SOFIA: Studies On FIssion with Aladin

FISSION OF NEUTRON-DEFICIENT NUCLEI IN THE 180-205 MASS REGION

T. GORBINET (CEA, DAM, DIF) **FOR THE SOFIA COLLABORATION**

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1) MAIN OBJECTIVE

ACCURATE MEASUREMENT OF FISSION FRAGMENTS YIELDS

fission of heavy nuclei (^{234}U,^{235}U,^{236}U,^{237}Np,^{238}Np) for *applications* purpose
→ need of high quality data means high statistics (also for calibration purpose)
→ a couple of days of data taking

2) EXPLORATORY OBJECTIVE

BROWSE THE NUCLEAR LANDSCAPE *(see next slide)*
FOR A NEW REGION OF INTEREST

EXOTIC neutron-deficient settings
→ allow to access many nuclei from Rn down to Hg
→ a few hours of data taking (low statistics)

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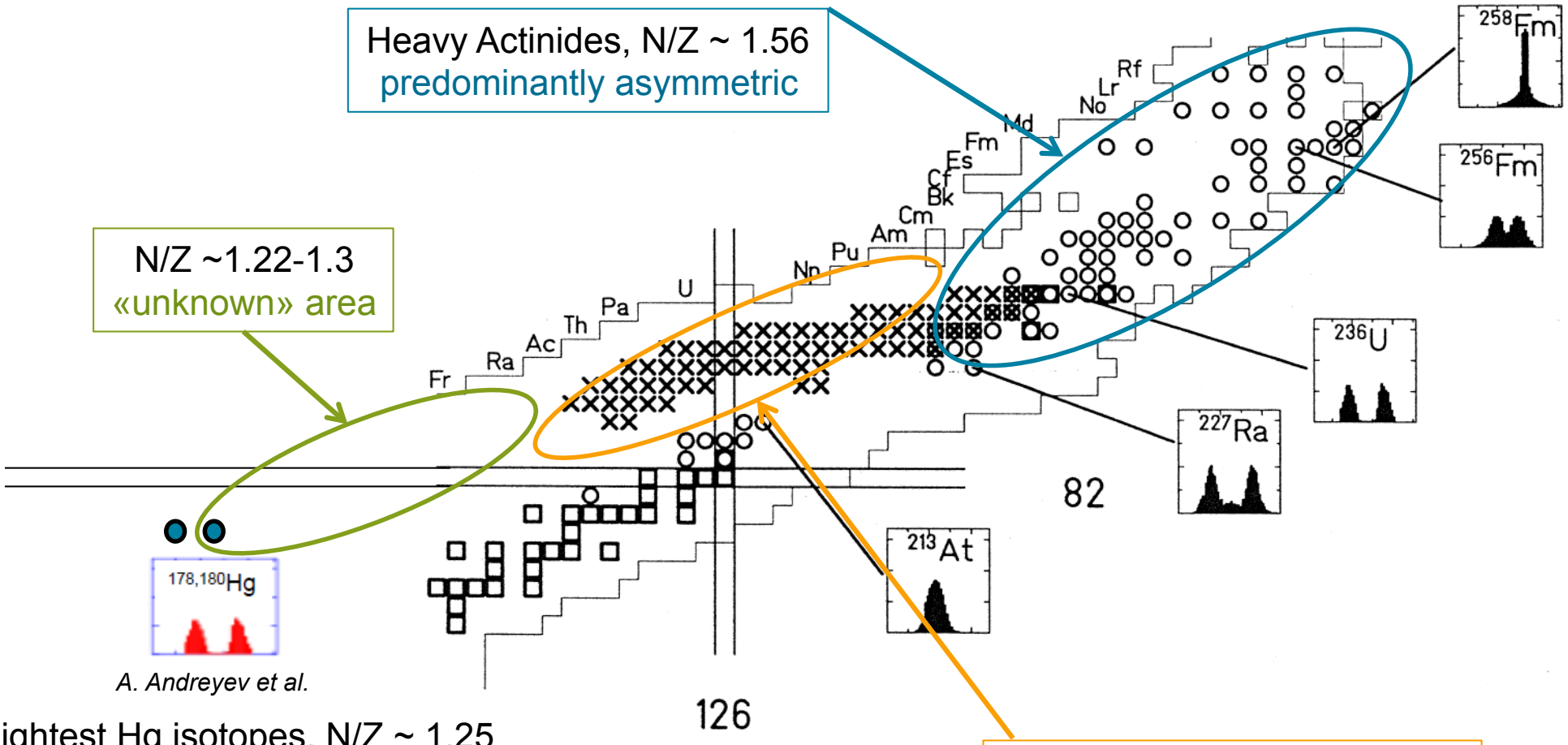
K.-H. Schmidt et al. / Nuclear Physics A 665 (2000) 221–267

Heavy Actinides, N/Z ~ 1.56
predominantly asymmetric

N/Z ~1.22-1.3
«unknown» area



A. Andreyev et al.

Lightest Hg isotopes, N/Z ~ 1.25
asymmetric !

Light Actinides, N/Z ~ 1.4-1.5
predominantly symmetric

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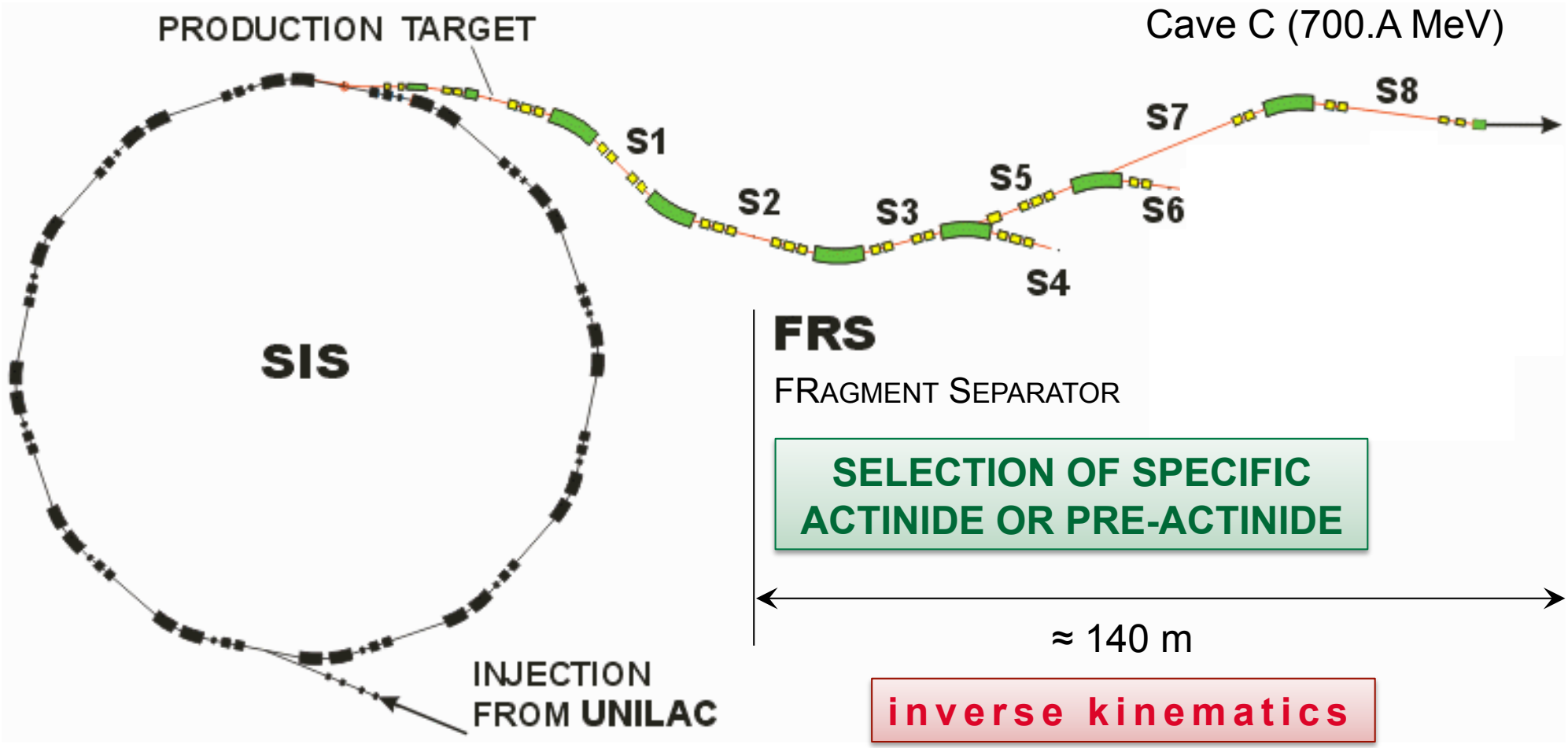
The GSI facility



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at such energies, the only way to identify both in charge and mass the nuclei is the

Bρ – ΔE – ToF TECHNIQUE

to get the mass A, we need the charge Z of the fragment, its velocity γv AND its magnetic deviation due to the dipole Bρ

$$A \propto \frac{B\rho}{\gamma v} Z$$

USED TWICE

1) FOR THE ID. OF THE INCOMING BEAM
2) FOR THE ID. OF THE FISSION FRAGMENTS

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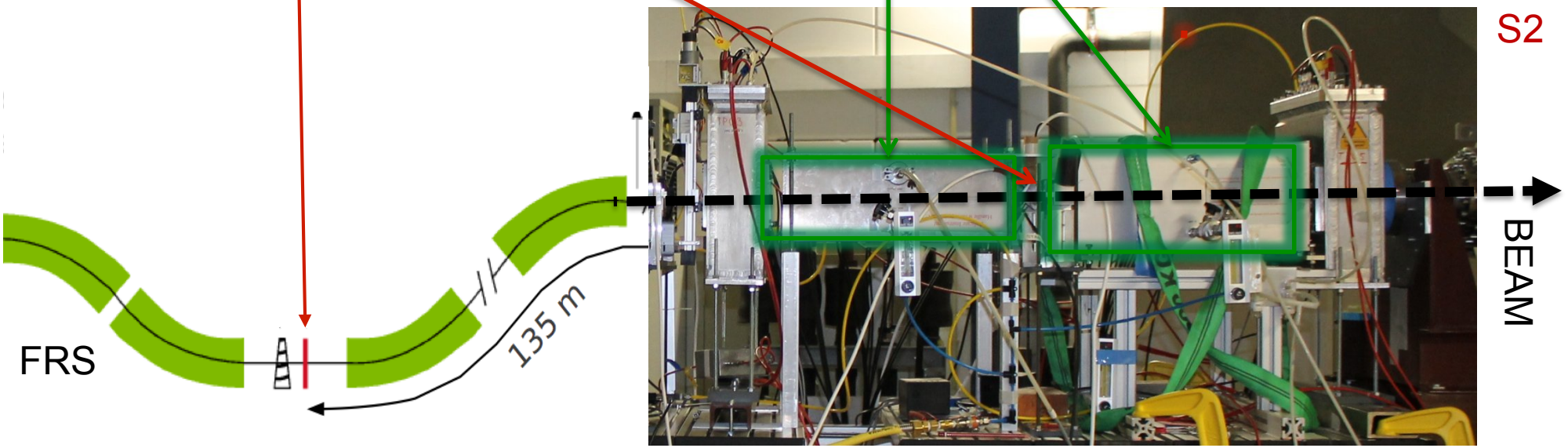
IDENTIFICATION OF THE SECONDARY BEAM

