u

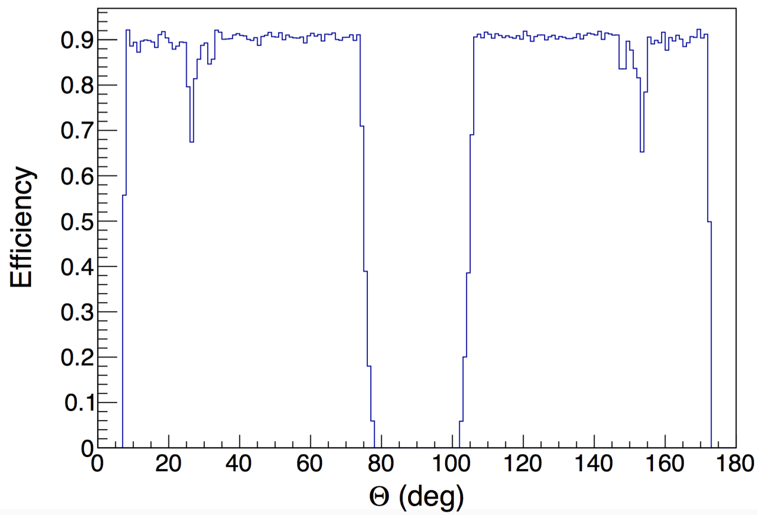
Table 2. Contributions from different features to the excitation energy resolution determined by Geant4 simulations. The contributions depend on the beam used, the values reported are for the d(^{22}Ne, p)^{23}Ne/d(^{30}Mg, p)^{31}Mg reaction, both at 2.85 MeV u^{-1}. The 12 μm thick Mylar™ foils in front of the forward barrel detectors contribute only on the order of 1 keV to the final resolution.

Feature	Amount	Excitation energy resolution (FWHM) [keV] Forward	Backward
Detector res.	100 keV	93 / 76	130 / –
Beam spot size	5 mm	120 / 81	40 / –
Target thickness	1 mg cm^{-2}	597 / 497	489 / –
	100 μg cm^{-2}	86 / 29	28 / –
ϑ_{lab} res.	2° to 6°	357 / 315	129 / –
Total res.	1 mg cm^{-2}	680 / 619	399 / –
	100 μg cm^{-2}	137 / 111	150 / –

