First experiments with $LaBr_3(Ce)$ in Oslo

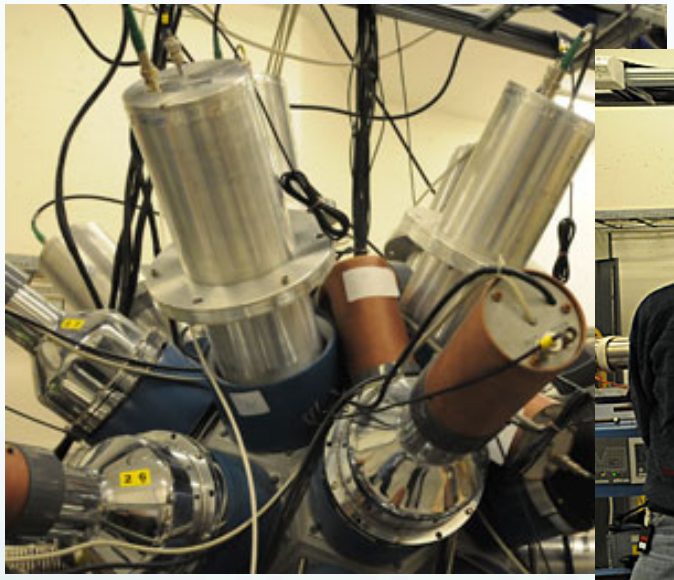
Ann-Cecilie Larsen
Post.doc., OCL/SAFE

UiO : Department of Physics
University of Oslo

SAFE
Senter for Akseleratorbasert
Forskning og Energifysikk

Special thanks to the Milano group!

- Franco Camera, Angela Bracco, Silvia Leoni, **Nives Blasi, Benedicte Million**



... and also special thanks to Sunniva, who started it all;
Andreas and Tamas, who transported the detectors;
Andreas and Magne, who did a great job with the electronics +++;
Eivind, Andrey, and Jon, who operated the cyclotron;
And all who took shifts!

OCL beam schedule March 2012

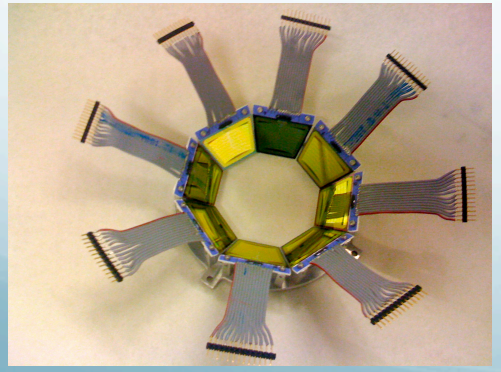
- **March 2 – 12: $LaBr_3$(Ce) commissioning and first experiment: 16-MeV protons on ^{56,57}Fe [Si, C, paper, mylar]. SiRi forward. ACL.**
- March 14 – 21: Second experiment: 38-MeV ^{3}He and 16-MeV protons on ^{195}Pt [C]. SiRi backward and forward. Francesca Giacoppo.
- March 23 – 29: Third experiment: 15-MeV deuterons on ^{12}C. SiRi forward. The Milano group.

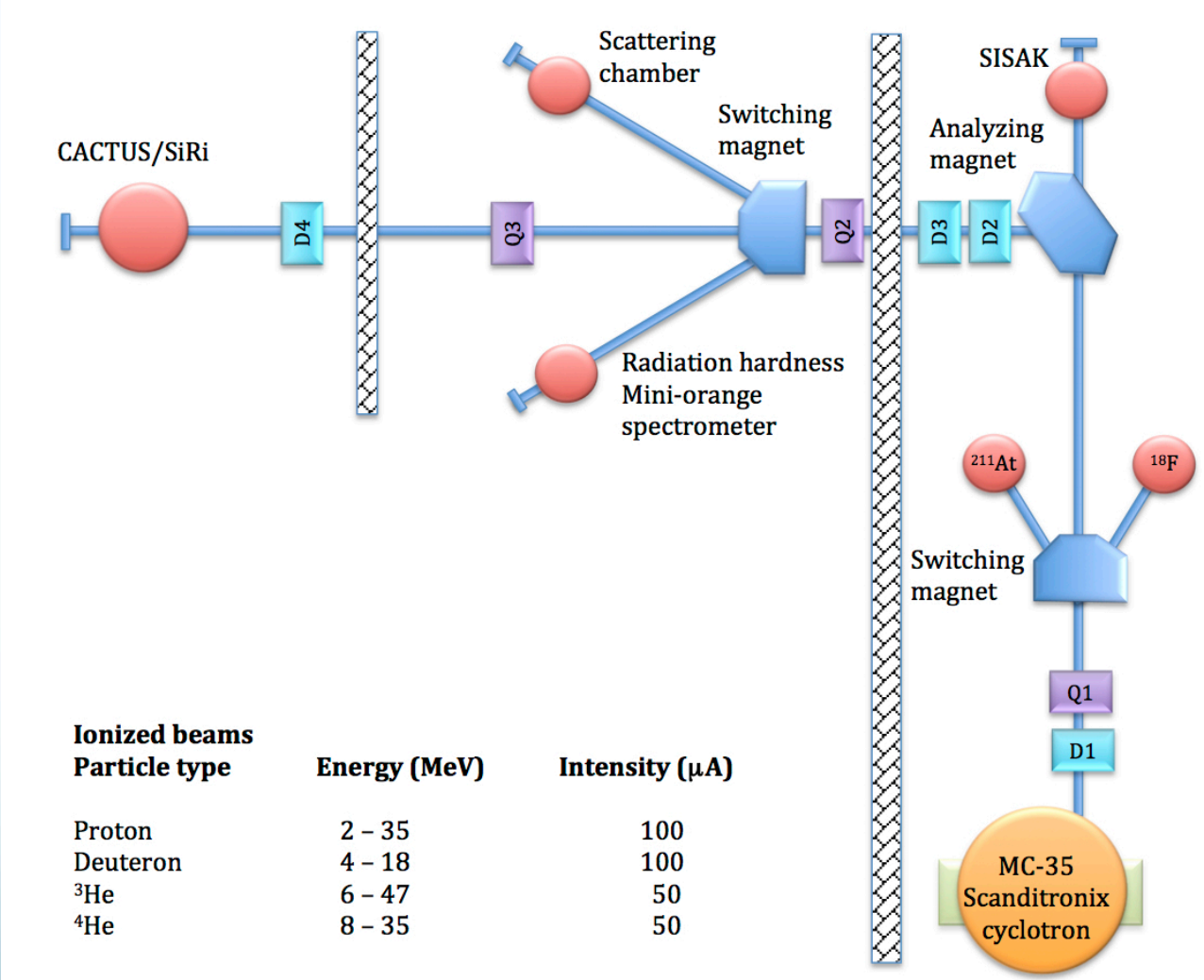
Now up and running ☺

OCL overview

CACTUS:
6 $LaBr_3$(Ce), 3.5” x 8”
22 NaI(Tl), 5” x 5”
[collimated]

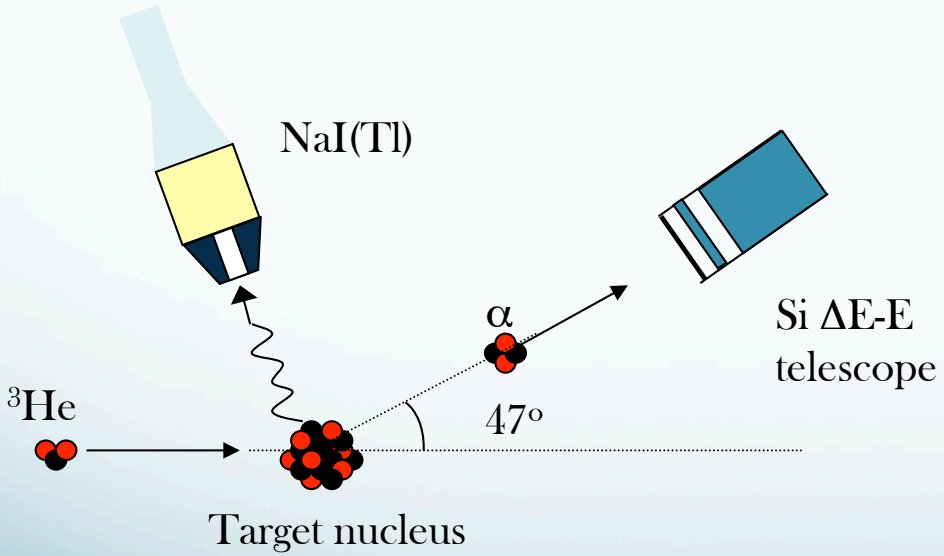
Silicon Ring (SiRi):
8 x 8 ΔE-E detectors
[130 and 1550 microns]