Bρ & ToF

Plastics for time-of-flight & positions measurement

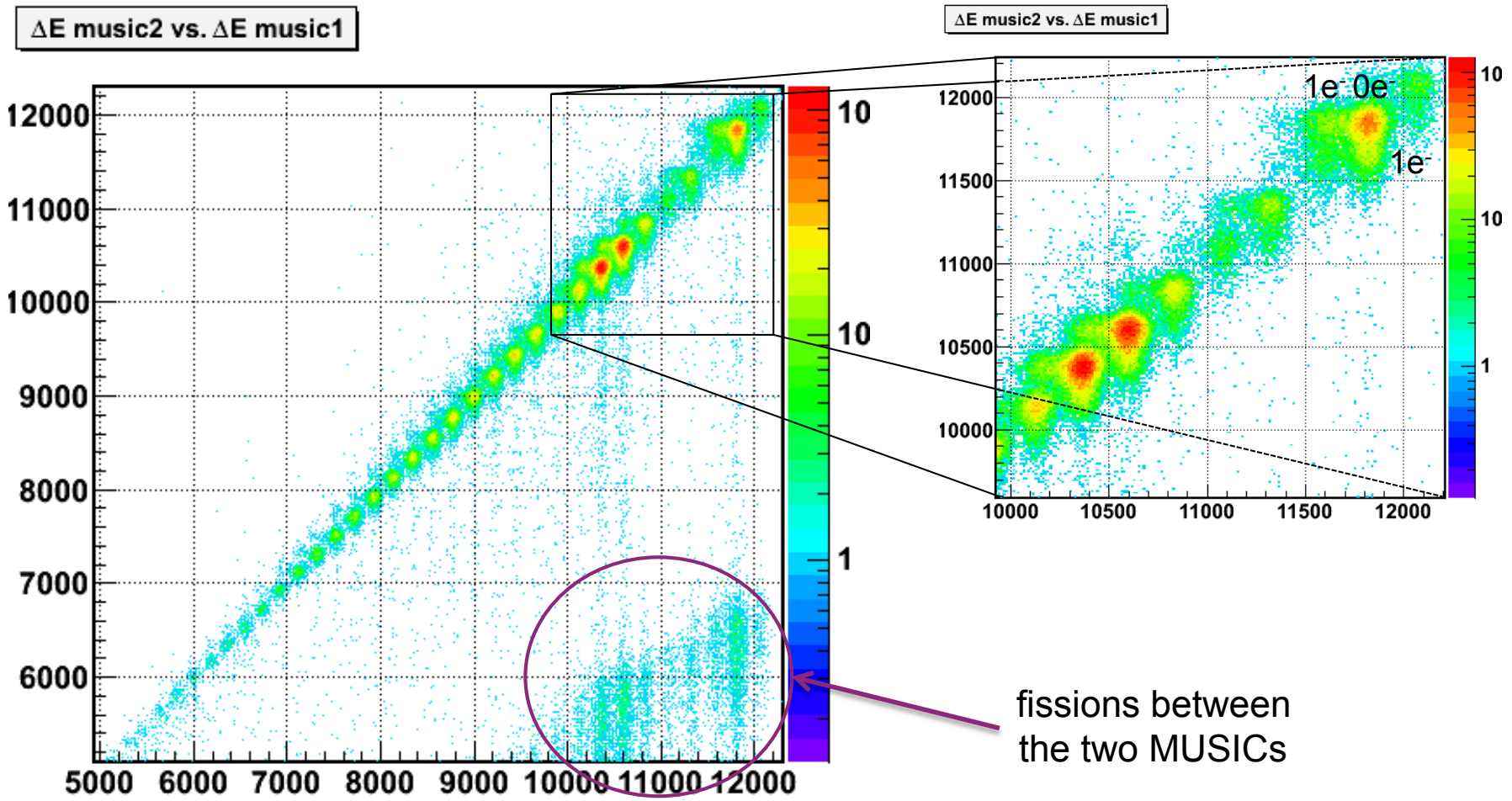
ΔE

MUSIC unambiguous determination of the charge of the incoming nuclei

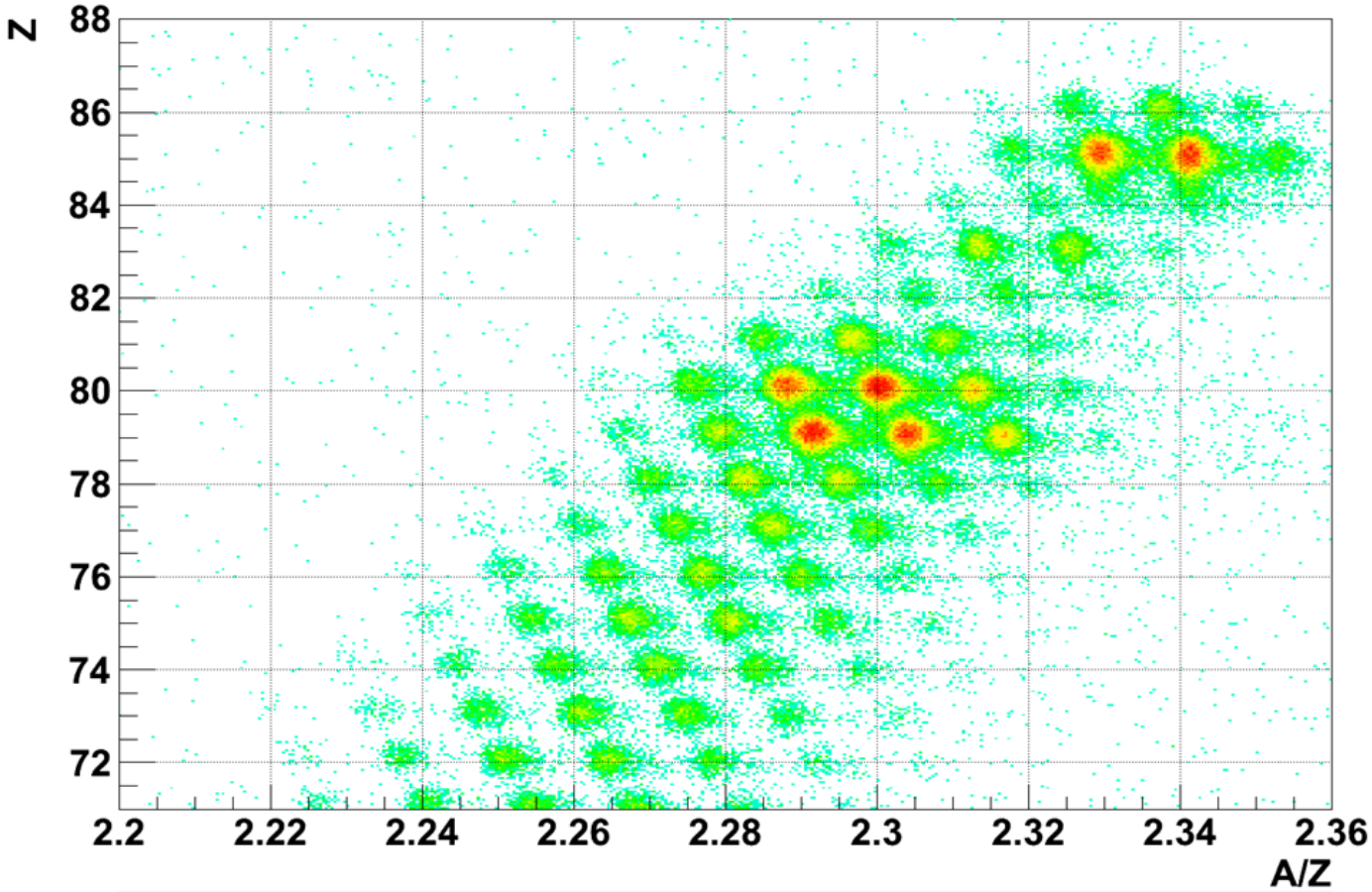


IDENTIFICATION OF THE SECONDARY BEAM NUCLEAR CHARGE

FRS setting: ^{200}Rn



IDENTIFICATION OF THE SECONDARY BEAM NUCLEAR CHARGE & MASS

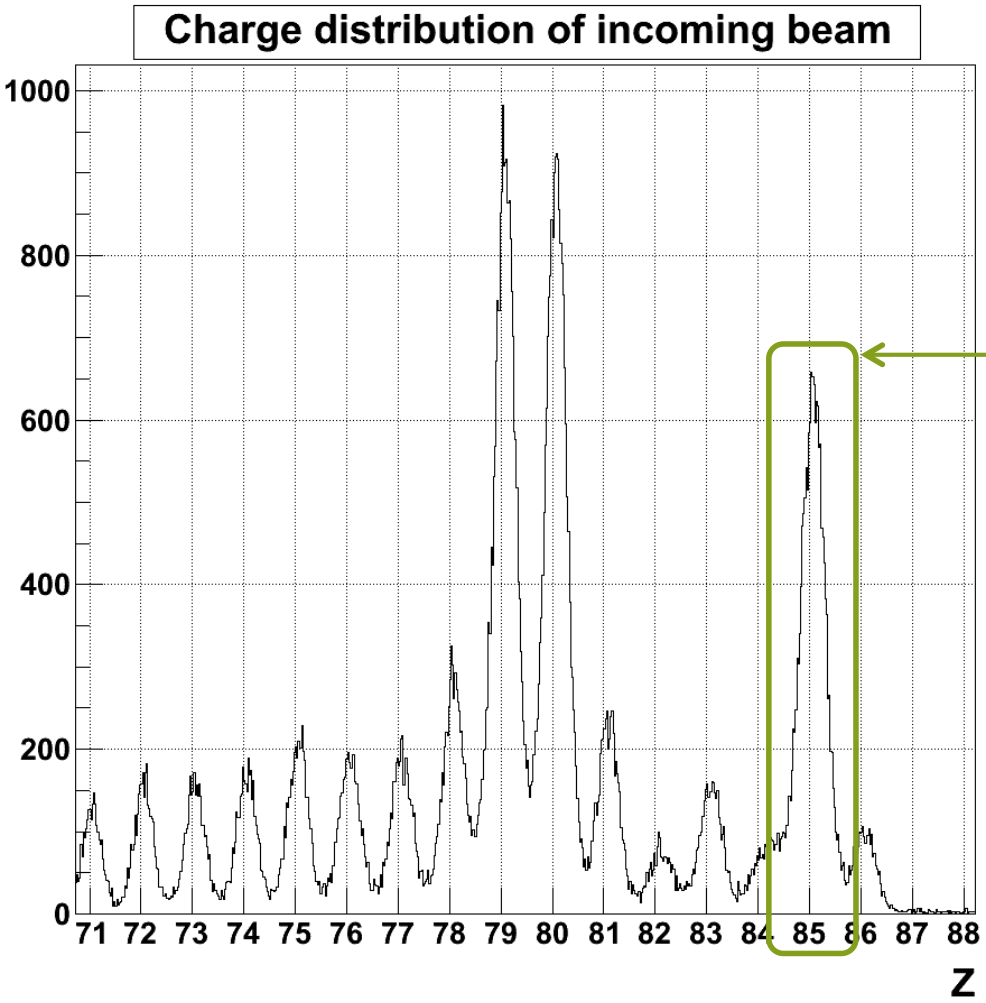


FRS setting: ^{200}Rn

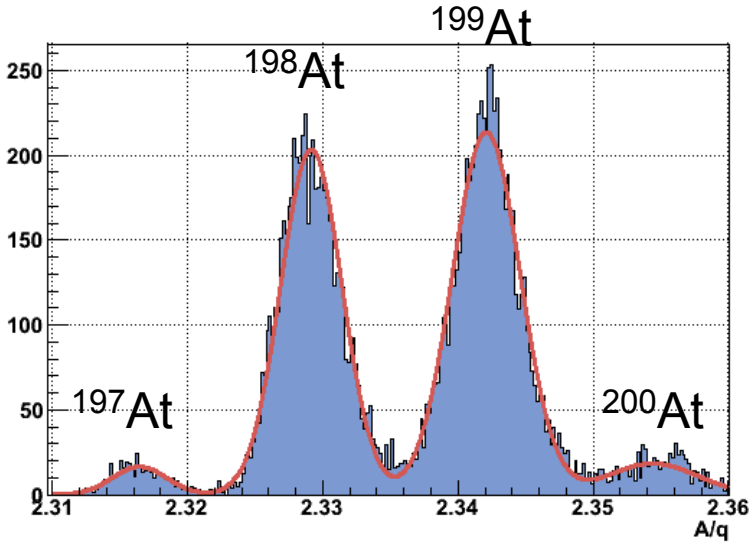
VERY GOOD IDENTIFICATION OF THE SECONDARY BEAM