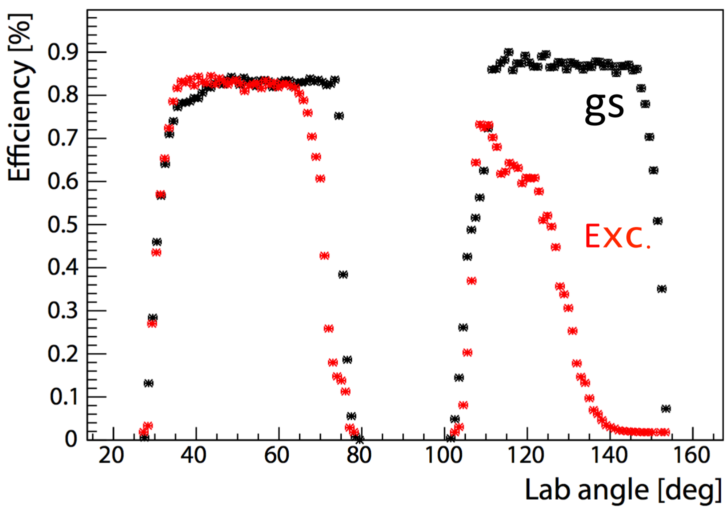
Exp(1mg.cm^{-2}) : FWHM =1 MeV

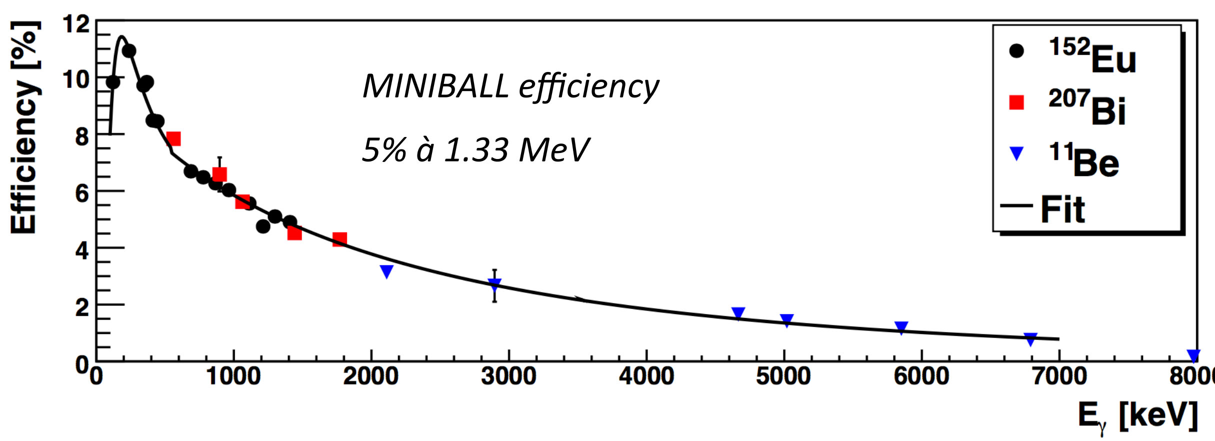
TREX+MINIBALL: Efficiencies

TREX (Full) SImple Geometrical Efficiency



TREX Barrel efficiency for $^{66}Ni(d,p)^{67}Ni$



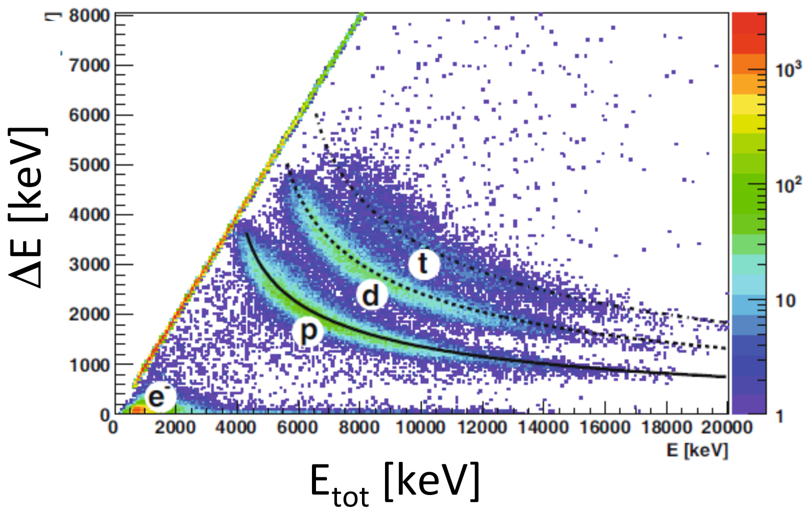


MINIBALL efficiency

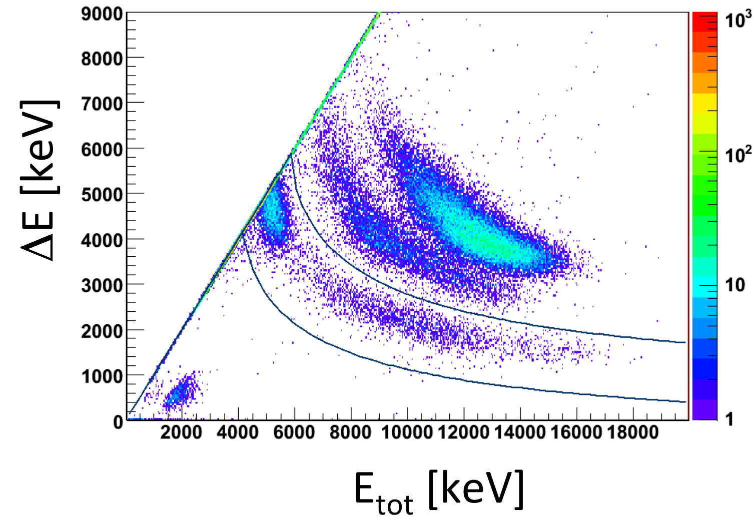
5% à 1.33 MeV

TREX: Particle identification (examples)