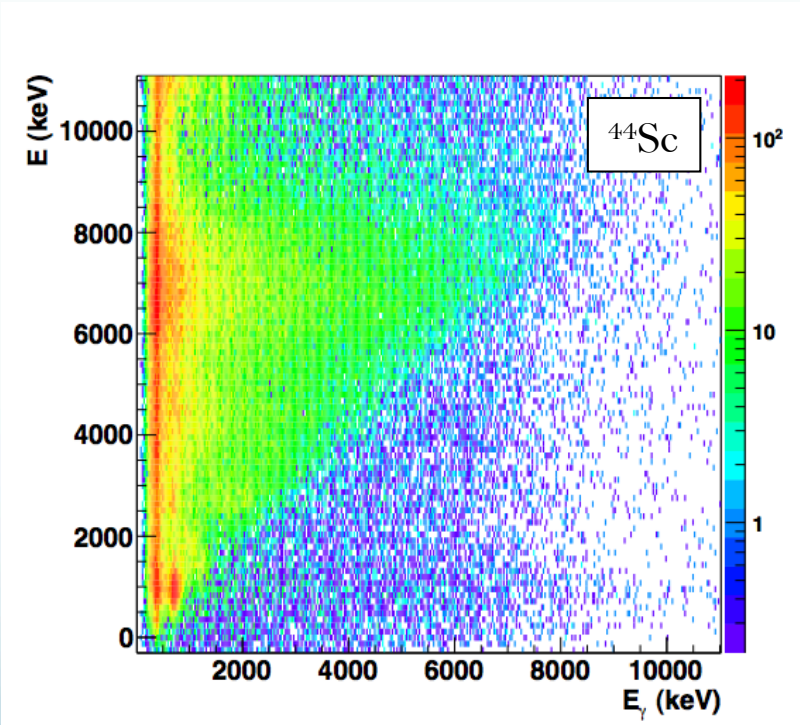




Ionized beams Particle type	Energy (MeV)	Intensity (μA)
Proton	2 – 35	100
Deuteron	4 – 18	100
^{3}He	6 – 47	50
^{4}He	8 – 35	50