BOTH IN CHARGE AND MASS (see next slide)

IDENTIFICATION OF THE SECONDARY BEAM NUCLEAR CHARGE & MASS

FRS setting: ^{200}Rn



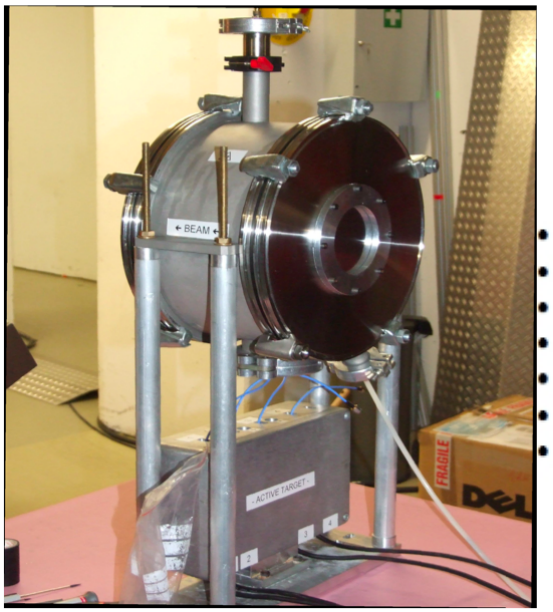
projection of A /q for Z = 85

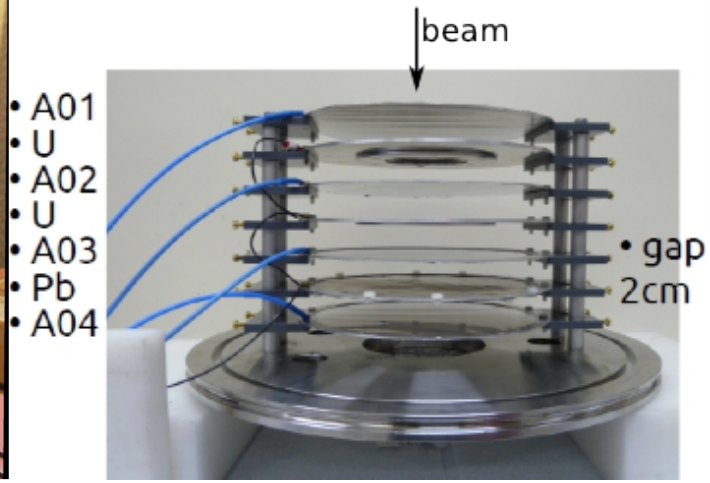


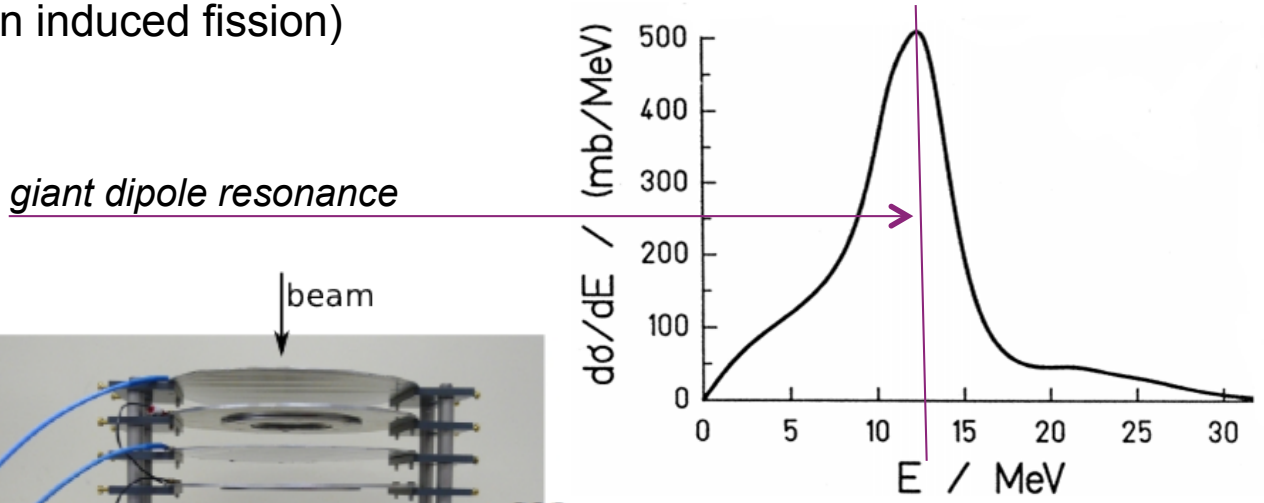
ACTIVE TARGET

once the projectile (A,Z) is identified, its fission is induced in our active target by *Coulomb excitation (COULEX)* in the vicinity of heavy target material (uranium)

→ GDR excitation of the projectile
(around 11 MeV ⇔ 6 MeV neutron induced fission)