Forward Barrel - 30Mg(d,p)31Mg



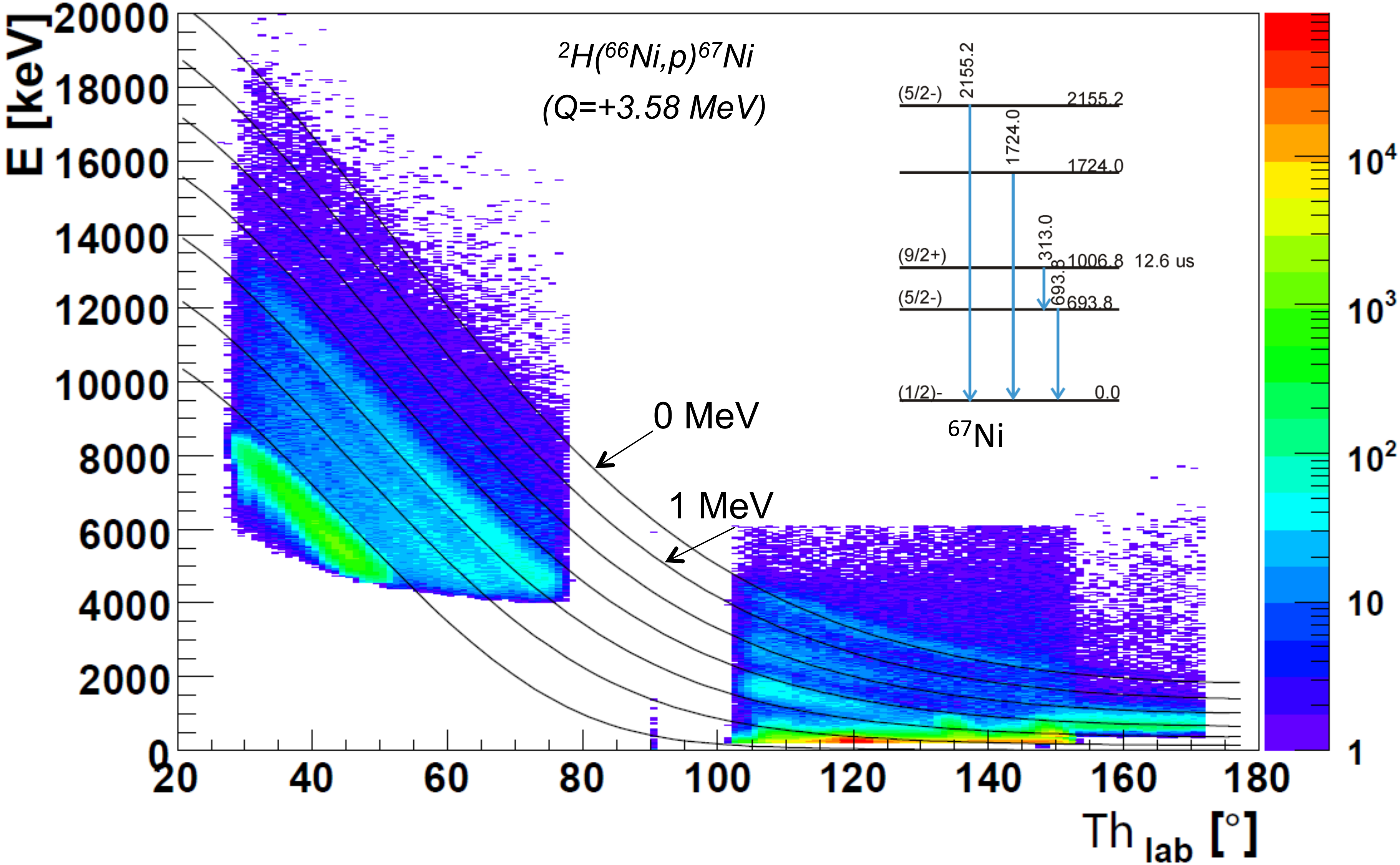
Forward Barrel- 66Ni(t,p)68Ni



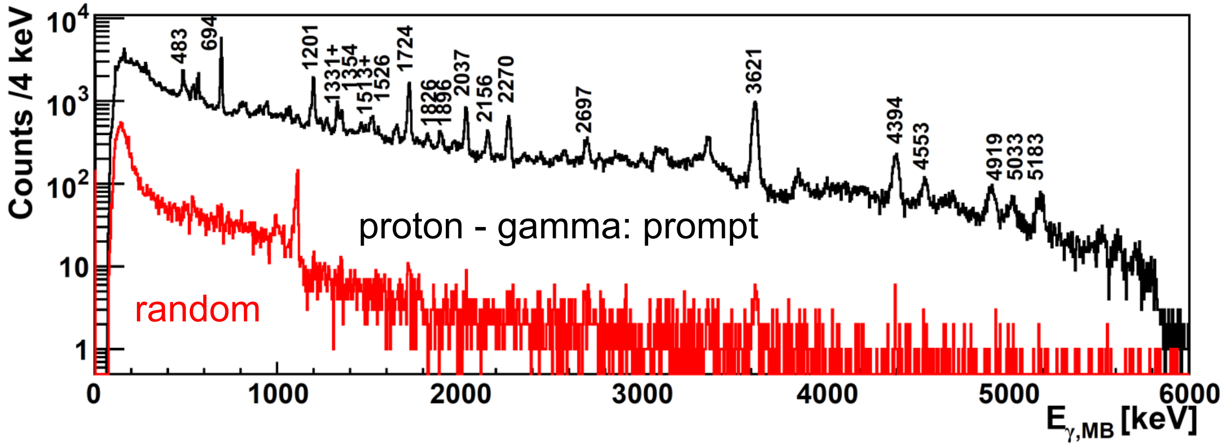
- Backward:
  - Proton stopped in dE, Eres used as a veto