Experimental technique

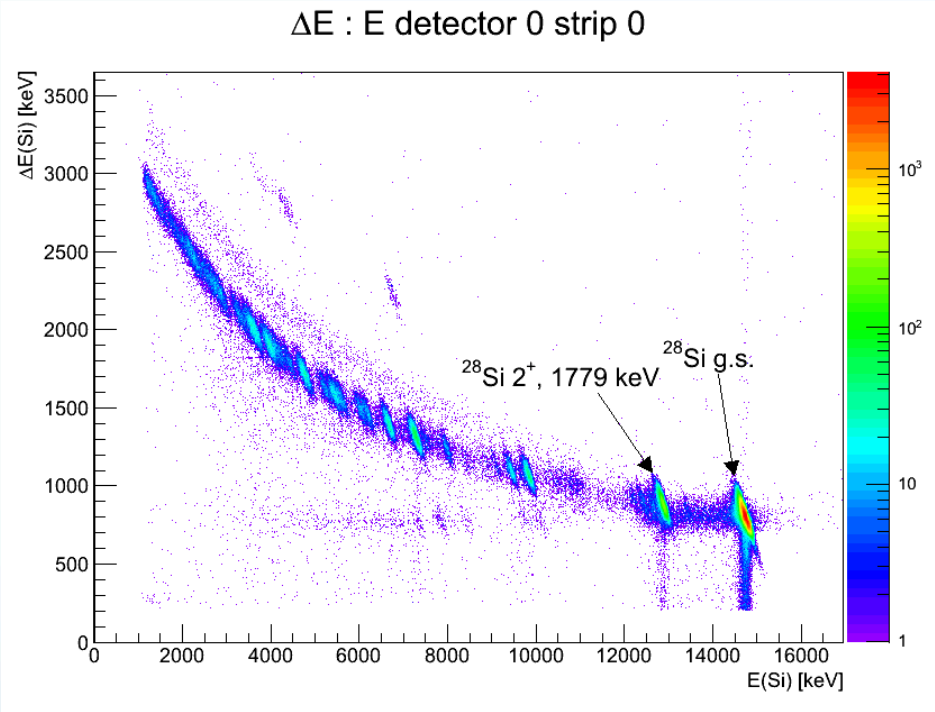


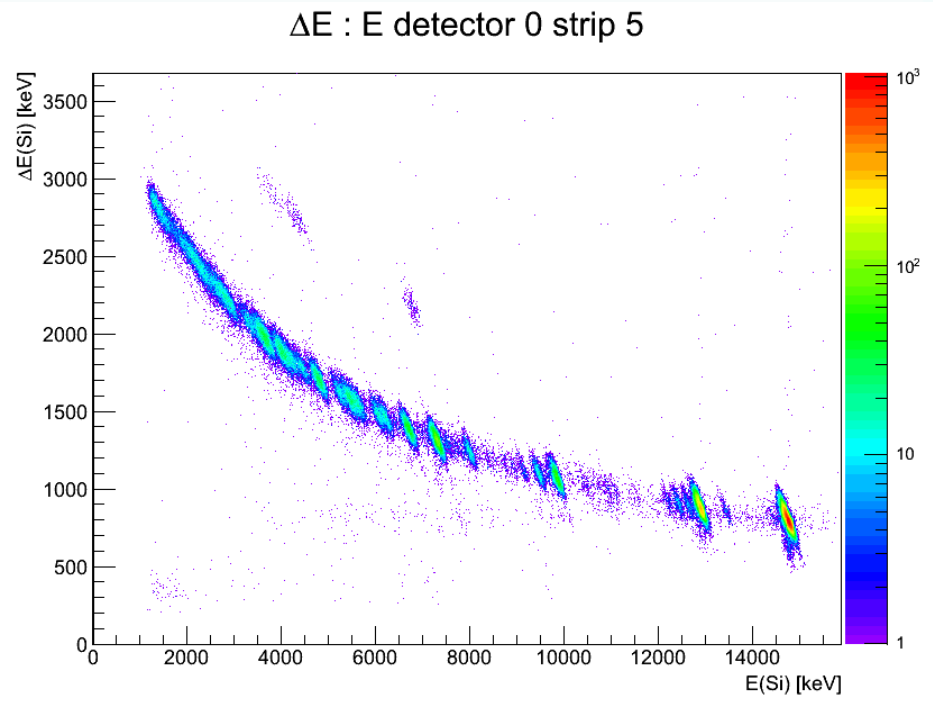


$LaBr_3(Ce)$ commissioning

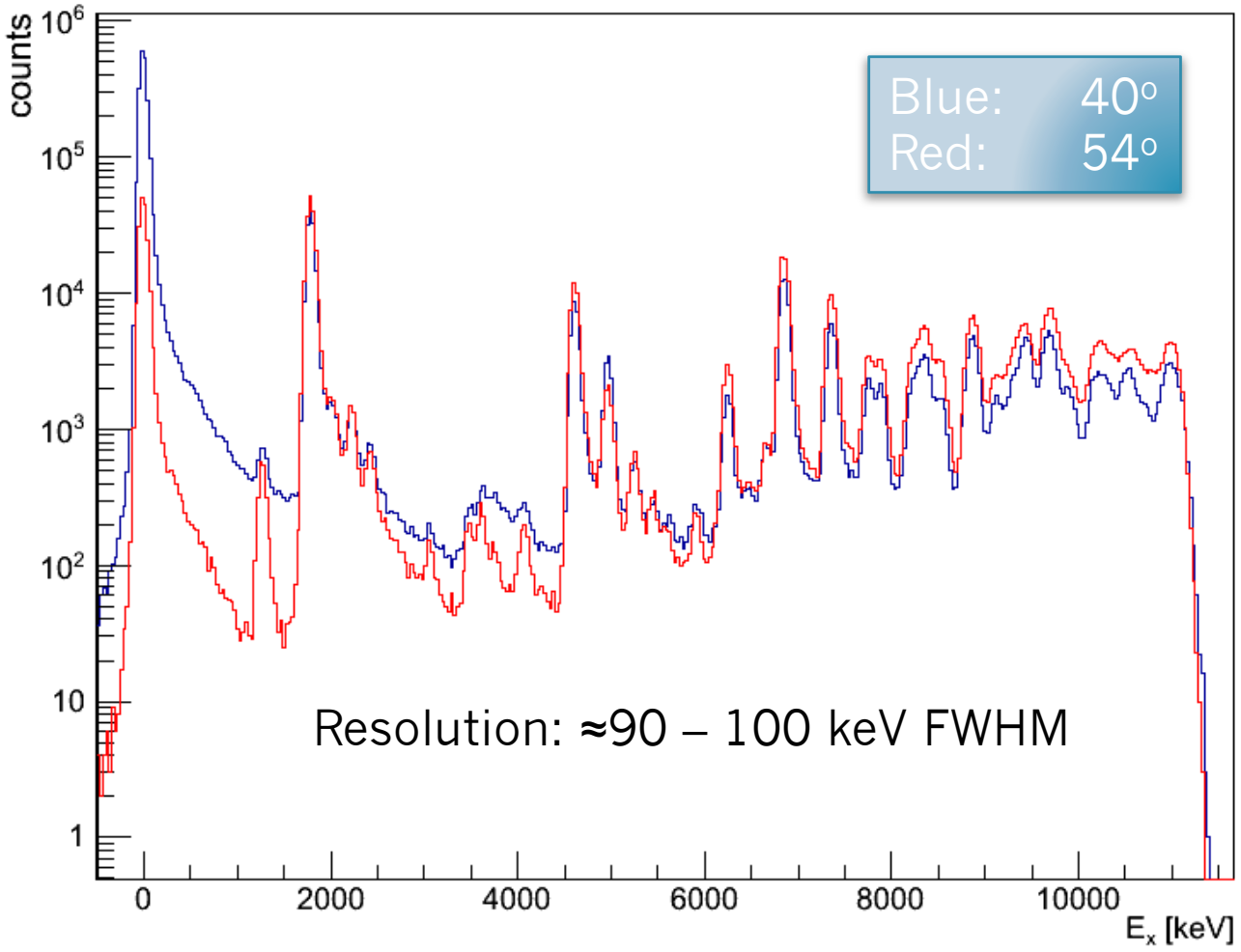
- 16-MeV protons on the targets Si (3.5 mg/cm^2) and C (1 mg/cm^2) => response functions and calibration
- Natural Si: 92.2% ^{28}Si, 4.7% ^{29}Si, 3.1% ^{30}Si
- Natural C: 98.9% ^{12}C, 1.1% ^{13}C
- SiRi angles: 40 – 54^o

