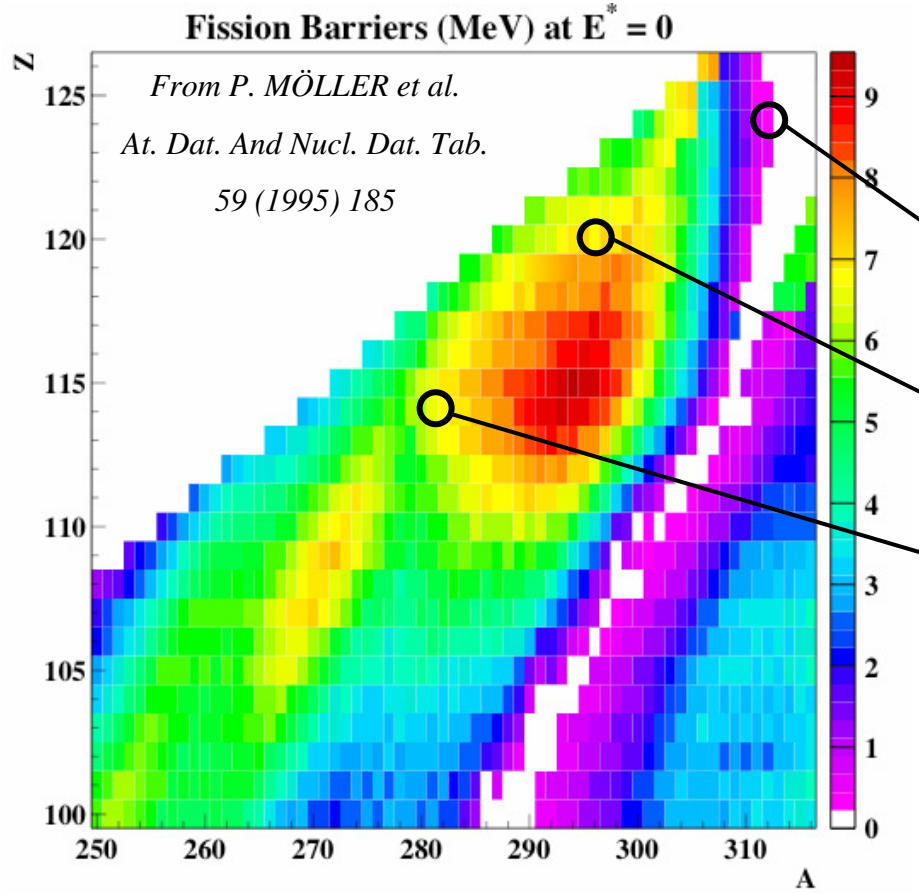
Detection of long fission times of super-heavy compound nuclei

- Where is the stability island of Super-heavy Elements ?
- Fission barrier ⇔ Fission times
- The blocking technique in single crystals
- Experiments on Z=114, 120 and 124 compound nuclei
- Hints of strong shell effects in Super-Heavy Nuclei

Stability of SHE

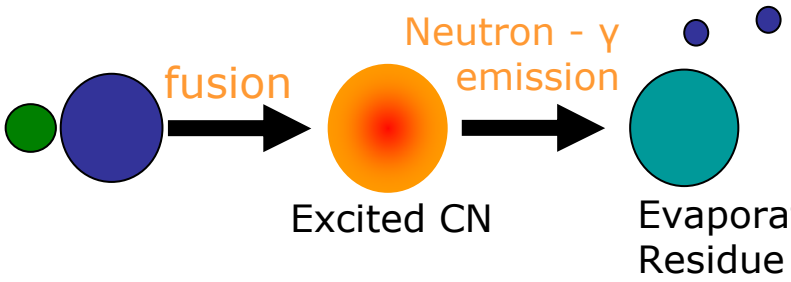


Z	B_f (MeV) *Möller et al.*	B_f (MeV) *Berger et al.* *
124 , 312	0.2	10.8
120 , 296	6.8	11.0
114 , 282	6.7	6.3