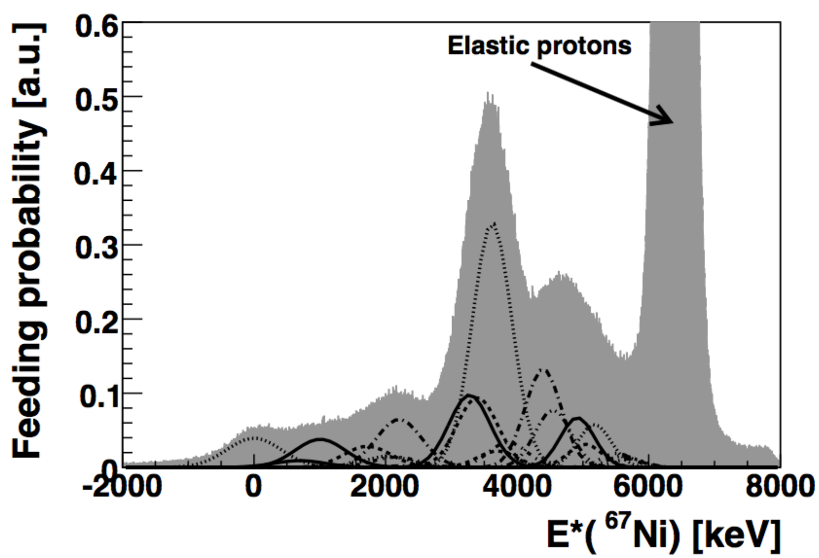
- Forward:
  - dE Vs E

Kinematics for $^{66}Ni(d,p)^{67}Ni$



Particle-gamma coincidences