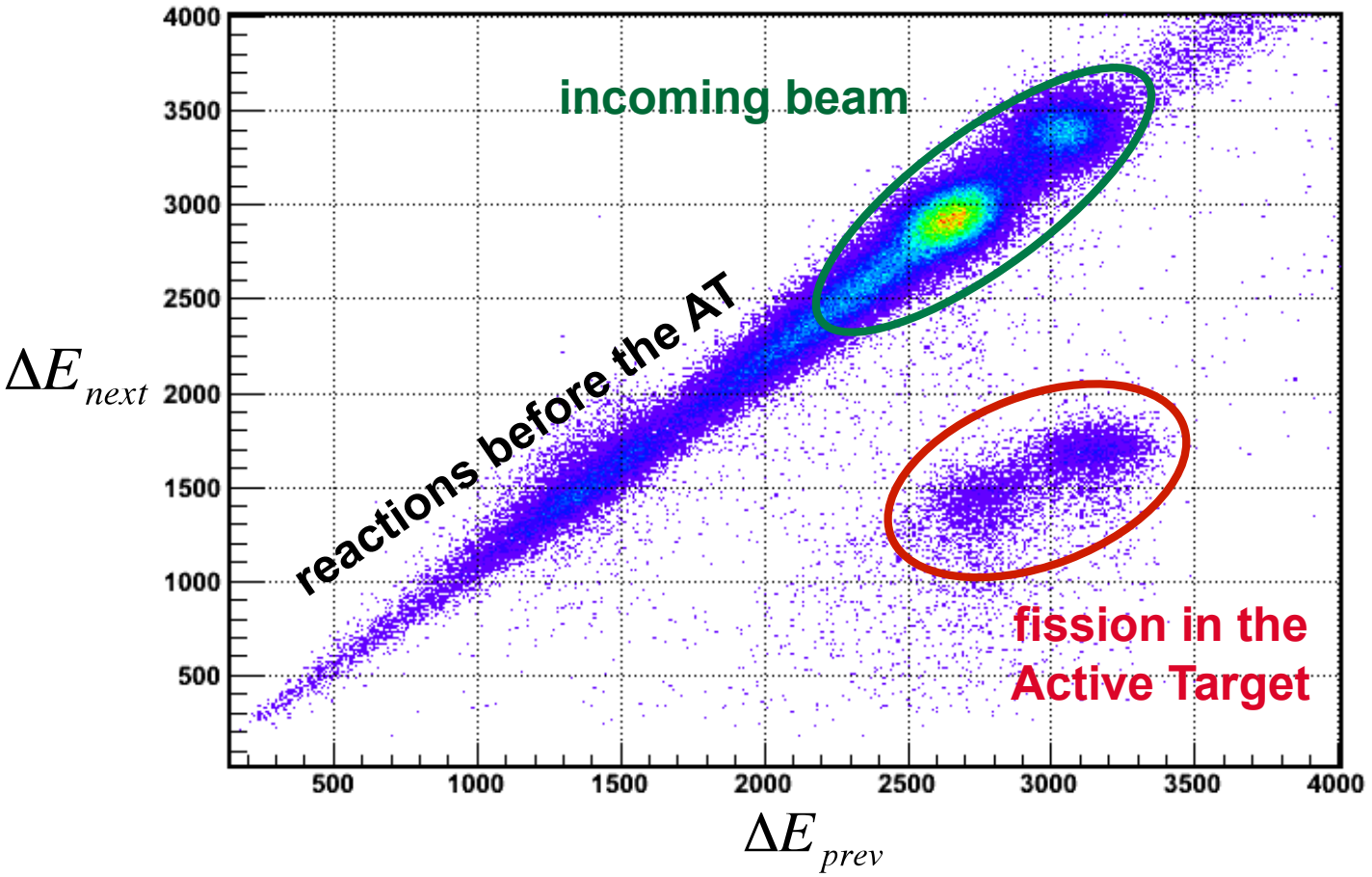




ACTIVE TARGET

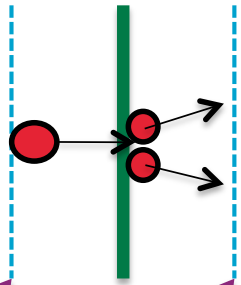
ENERGY LOSS IN THE ACTIVE TARGET

$$\Delta E \propto Z^2$$



if fission occurs

aluminium *(anode)* **uranium** *(cathode)*



$$\Delta E_{prev} \propto Z^2$$

$$\Delta E_{next} \propto 2 \times \left(\frac{Z}{2}\right)^2$$

$$\approx \frac{\Delta E_{prev}}{2}$$

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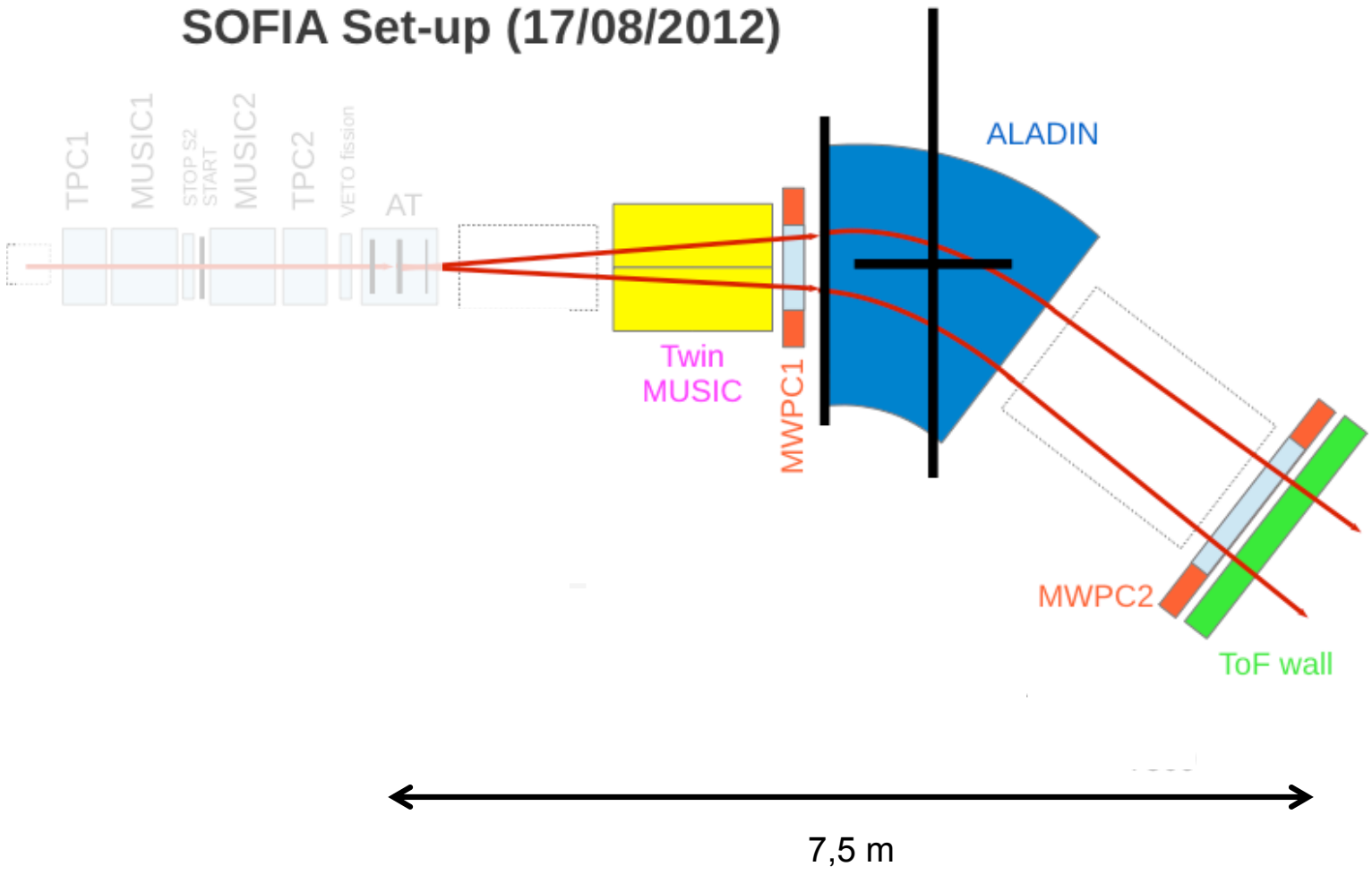
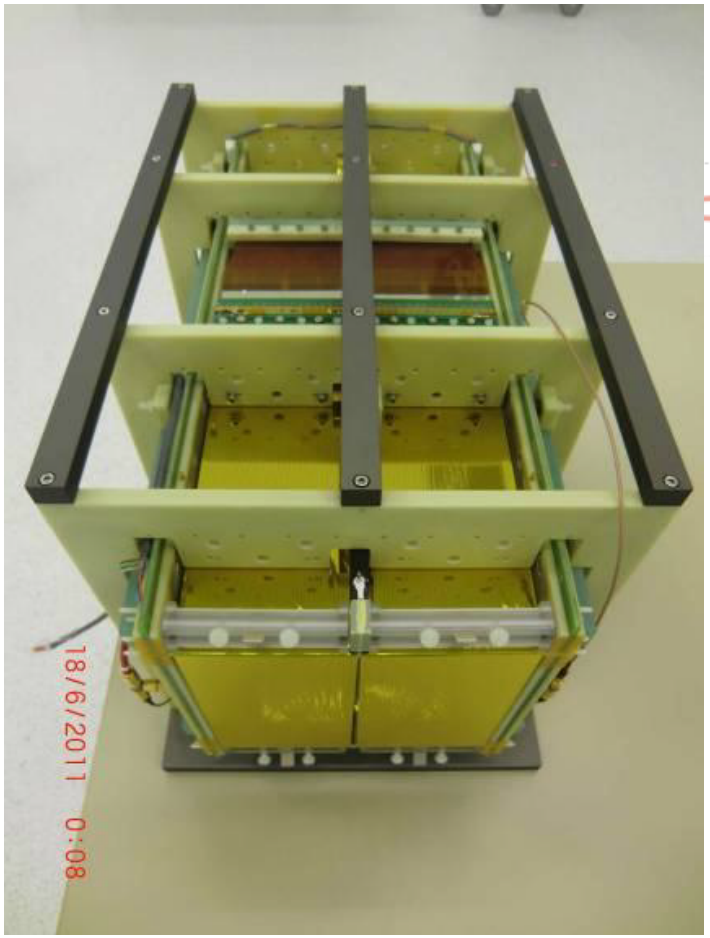
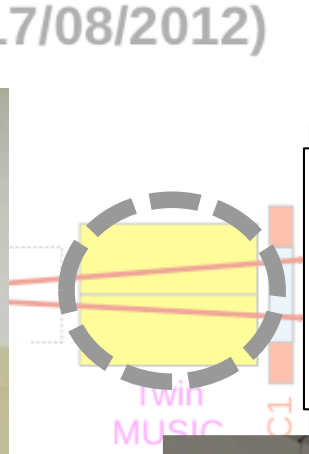
IDENTIFICATION OF THE FISSION FRAGMENTS



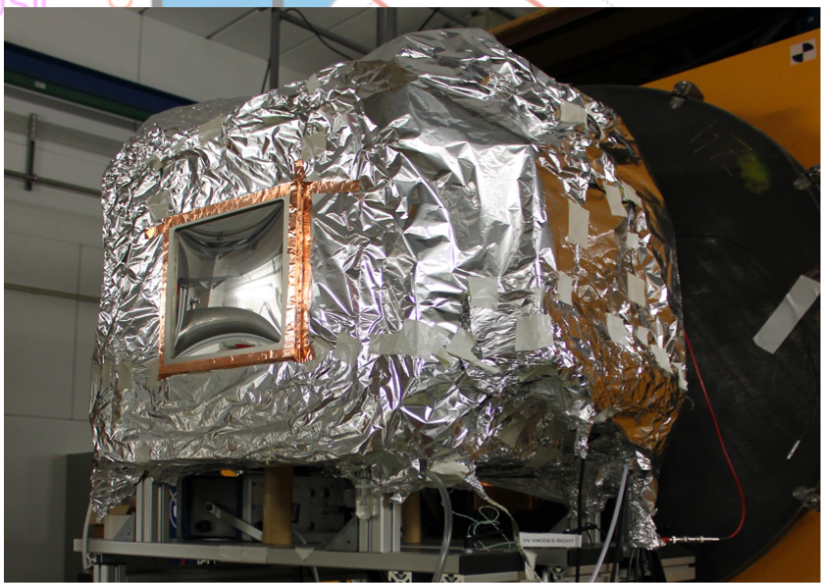
IDENTIFICATION OF THE FISSION FRAGMENTS

ΔE





two identical volumes of detection
500 x 100 x 200 mm^3
with common central cathode
and 10 anodes on each side



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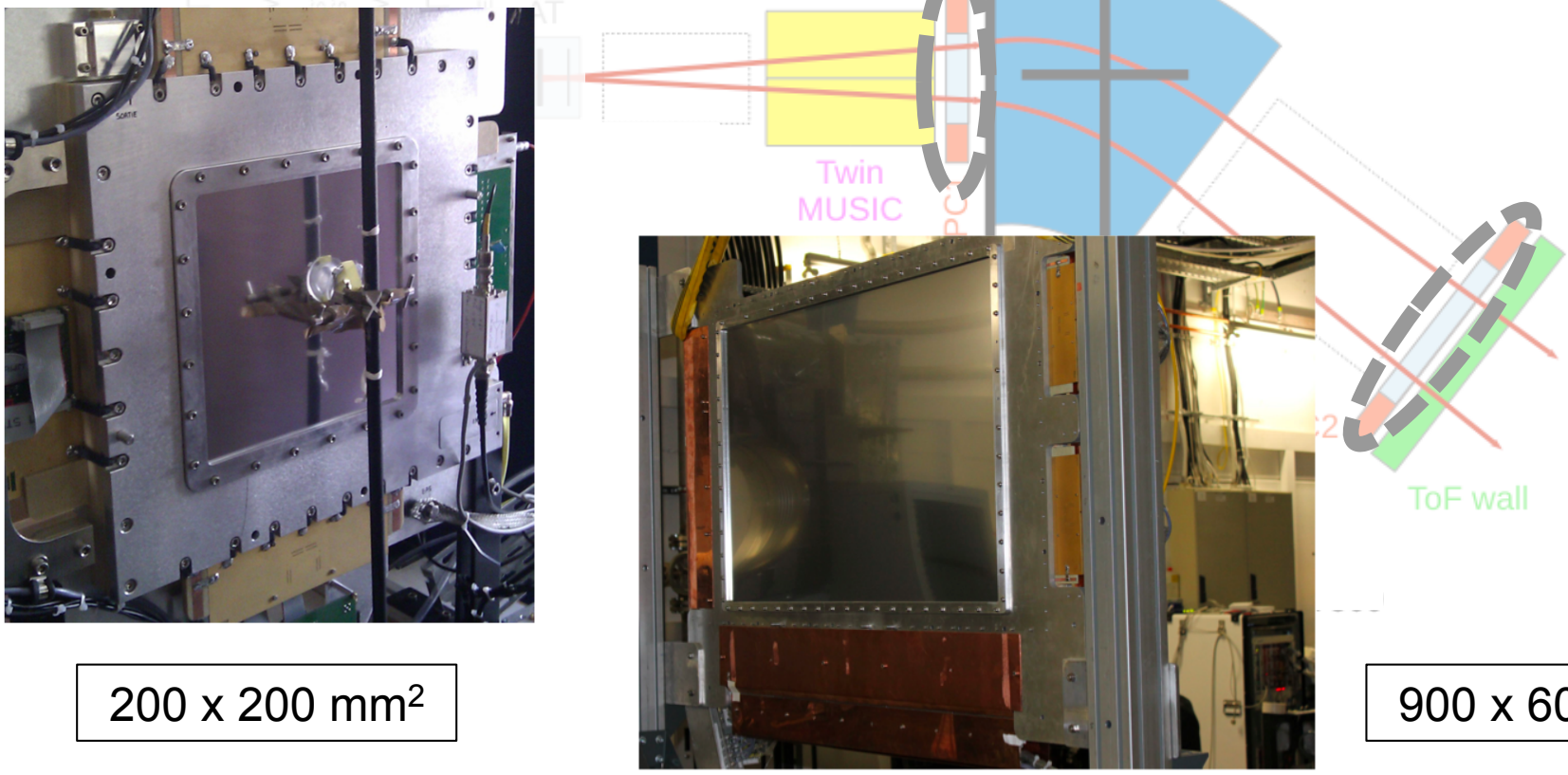
IDENTIFICATION OF THE FISSION FRAGMENTS