Particle spectra – Si target



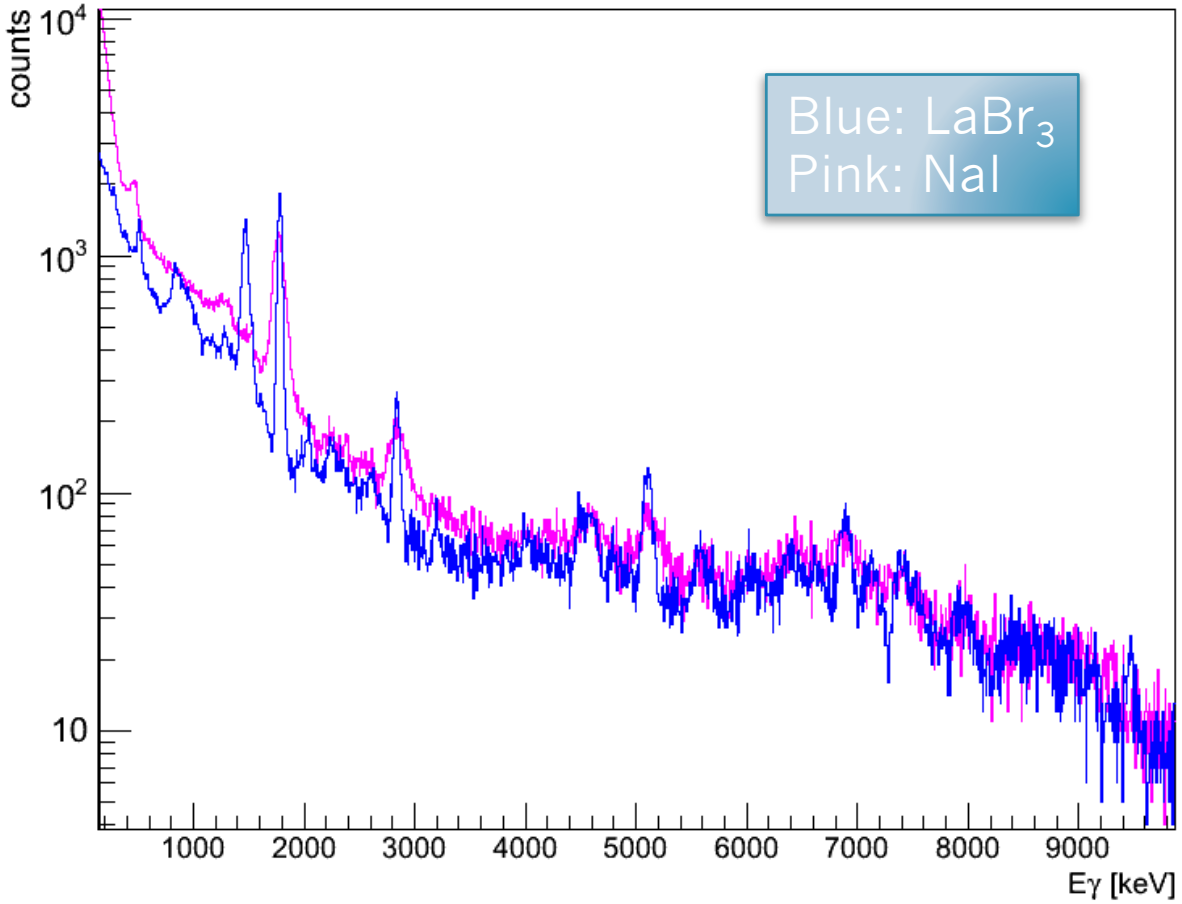


Excited states – Si target

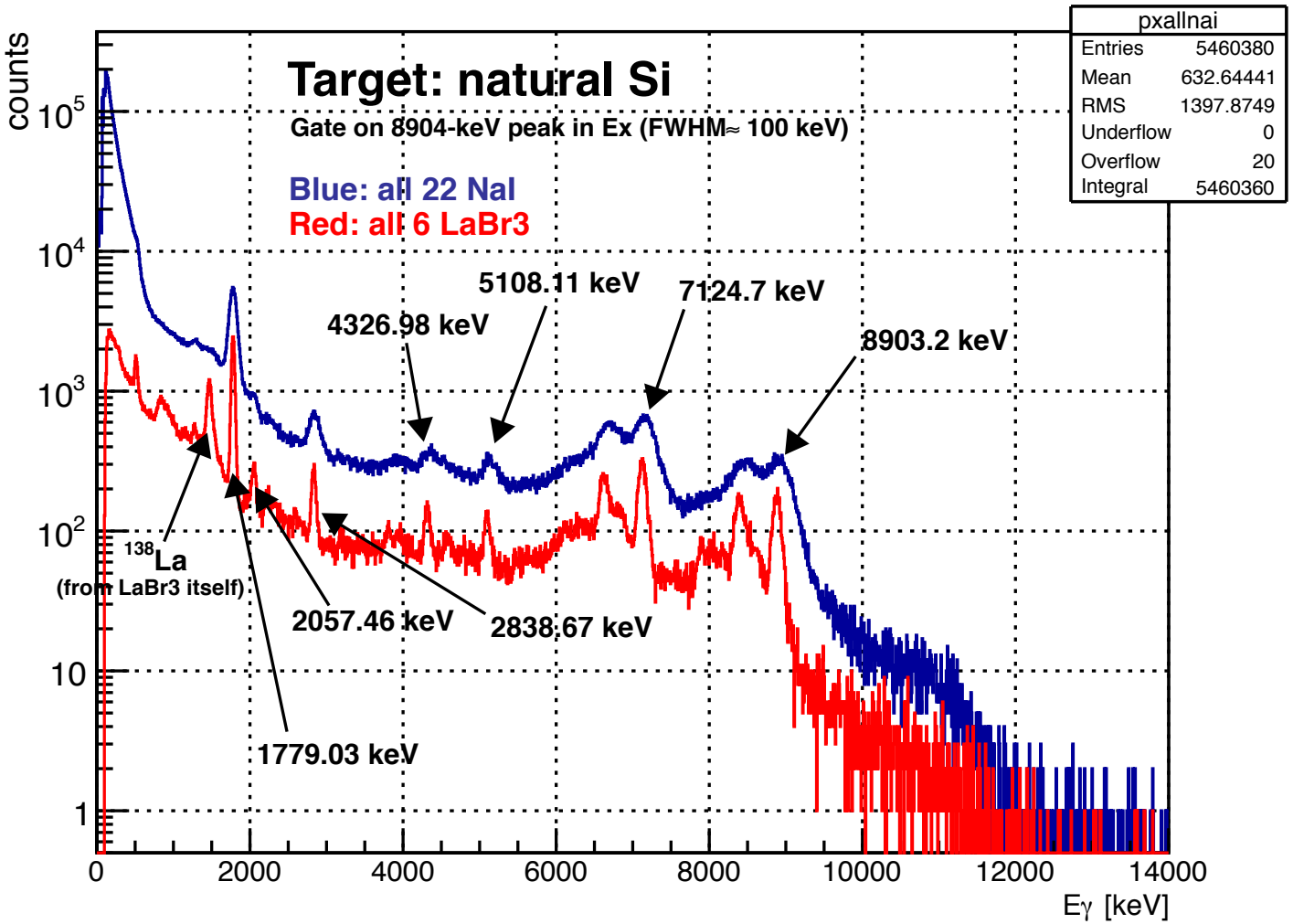


NaI vs. $LaBr_3(Ce)$

Only requirement: signal in E detector (master gate)
No gate on excitation energy. Si target.