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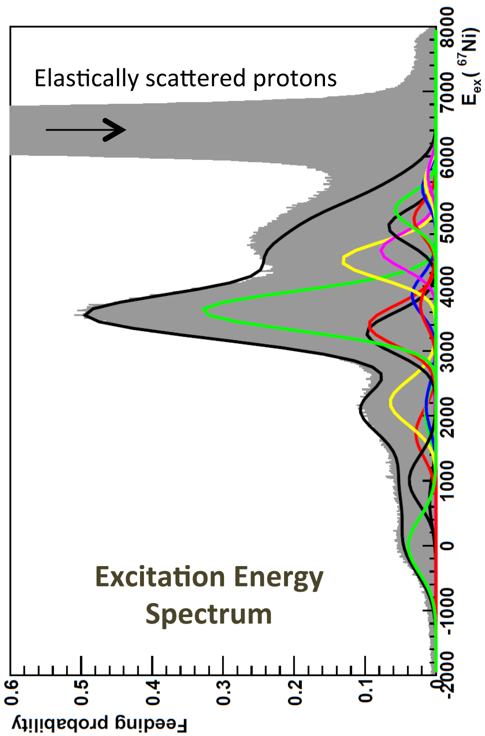
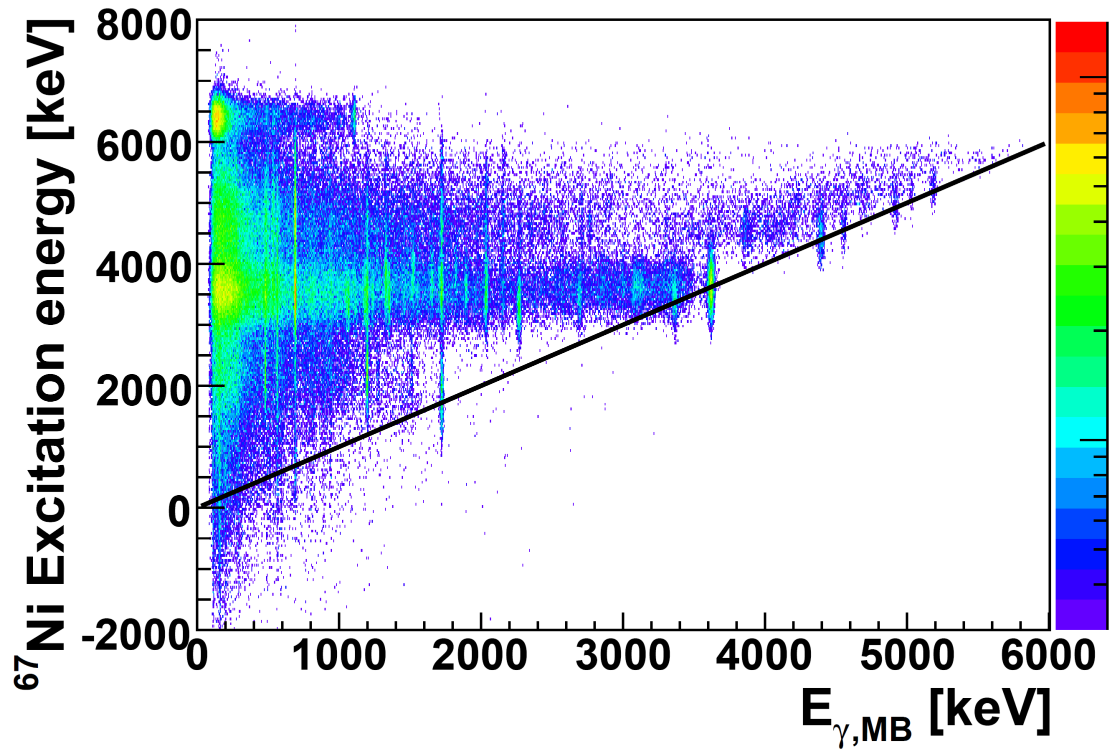
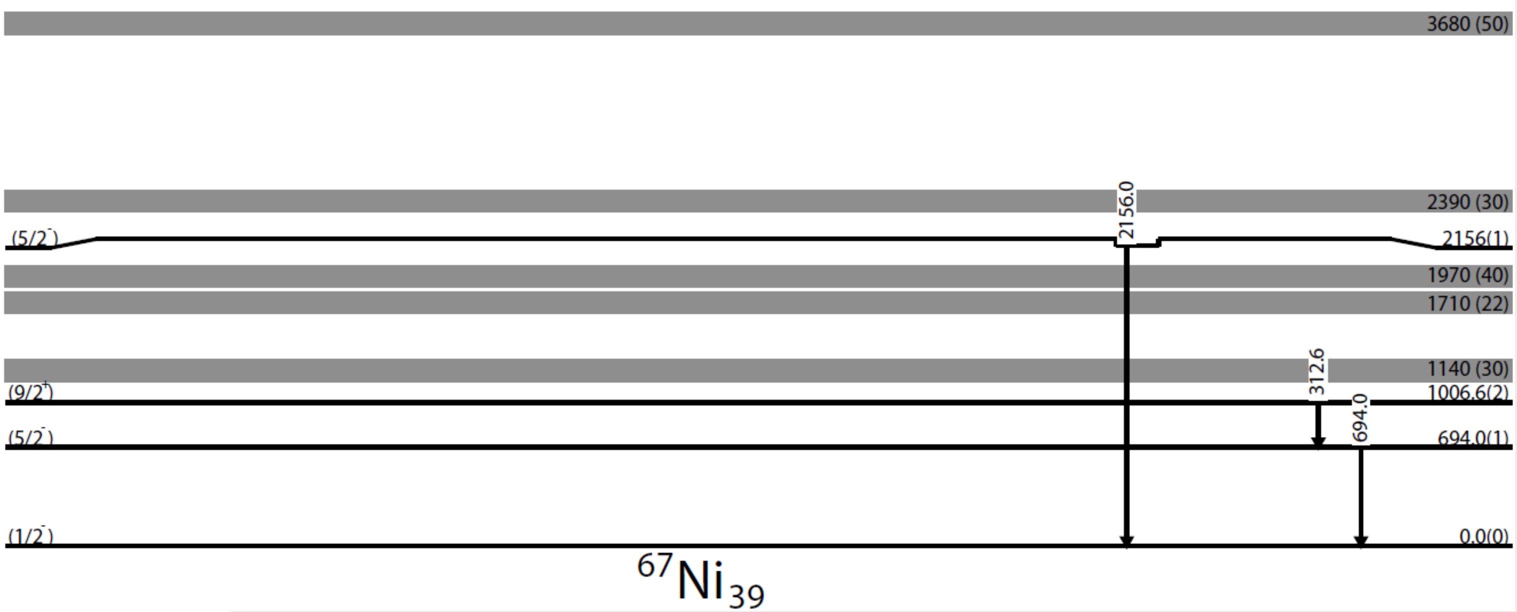