Bρ



200 x 200 mm²

900 x 600 mm²

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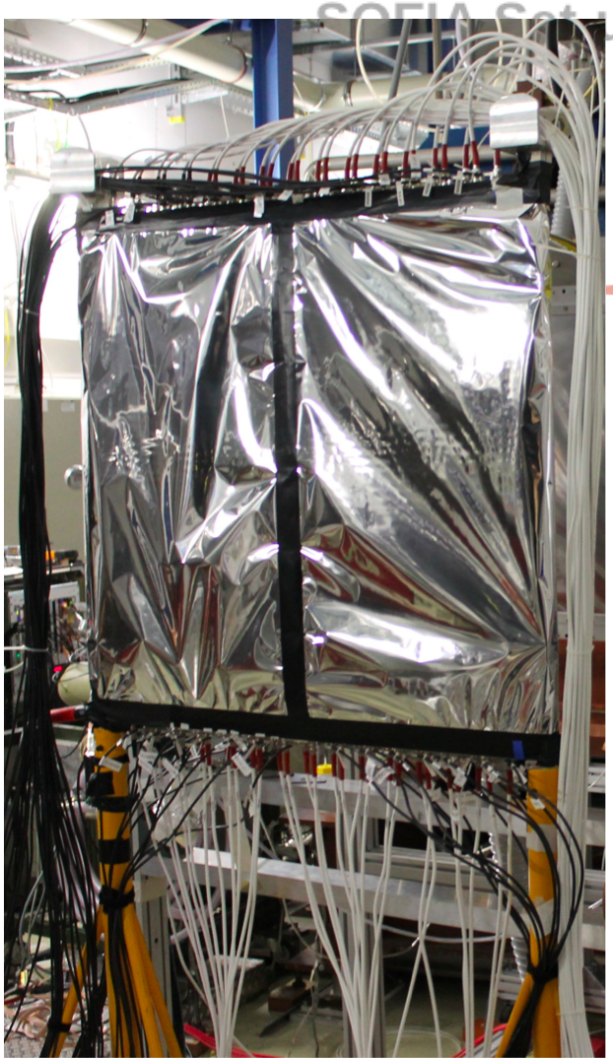
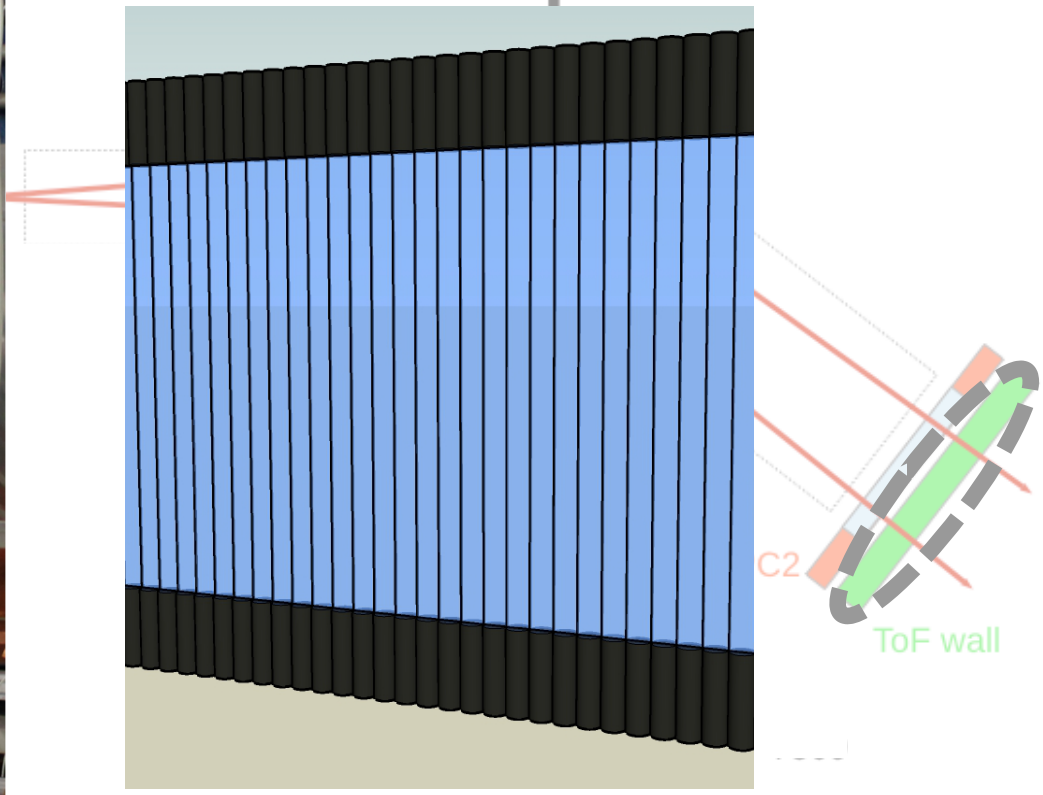
IDENTIFICATION OF THE FISSION FRAGMENTS