*** HFB calculations by J.F. Berger et al., *Nucl.Phys.A685 (2001) 1***

Large uncertainties in model

Direct Studies

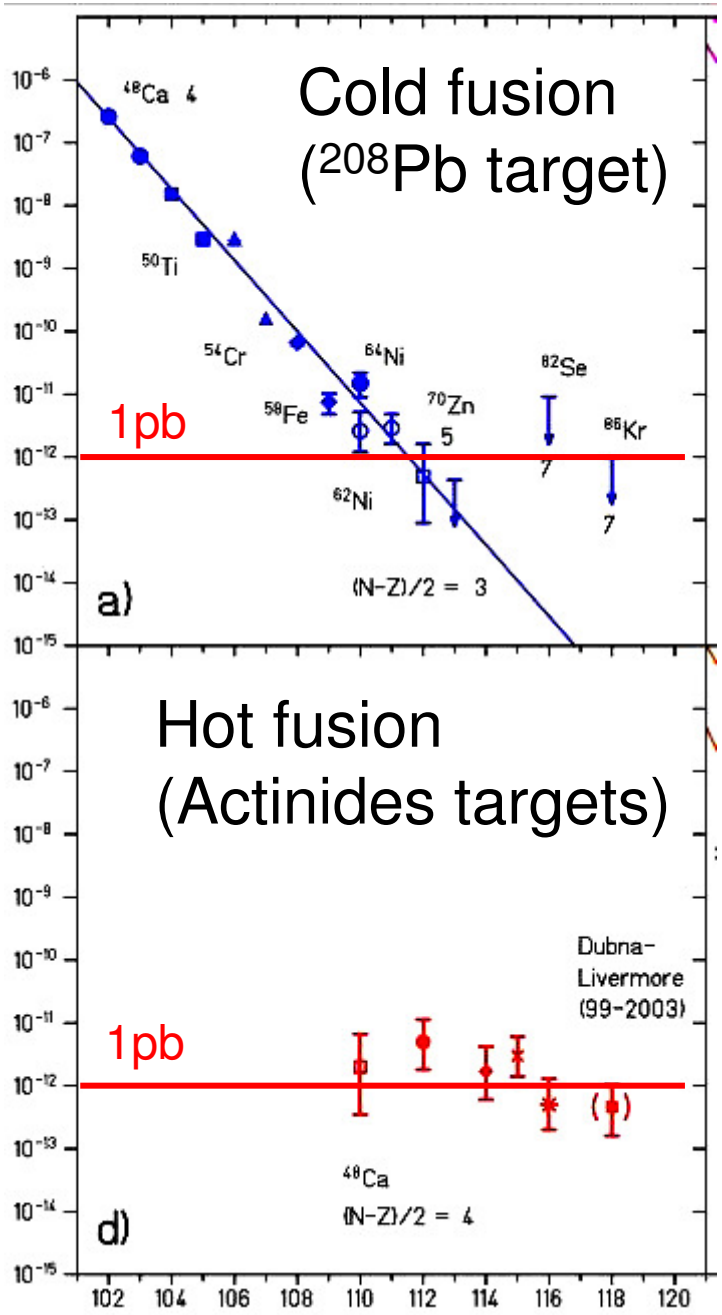


Very low production cross sections

1pb ➔ 1 event / week

Structure studies are impossible For Z>110

➔ Study of a more dominant mechanism: fusion-fission



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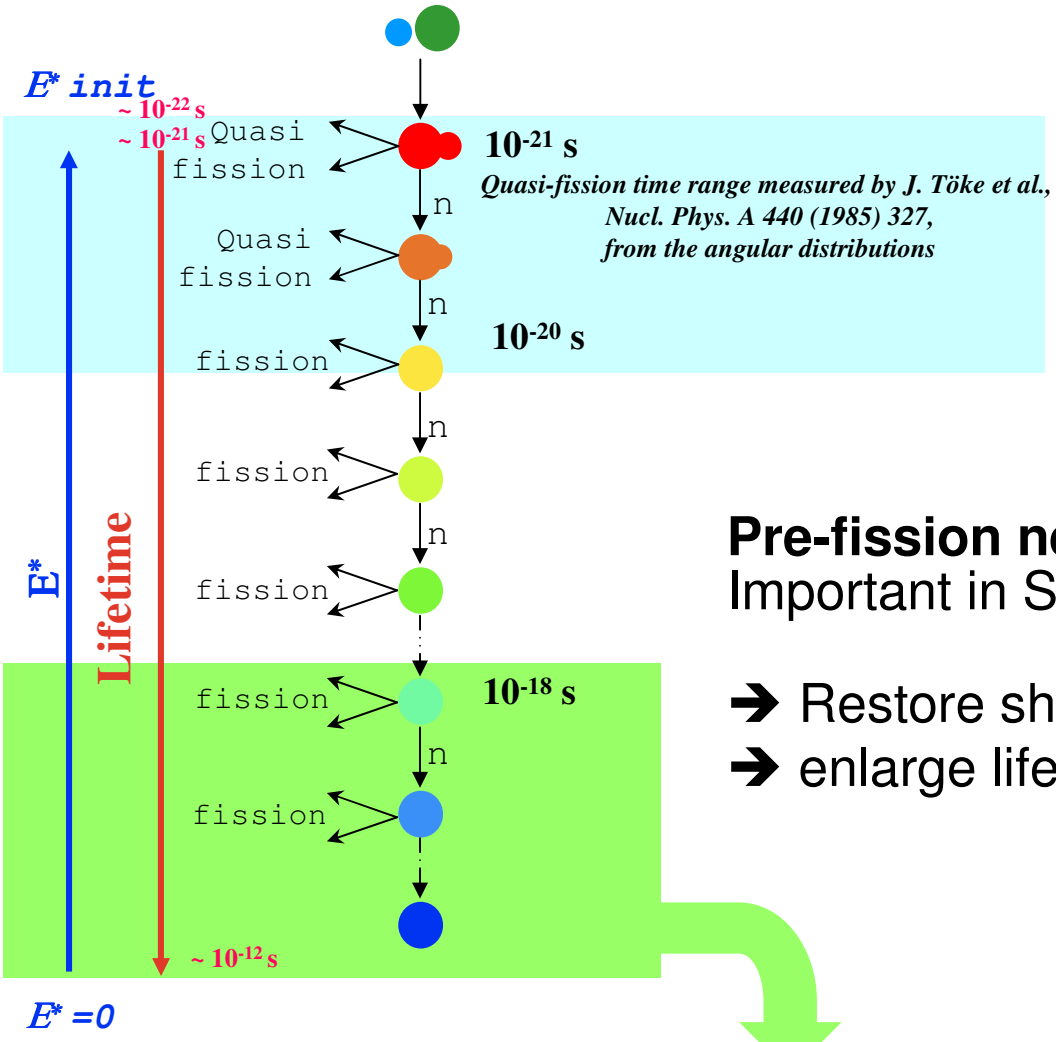