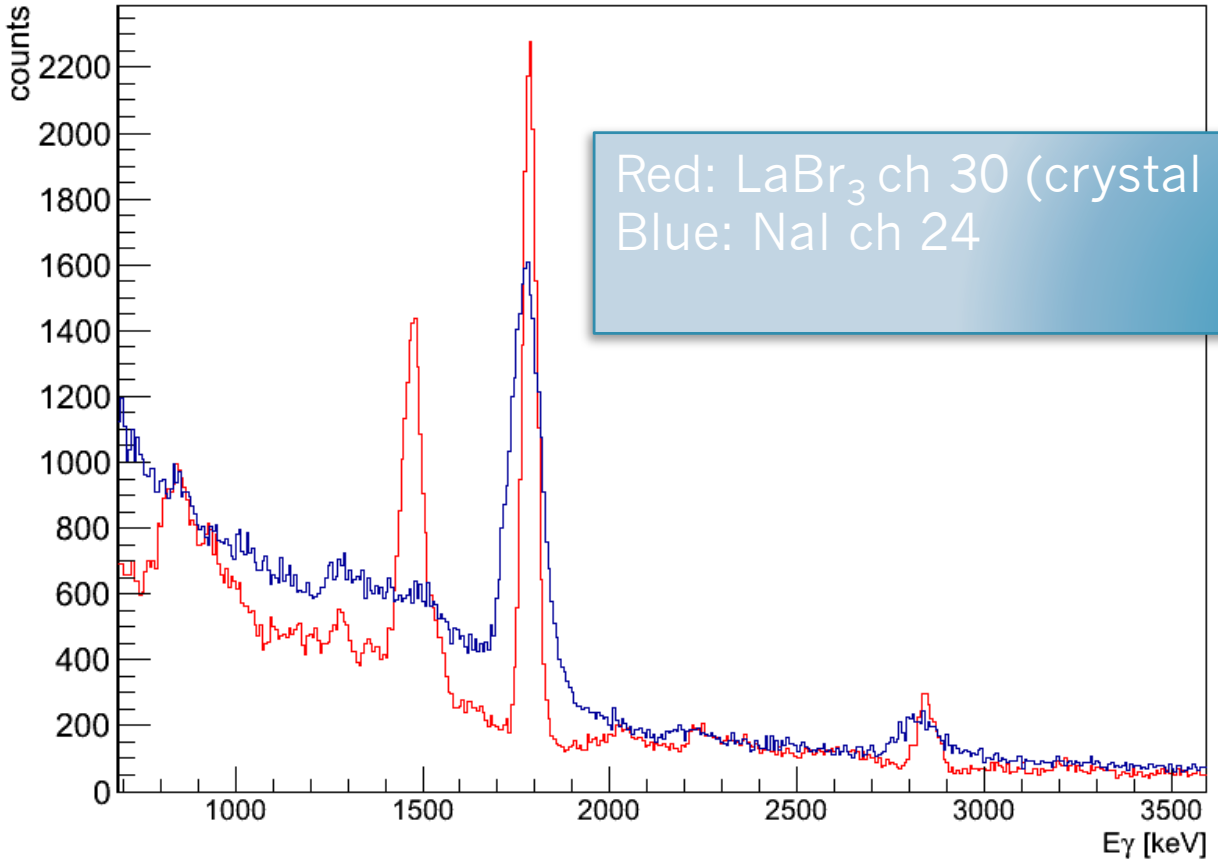


NaI vs. $LaBr_3(Ce)$



NaI vs. $LaBr_3(Ce)$

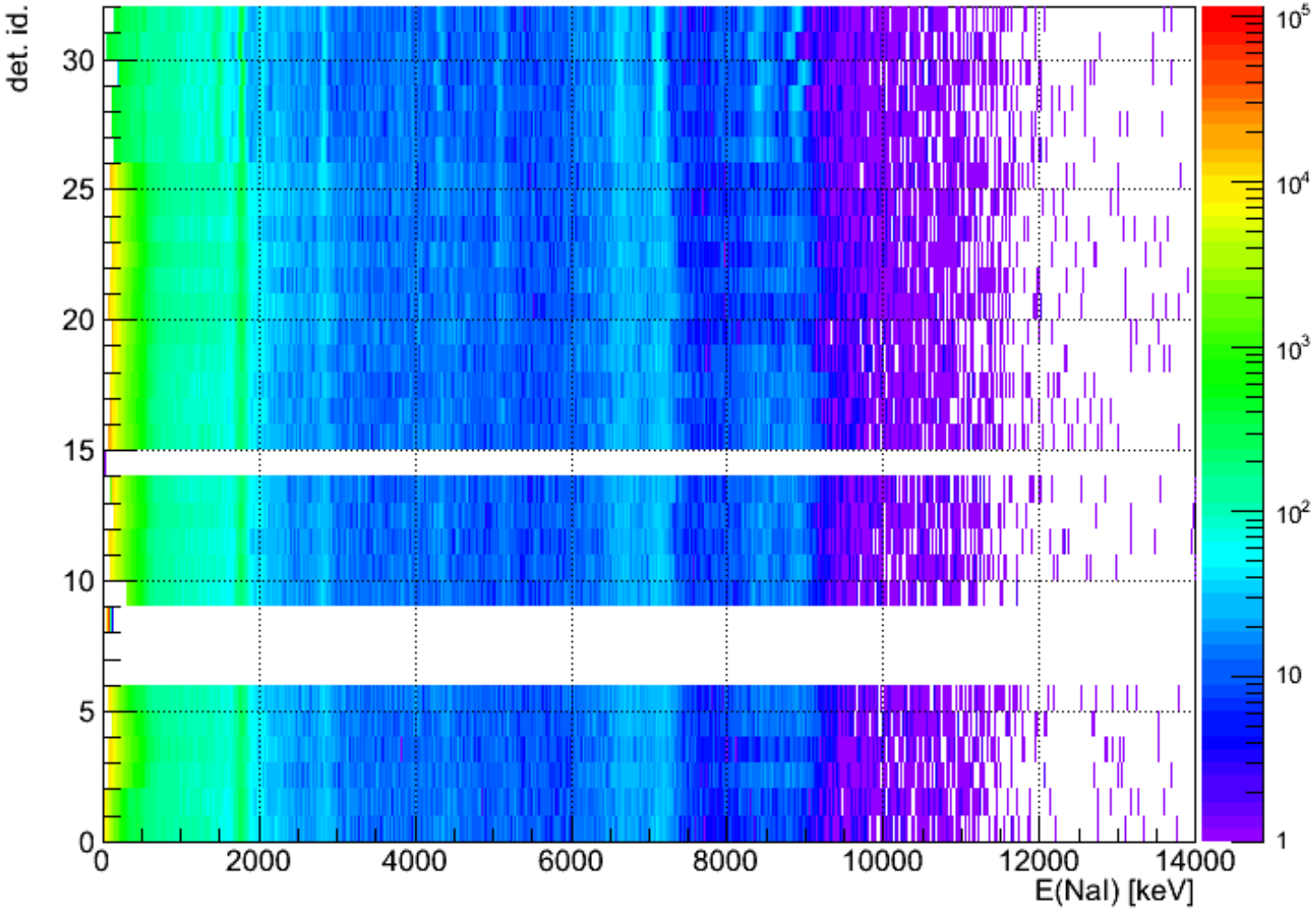
1779.0-keV peak, ^{28}Si



Linearity of $LaBr_3(Ce)$?

[Gate on peak @ E_x=8904 keV]

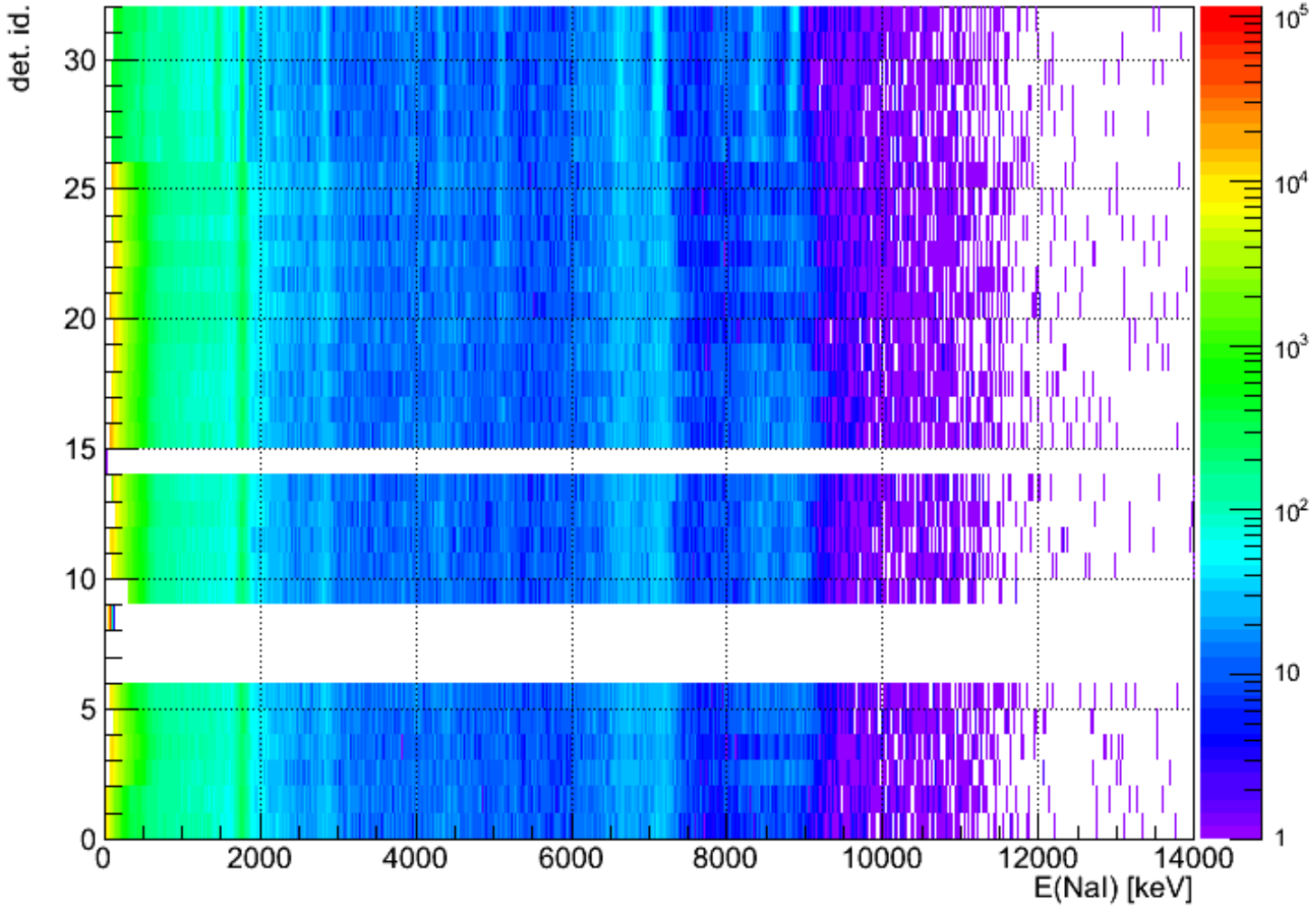
Linear calibration



Linearity of $LaBr_3(Ce)$?

[Gate on peak @ E_x=8904 keV]

Quadratic calibration



Linearity of $LaBr_3(Ce)$?

[Gate on peak @ E_x=8904 keV]

	Si peaks (keV)				χ^2	
$LaBr_3$	**1779.0**	**2838.8**	**5108.1**	**7124.7**	**Linear**	**Quad.**
1	2040.0	3223.3	5792.4	8111.1	232.0	0.704
4	2103.2	3319.8	5944.0	8298.8	82.0	0.002
5	2165.3	3433.3	6149.2	8594.6	87.0	16.60
6	2282.0	3639.1	6609.9	9351.3	1090.0	5.40
7	2077.8	3286.7	5835.9	8055.3	361.0	0.20
8	2092.5	3329.8	5999.5	8386.4	46.3	1.50