ToF

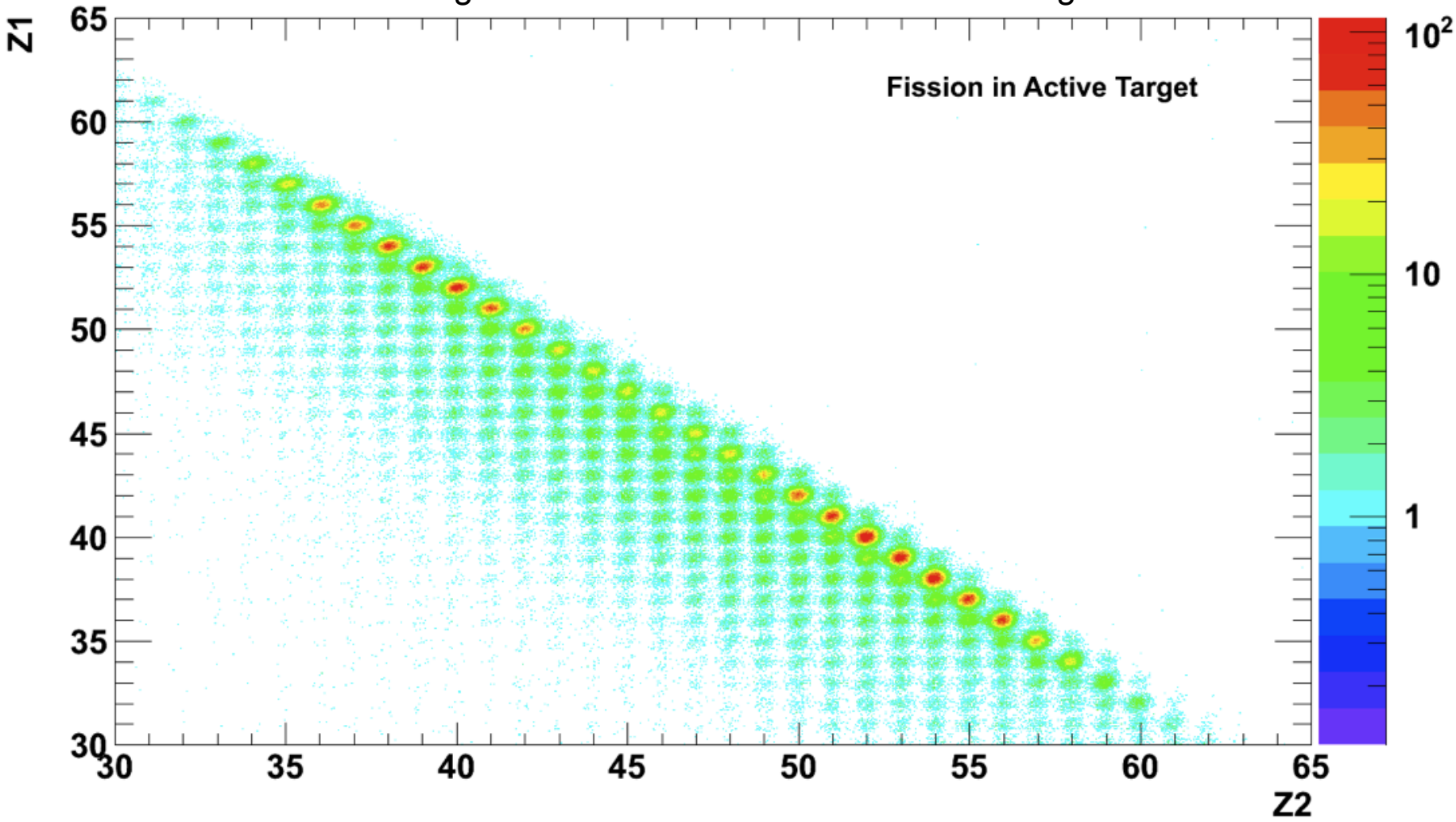




28 scintillators read at both side by PMT

COULEX-induced fission of ^{235}U

the nuclear charge correlation between the 2 fission fragments

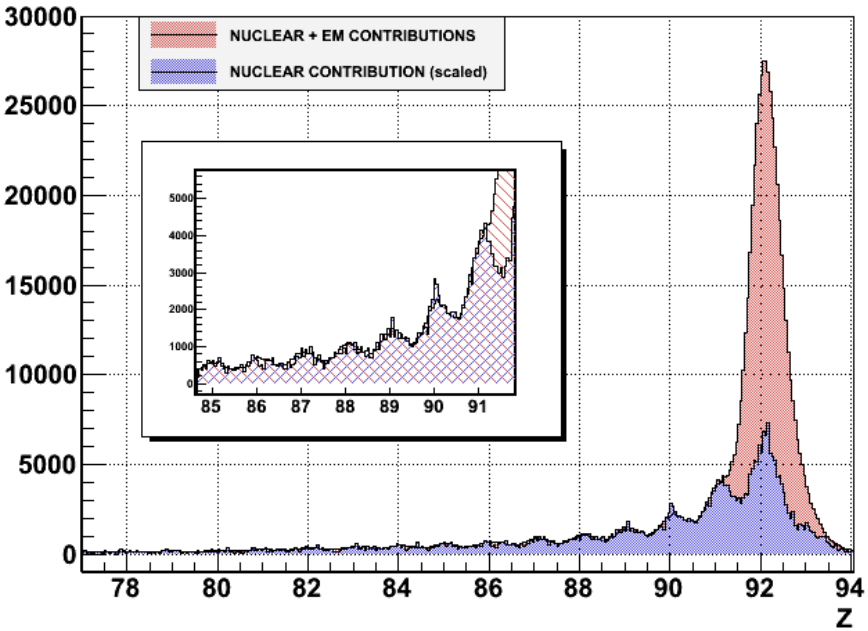


COULEX-induced fission of ^{235}U

the fragmentation-fission background substraction

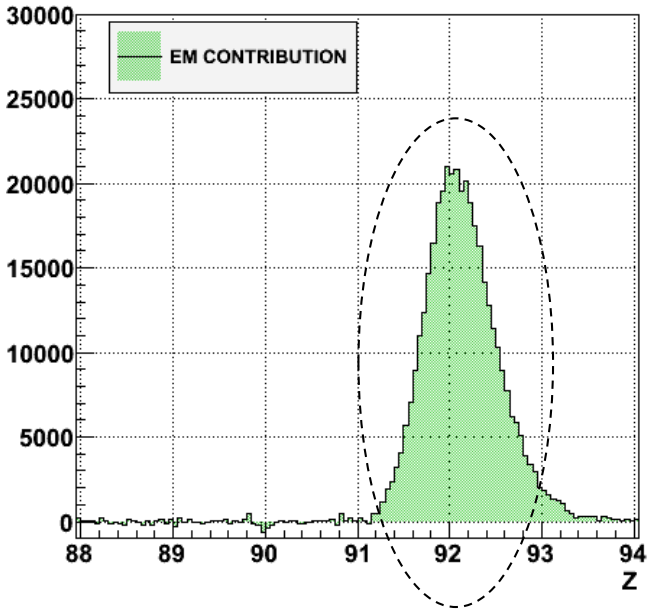
PRELIMINARY

$Z_{HF} + Z_{LF}$ ($Z_{BEAM} = 92$)
fission in uranium* / aluminium*



* nuclear + electromagnetic fission
* nuclear fission

electromagnetic fission in uranium
after nuclear contribution removal



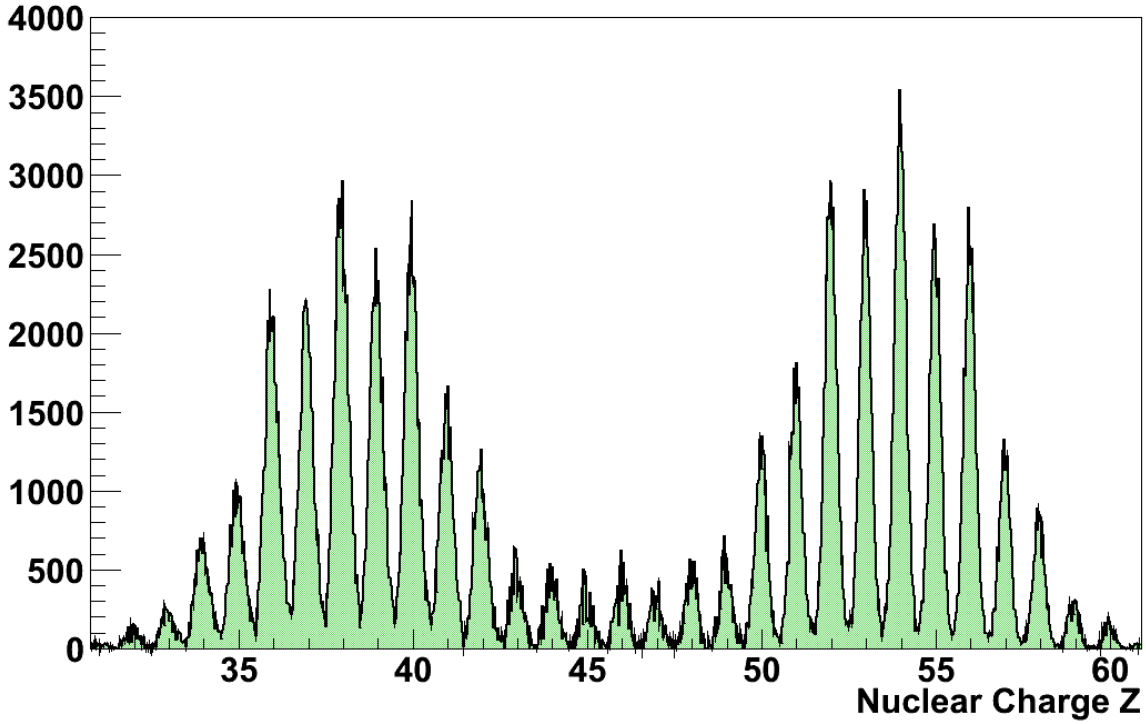
COULEX-induced fission of ^{235}U

the nuclear charge yield

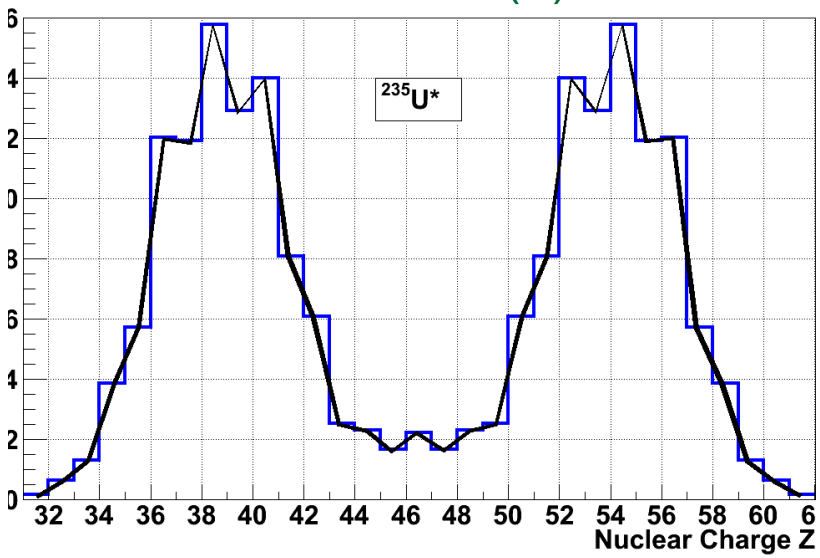
PRELIMINARY

FF charge distribution ($Z_{HF}+Z_{LF}$ = 92) (Z_{BEAM} = 92)

after nuclear contribution removal



FF Yield Y(Z)



nice odd-even staggering + asymmetric / symmetric

➔ mean E* is about 6 MeV equivalent neutron

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MOST EXOTIC SETTINGS !

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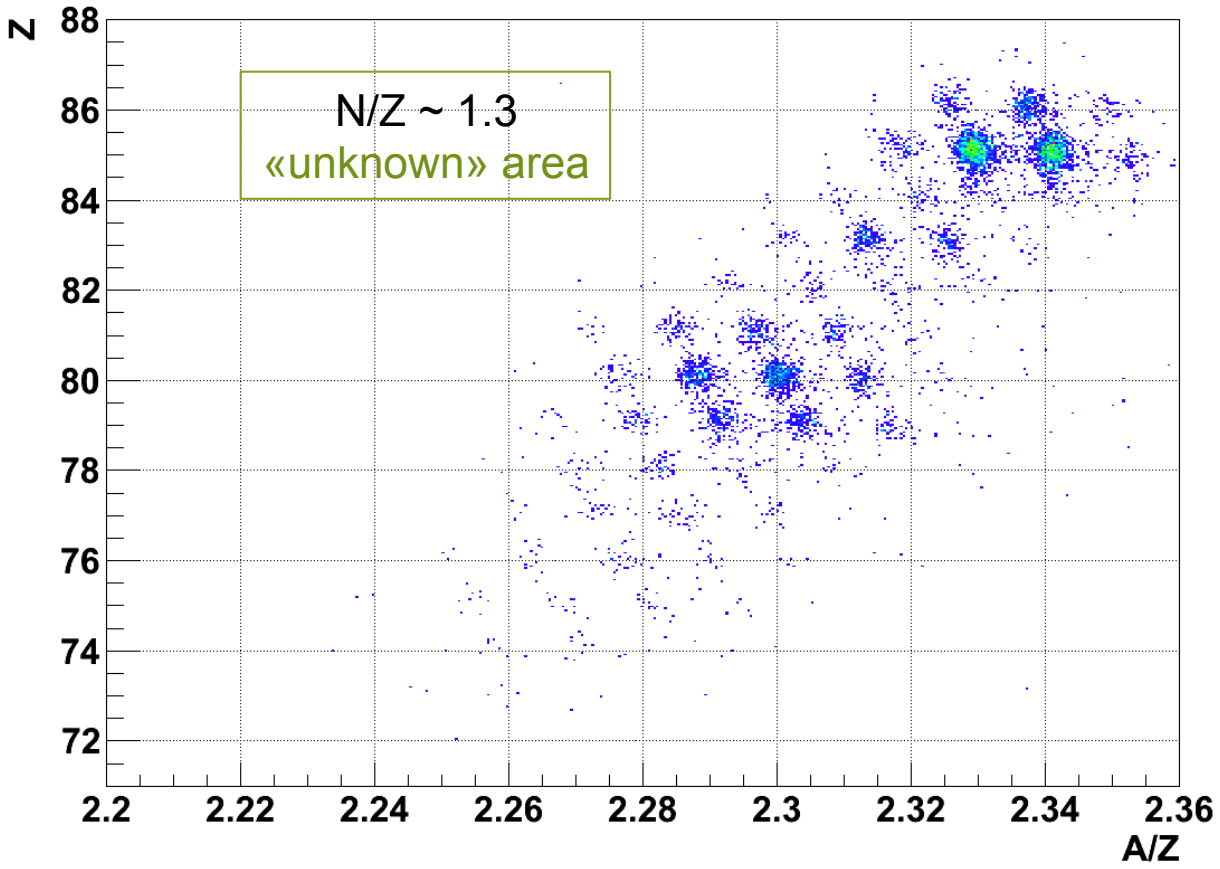
Z vs. A / Z – Fission in Active Target