Colors: feeding to all different levels populated in ^{67}Ni

Improved level scheme



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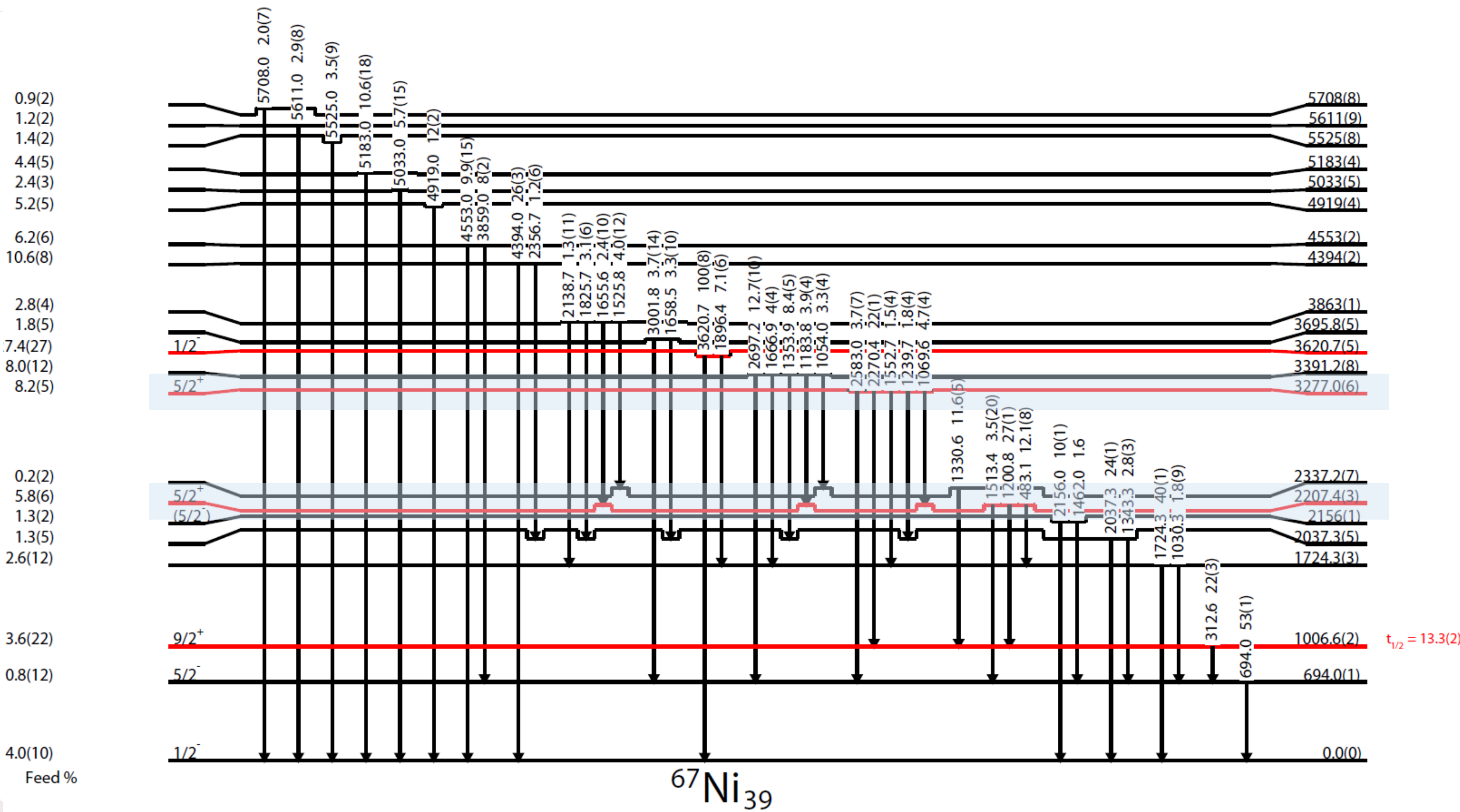
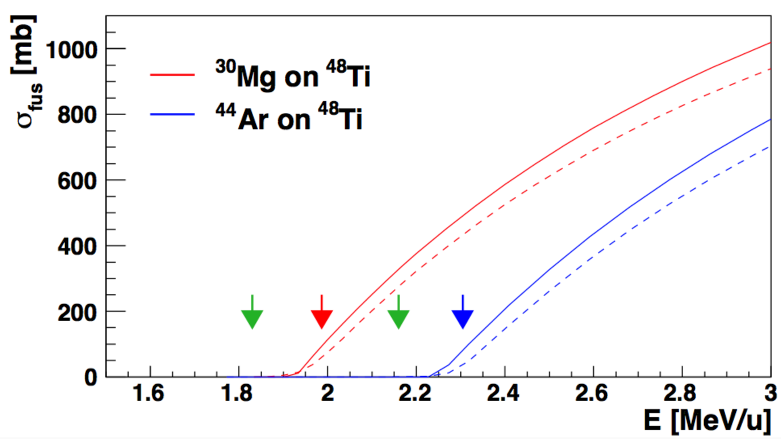