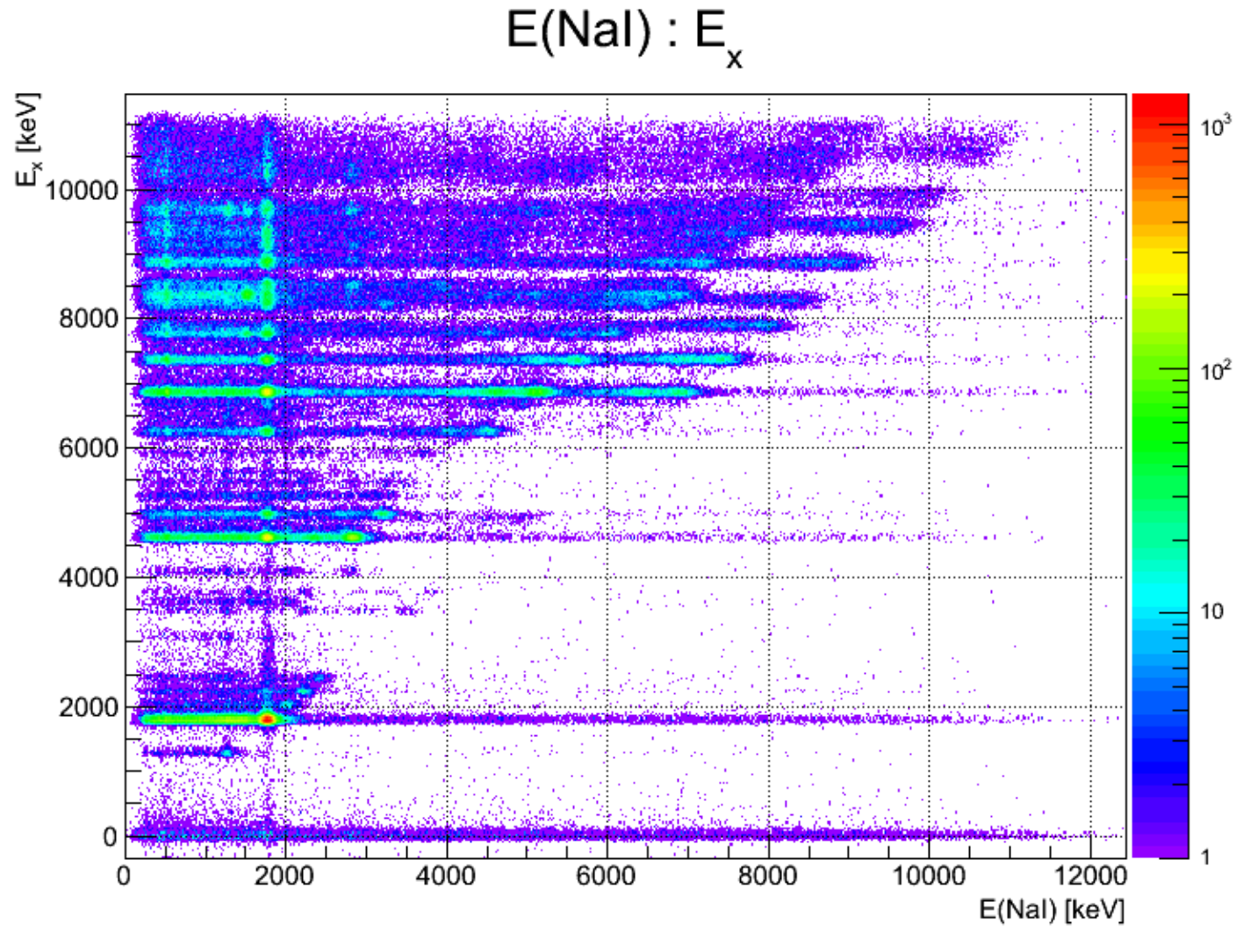
Resolution

Source and in-beam [acquisition room]

Quadratic calibration, ^{28}Si target

Detector	^{137}Cs	^{28}Si		^{28}Si	
	FWHM [keV] @ 662 keV	1779.0 keV	%	7124.7 keV	%
NaI 1		113.4	6.4	283.2	4.0
$LaBr_3$ 1	29	51.8	2.9	153.2	2.2
$LaBr_3$ 4	28	49.3	2.8	168.6	2.4
$LaBr_3$ 5	28	42.7	2.4	106.4	1.5
$LaBr_3$ 6	27	46.6	2.6	116.5	1.6
$LaBr_3$ 7	29	42.7	2.4	104.8	1.5
$LaBr_3$ 8	24	51.8	2.9	119.4	1.7

E_x vs. E_γ matrix, Si



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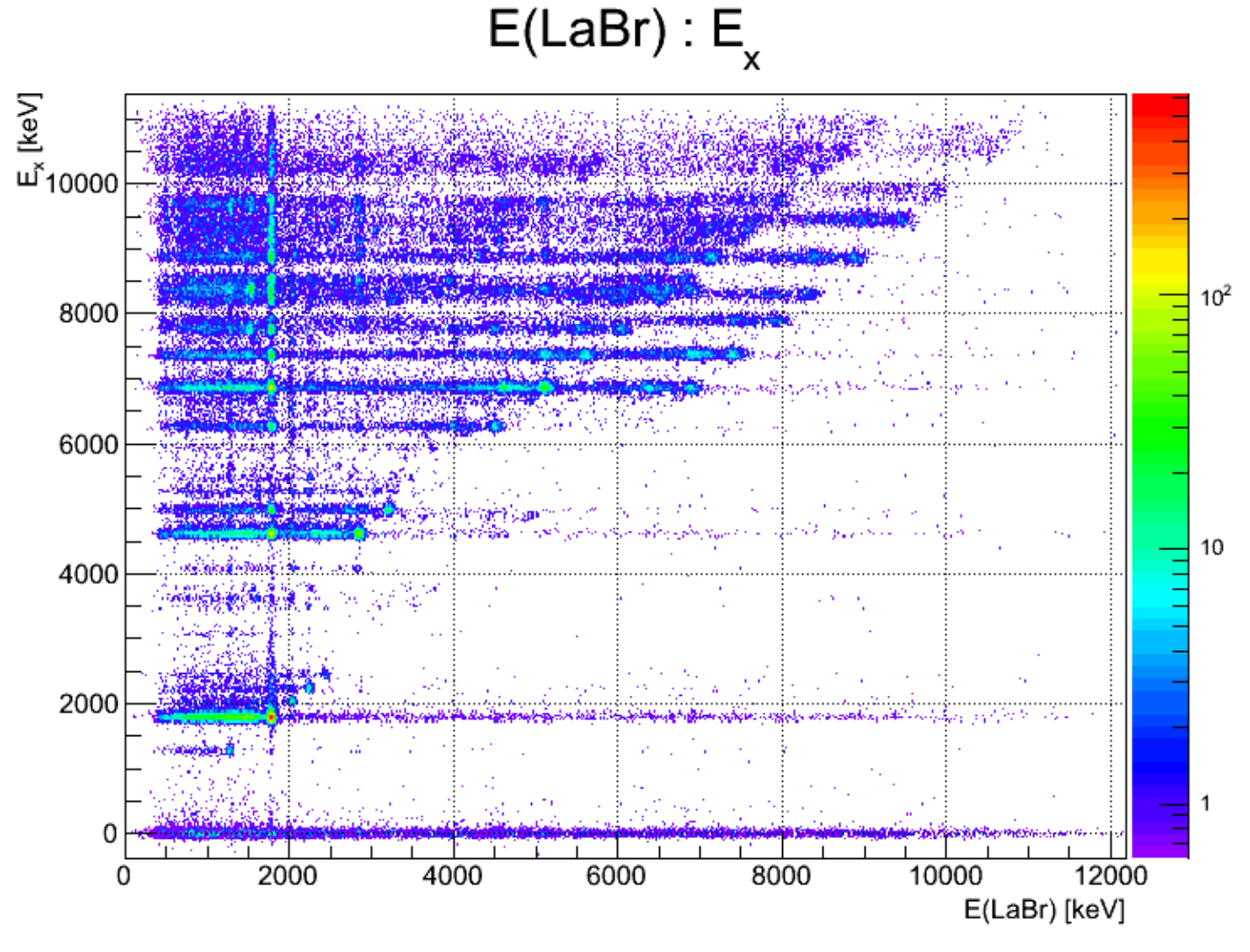