(NON-EXHAUSTIVE)
LIST & STATISTICS
OF FISSIONNING NUCLEI:

FRS setting:
^{200}Rn & ^{202}Rn

^{205,206}Fr	≈ *a few* 10^1
^{201,202,203,204}Rn	≈ 10^2 - 10^3
^{198,199,200,201,202}At	≈ *a few* 10^2
^{192,193,194,195,196}Bi	≈ *a few* 10^1
^{186,187,188,189}Tl	≈ 10^1
^{183,184,185,186,187}Hg	≈ *a few* 10^1

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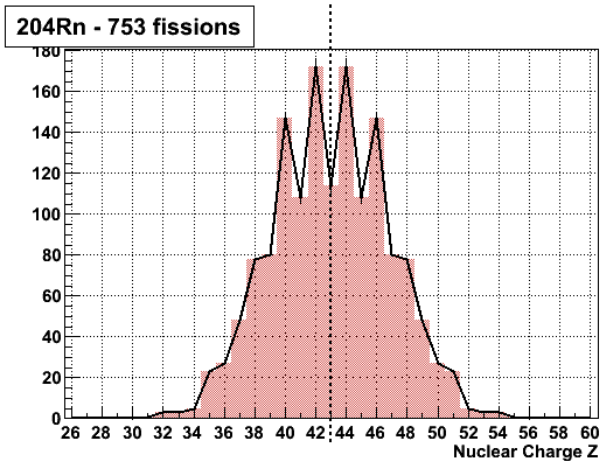
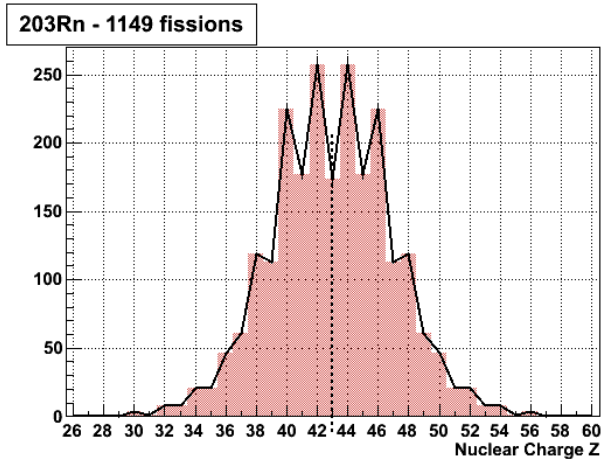
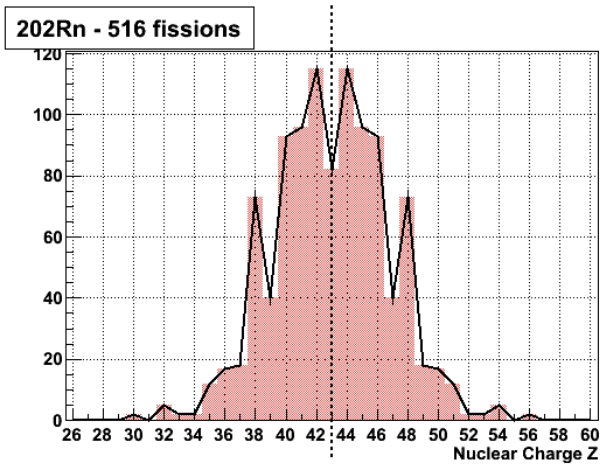
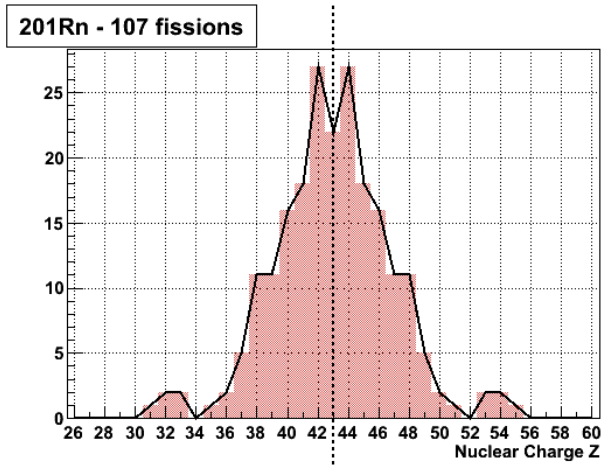
RADON ISOTOPIC CHAIN - N/Z ≈ 1.34 – 1.37









- ^{204}Rn compatible with data by K.-H. Schmidt *et al.*
- ***strong odd-even staggering***
- not neutron-deficient enough to see transition from symmetry to asymmetry… ?

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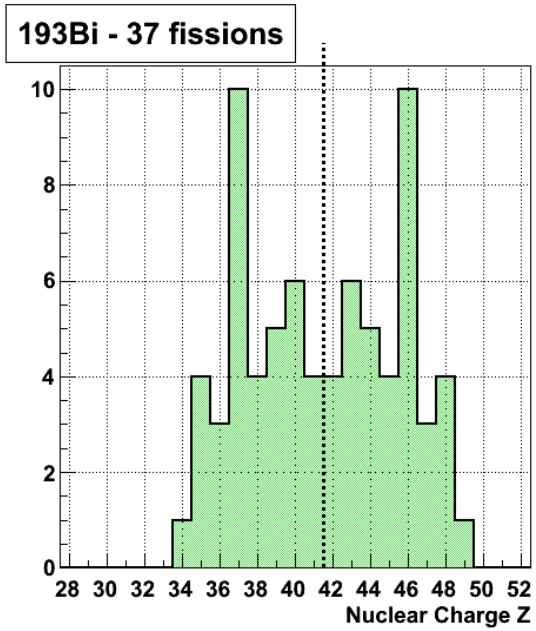

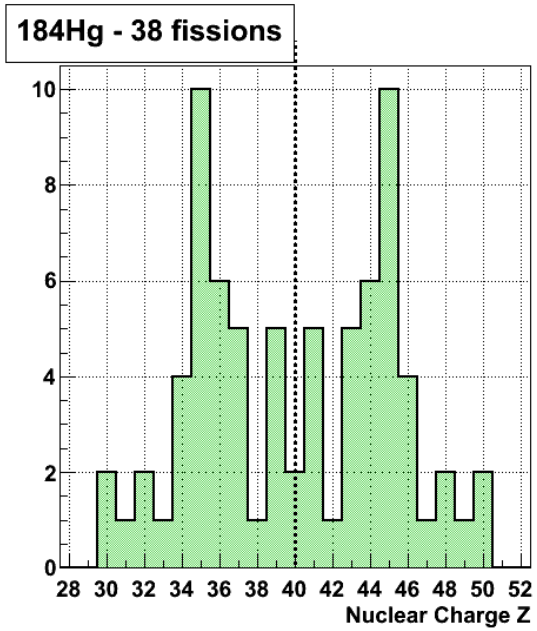

N/Z ≈ 1.32 – 1.30

even if statistics is low,

asymmetric behavior

is clearly visible

(ongoing analysis for other nuclei)

CONFIRMATION OF ASYMMETRIC BEHAVIOR IN THIS MASS REGION

AS FIRST SEEN BY A. ANDREYEV *ET AL.*

CONCLUSIONS

- VERY PROMISING RESULTS CONCERNING HEAVY ACTINIDES

- ON-GOING ANALYSIS CONCERNING NEUTRON-DEFICIENT NUCLEI

  PRELIMINARY RESULTS: TOO SOON TO MAKE ANY CONCLUSIONS ON PHYSICS YET

- HOWEVER REGION OF $N/Z \approx 1.3$ SEEMS REALLY INTERESTING …

  PLANS TO INVESTIGATE THIS REGION WITH UPDATED SOFIA SETUP AND (OBVIOUSLY) MORE STATISTICS IN THE BEGINNING OF 2014

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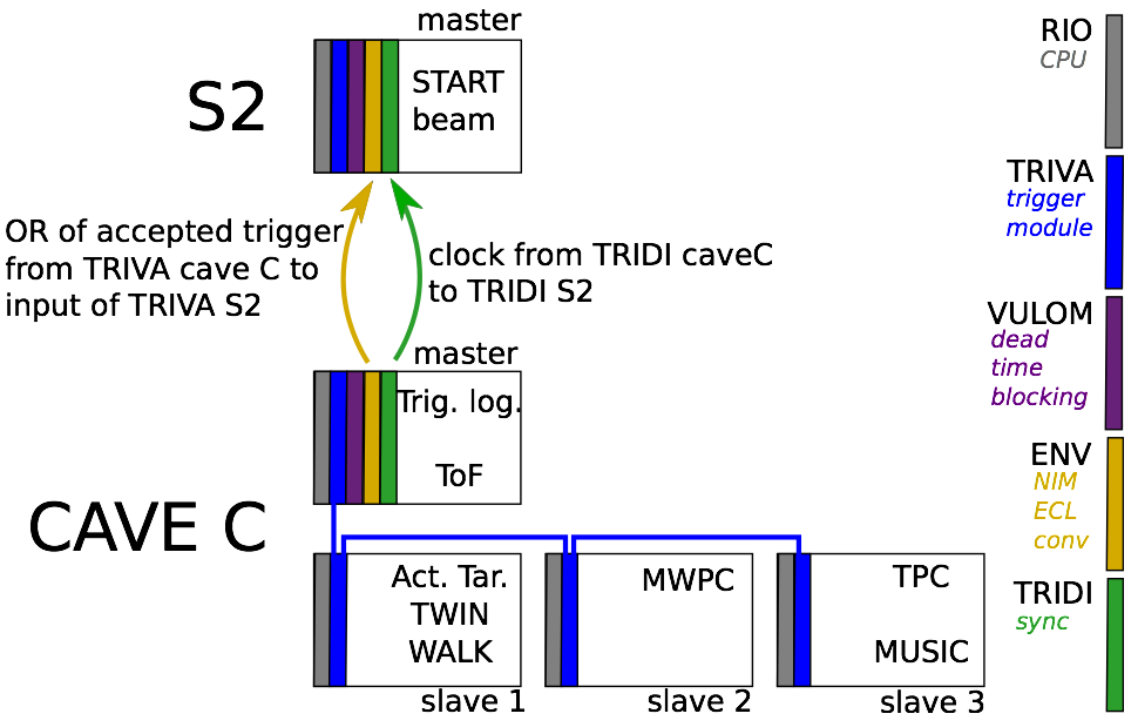
electronic and data flow issues (1/2)