Identification of 5/2+ states (neutron excitations above the N=50 shell gap, d5/2)

Fusion and Elastic Scattering

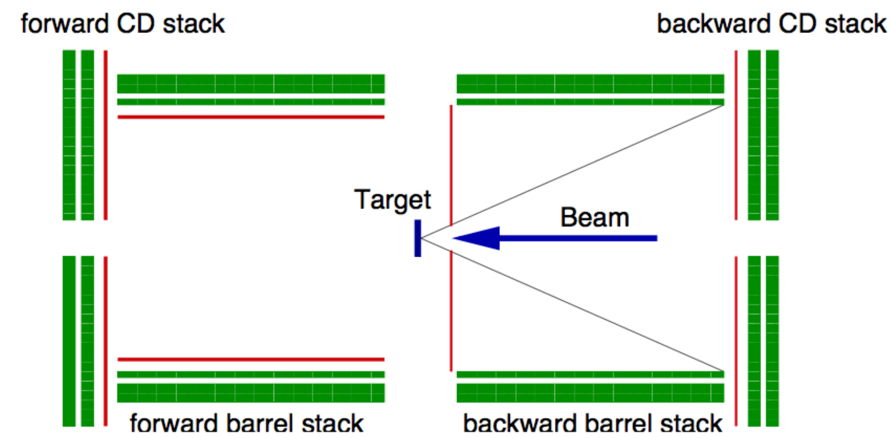
Fusion Cross sections

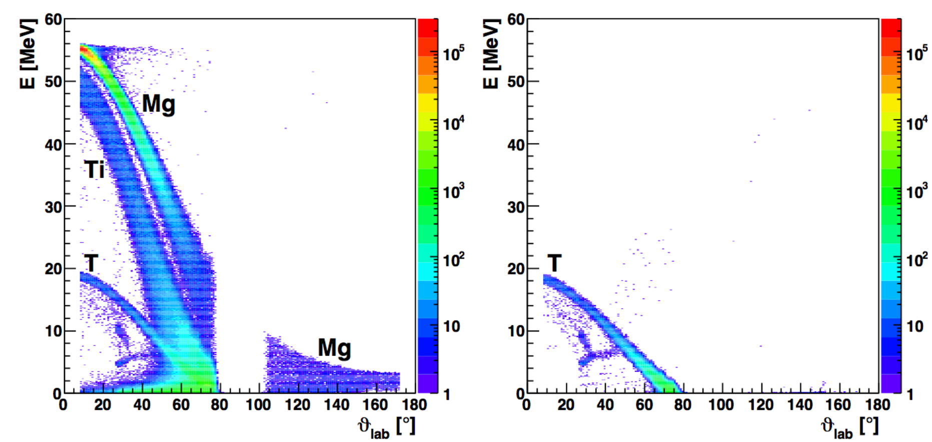


At higher E:

- Need for Trifoil-like det.
- Or recoil spectrometer

Mylar foils in front of detectors





K. Wimmer, PhD Thesis, TU Munich.

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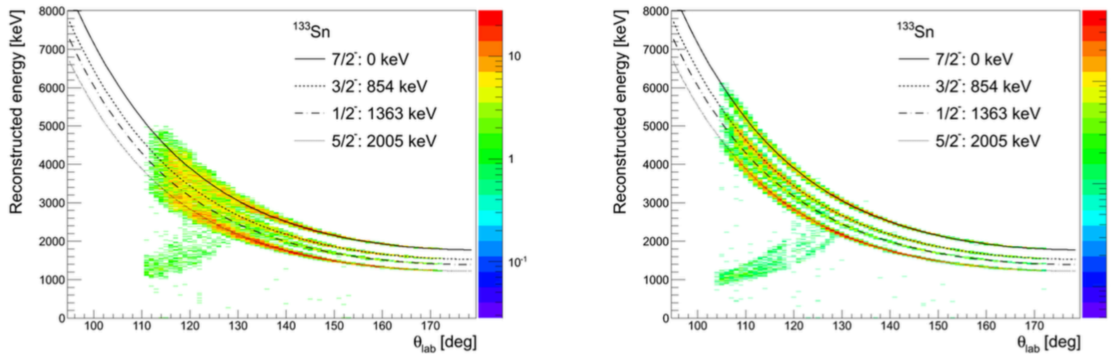
2. MINIBALL + TREX