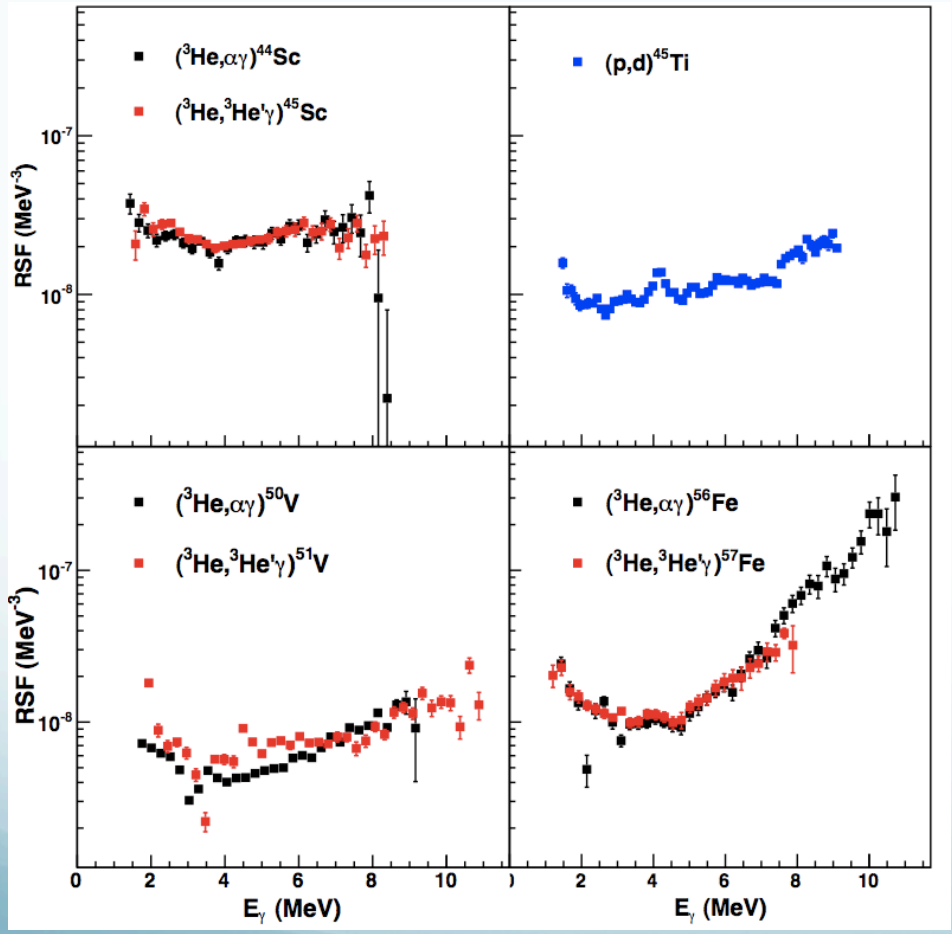
Fe experiment

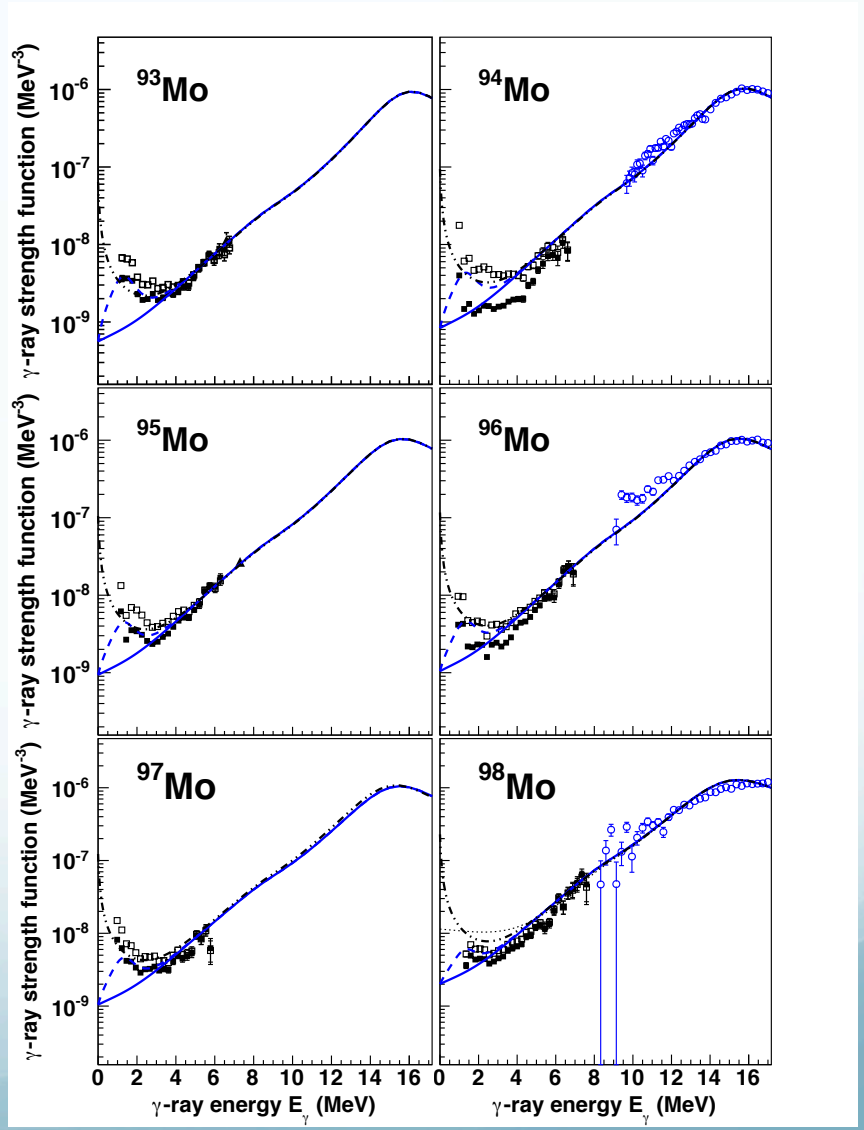
- Again, 16-MeV protons, SiRi forward
- ^{57}Fe target (92.44%) and ^{56}Fe target (99.93%)
- Famous “upbend” in the gamma strength

  [A. Voinov et al., PRL 93, 142504 (2004)]

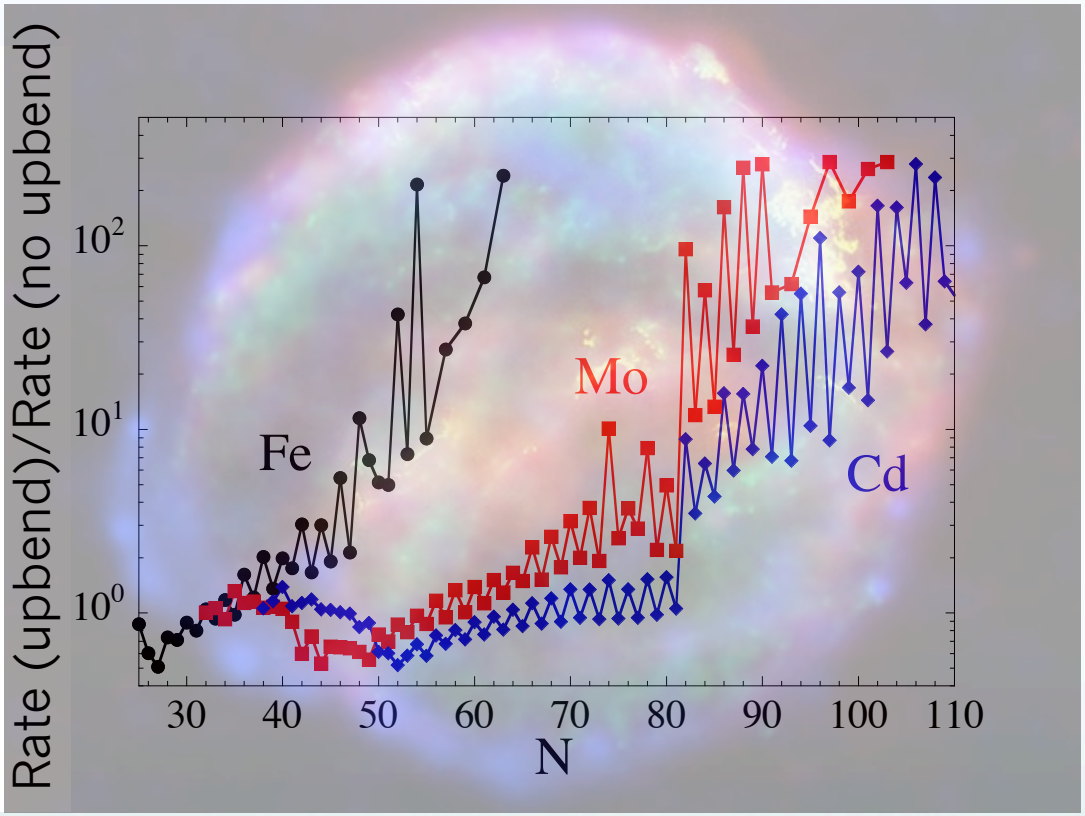
- Now: much better E_x energy resolution (≈400 keV vs. ≈100 keV), much better statistics, possibility of angular distributions (40 – 54^o + CACTUS), and $LaBr_3$(Ce)!