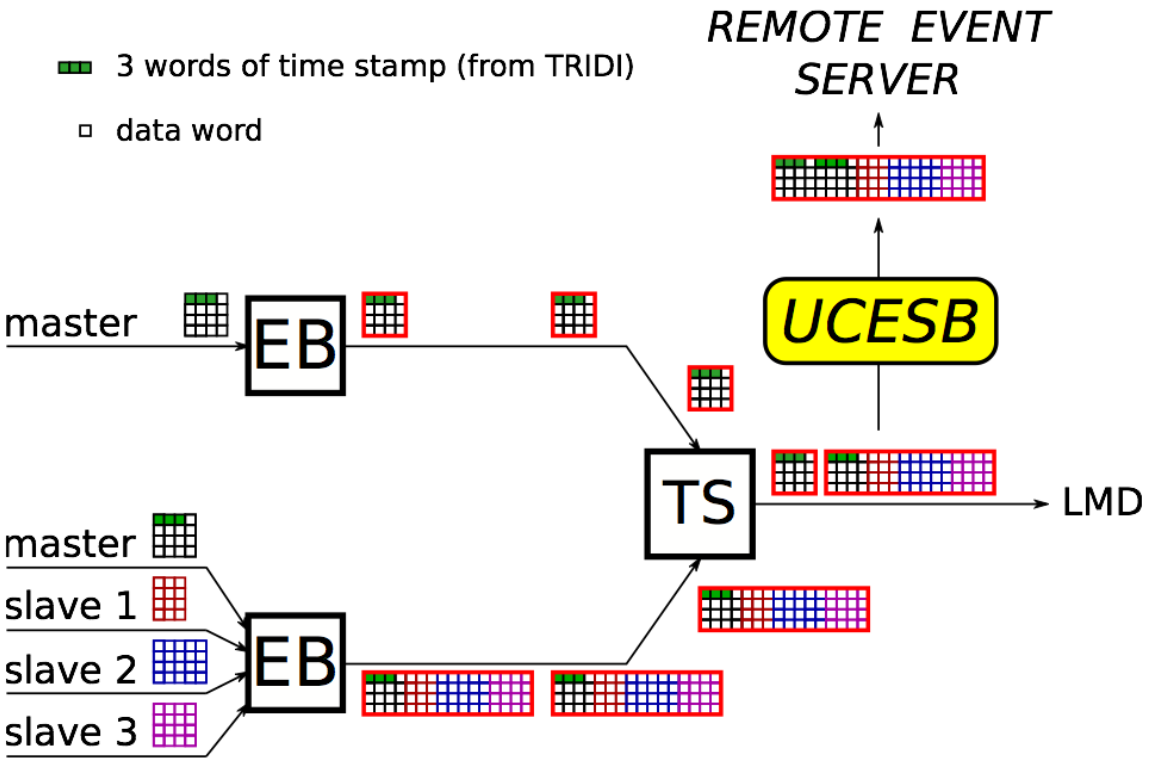
distance between S2 (dispersive focal plane of FRS spectrometer) and Cave C: **140 m !**



electronic diagram

- for some technical reasons impossible to use a single DAQ
- solution: two independent acquisitions "synchronized" together via *TRIDI* modules (TRIggerDIstribution)

electronic and data flow issues (2/2)



data flow diagram

- *TRIDI* time stamps every single event at Cave C and S2

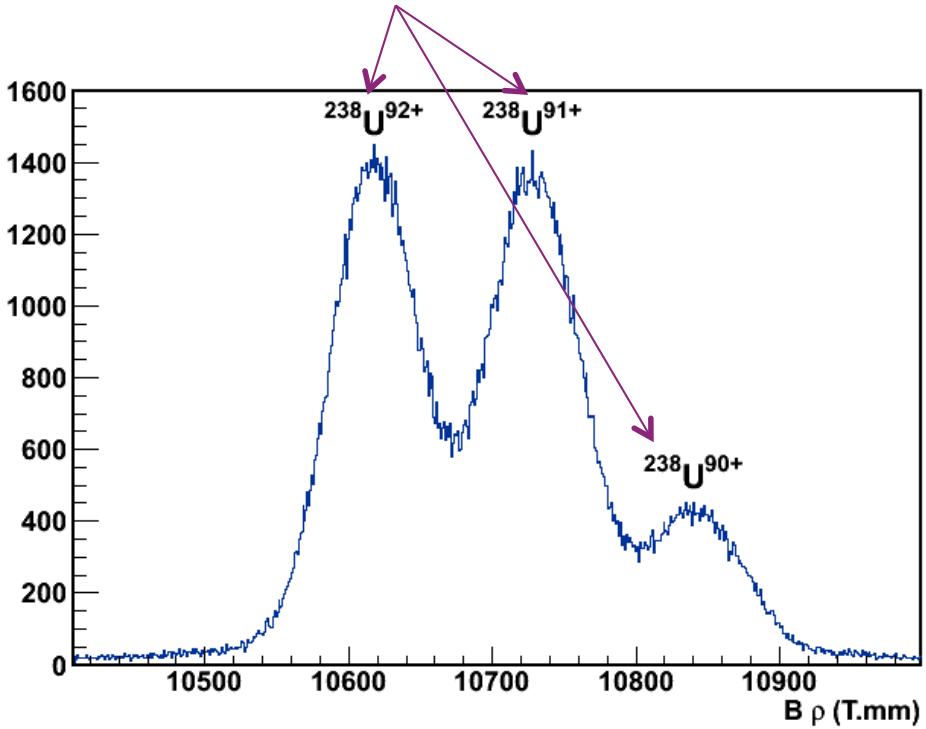
- the two data flows then go through a time sorter algorithm which "merge" the two corresponding events
(merging is based on a time window criterion)

- TRIGGER = two plastics fired on the ToF wall (2x2 PMT)
(logical algorithm implemented in the FPGA of the trigger module *VUPROM*)

mass reconstruction to be done:

we need the Bρ and the time-of-flight

preliminary Bρ reconstruction for ^{238}U (primary beam) after the dipole ALADIN
⇒ 3 charge states



more difficult to extract – we need:

- walk correction (due to the CFDs) of all ToF channels (energy dependence of the ToF signal)
- precise calibration in absolute time of all plastics (rough calibration done for ΔE(β))

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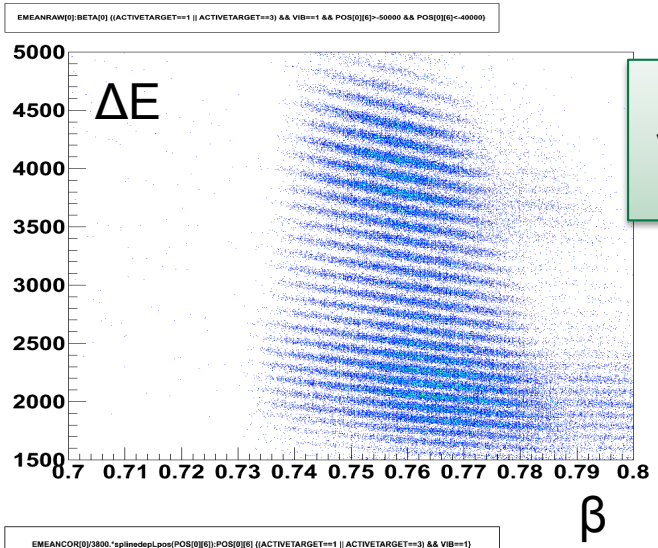
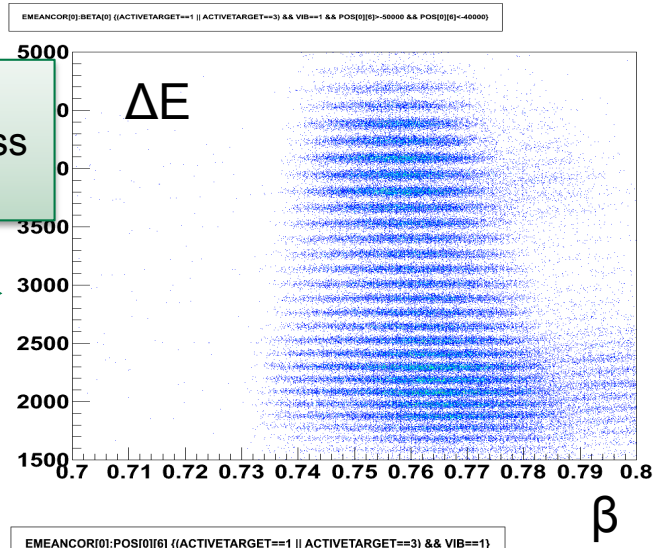
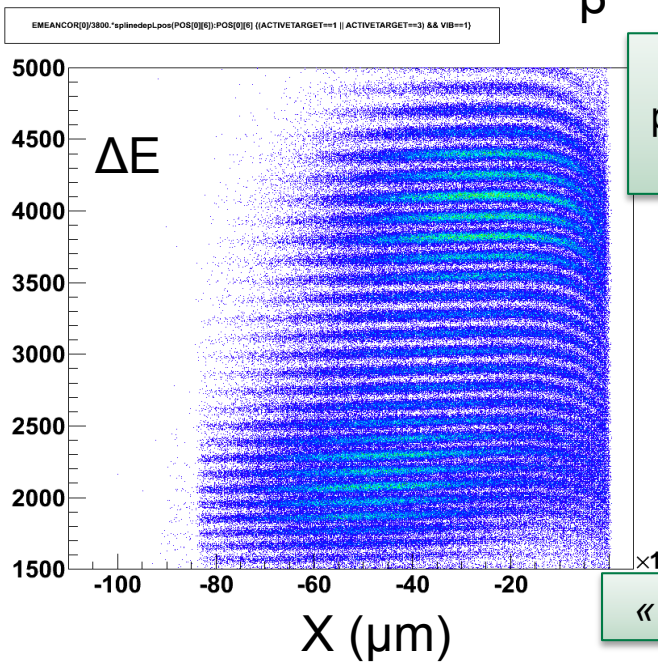
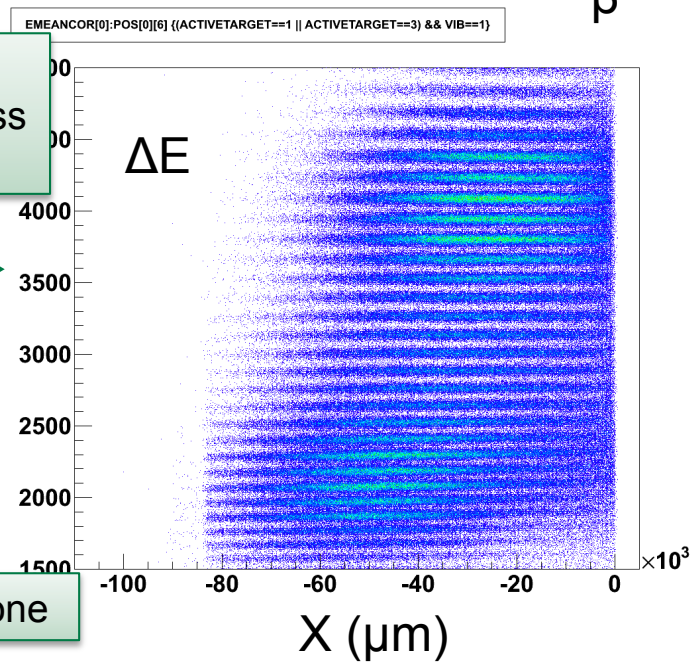


ΔE(β) → ΔE
velocity correction of energy loss in the Twin Music





ΔE(x) → ΔE
position correction of energy loss in the Twin Music



« cross-talk » correction to be done