3. **Perspectives**

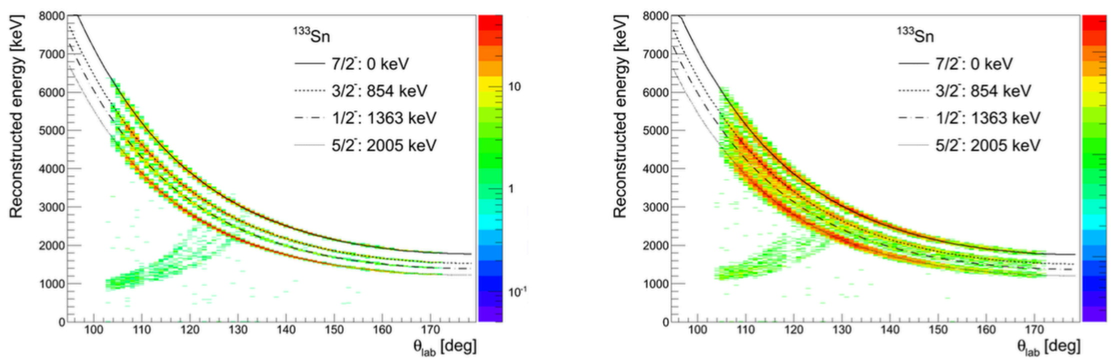
A TREX upgrade ?

$^{132}Sn(d,p)^{133}Sn$ @ 10 MeV/u (Back. Barrel)



a) 16 Barrel strips (T-REX setup), 0.1 mg/cm^2 thick dPE target

b) 64 Barrel strips, 0.1 mg/cm^2 thick dPE target



c) 128 Barrel strips, 0.1 mg/cm^2 thick dPE target

d) 64 Barrel strips, 0.5 mg/cm^2 thick dPE target

G4 simulations: S. Hellgartner, PhD Thesis, TU Munich.

Goals:

- Higher segmentation
- DSSDs
- Lower Threshold
- ASIC based readout (No more multiplexing)

But:

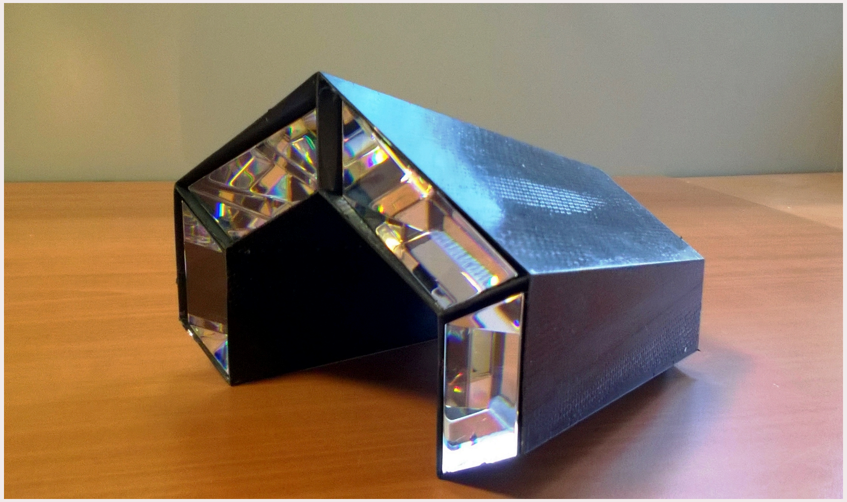
- Target Thickness effects
- Compromise: Resolution/Statistics

Ex:

Target:	0.1 to 0.5 mg/cm^2
FWHM(gs):	86 keV to 265 keV

MINIBALL upgrade ?

- Anti-Compton BGO shield
  - Designed at IPN Orsay
- New electronics?
  - GSI, FEBEX ?



Conclusions / Outlook

- **Unique physics opportunities at HIE-ISOLDE**
  - Large variety of beams due to target-ion source developments
  - Laser ionization selectivity
  - Higher E, allows to study heavier masses

- **Another Si array at ISOLDE?**
  - Future of TREX? Ressources, upgrade?
  - Main possibilities of improvements:
    - X Efficiency
    - ✓ Particle Identification (dE(TOF), PSA, …)
    - ✓ Resolution (yes but compromise with target thickness)
    - ✓ Physics with forward reactions
  - Technical aspects
    - Coupling with MINIBALL (ACQ, elect., mechanics..)
    - Pulsed beam (rate, readout, dead time)
    - Normalization