Low-energy enhancement of gamma strength





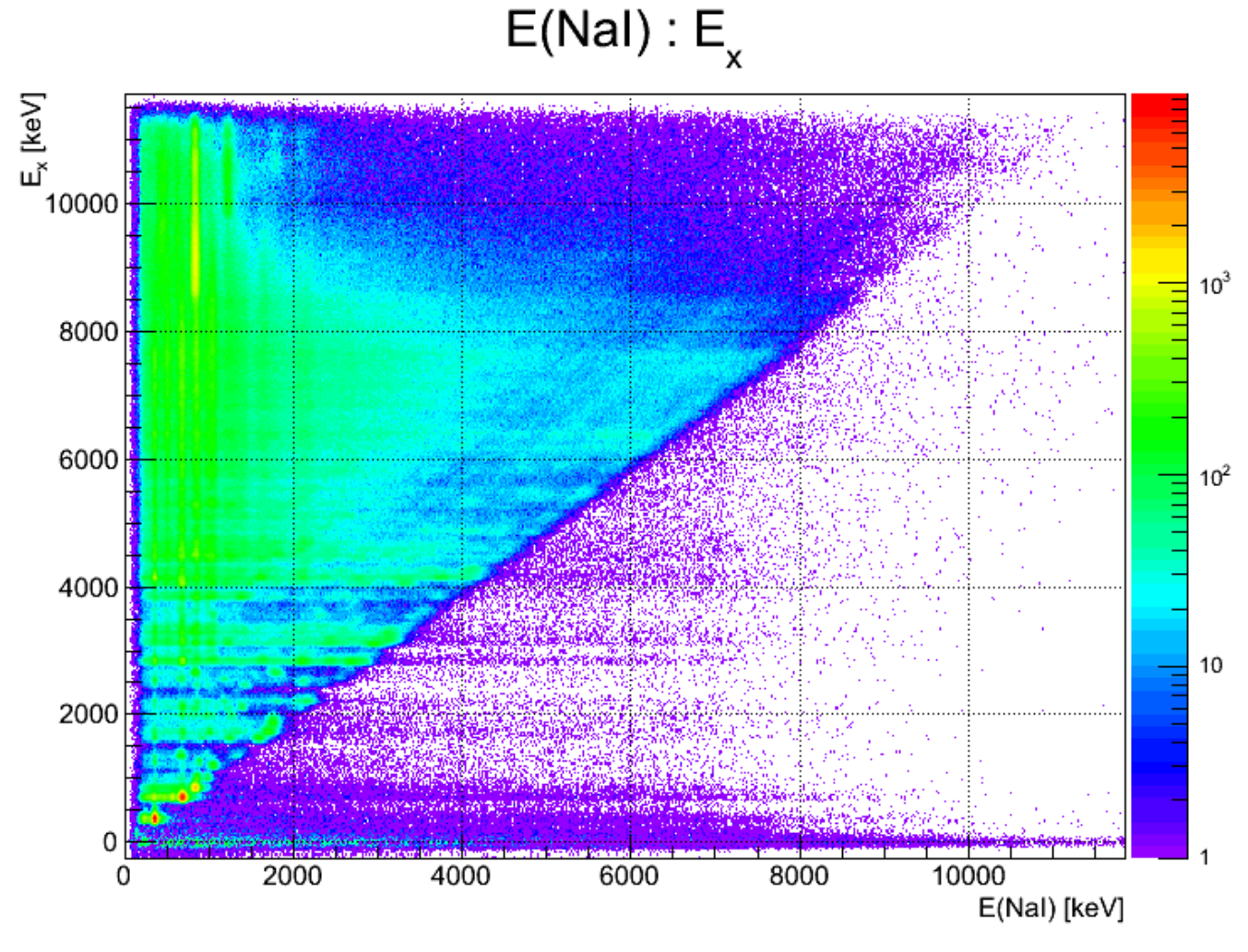
Potentially large impact on n-capture reaction rates



A.C. Larsen and S. Goriely, Phys. Rev. C **82**, 014318 (2010)

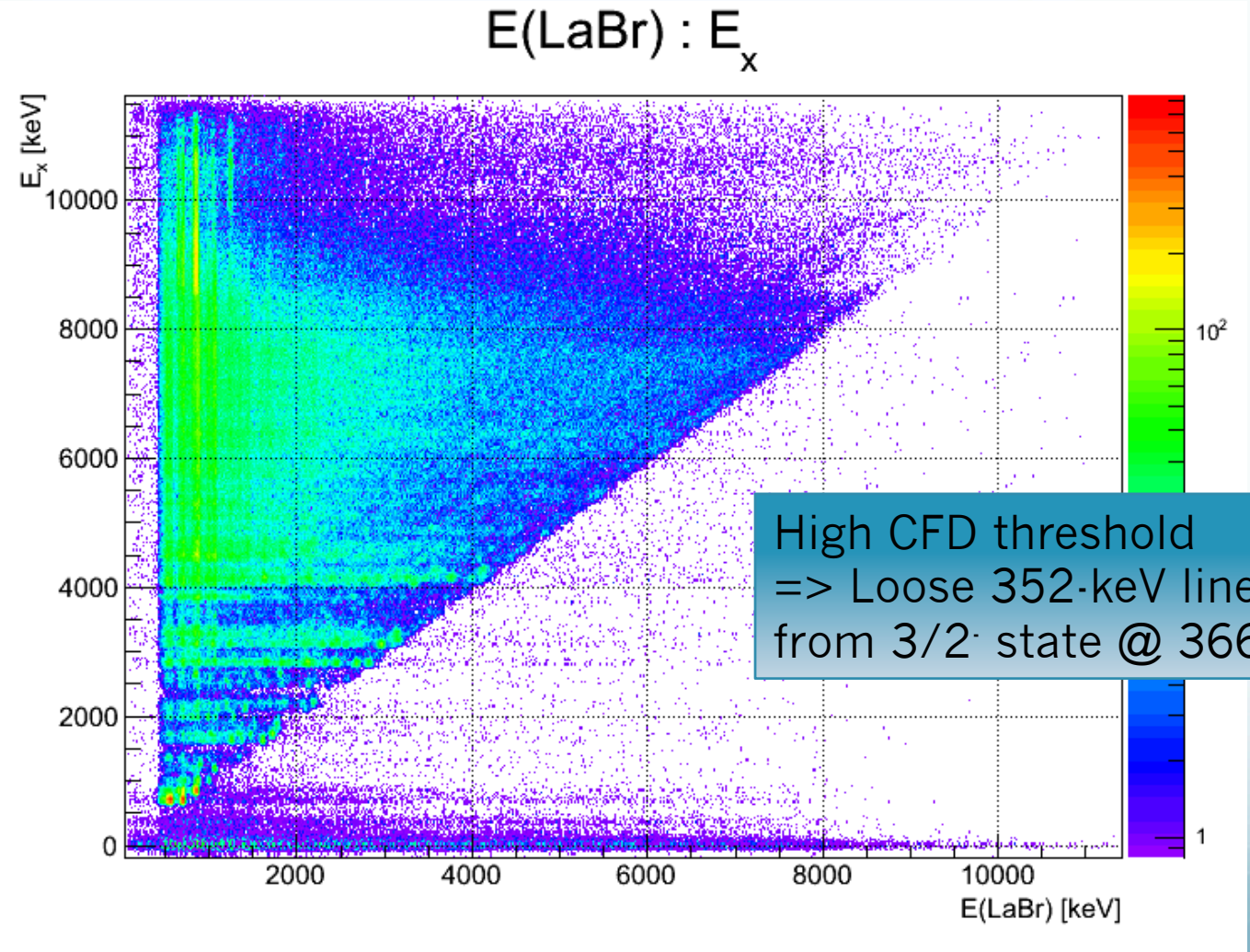
Research project: Nuclear structure studies relevant for astrophysics
Financed by the Research Council of Norway and Dep. of Physics

First results, ^{57}Fe



NaI: 10 million counts, $LaBr_3(Ce)$: 1.8 million counts

First results, ^{57}Fe



High CFD threshold
=> Loose 352-keV line
from 3/2$^-$ state @ 366.7 keV

NaI: 10 million counts, $LaBr_3(Ce)$: 1.8 million counts

Still a lot of work to do...

- Make response functions for $LaBr_3(Ce)$ for proper unfolding [also update NaI response functions]
- Extract (level density and) gamma strength for the various angles and look for differences
- CACTUS angular distributions => determine multipolarity of the upbend (probably L=1)
- Look carefully for gammas above neutron threshold (7.646 MeV in ^{57}Fe)

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Many thanks for your attention!