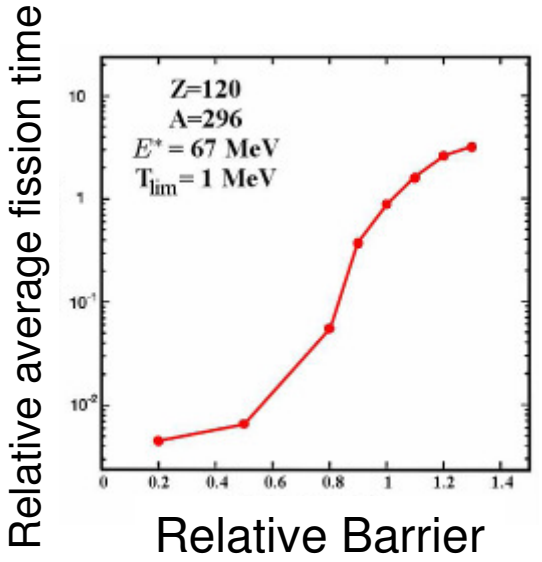
Fission Process



Quasi-fission time range measured by J. Töke et al., Nucl. Phys. A 440 (1985) 327, from the angular distributions



Pre-fission neutron emission
Important in Superheavy systems

M.G. Itkis & al, NPA 734 (2004) 136

➔ Restore shell effect
➔ enlarge life-times

Direct Measurement of fission times with the blocking technique

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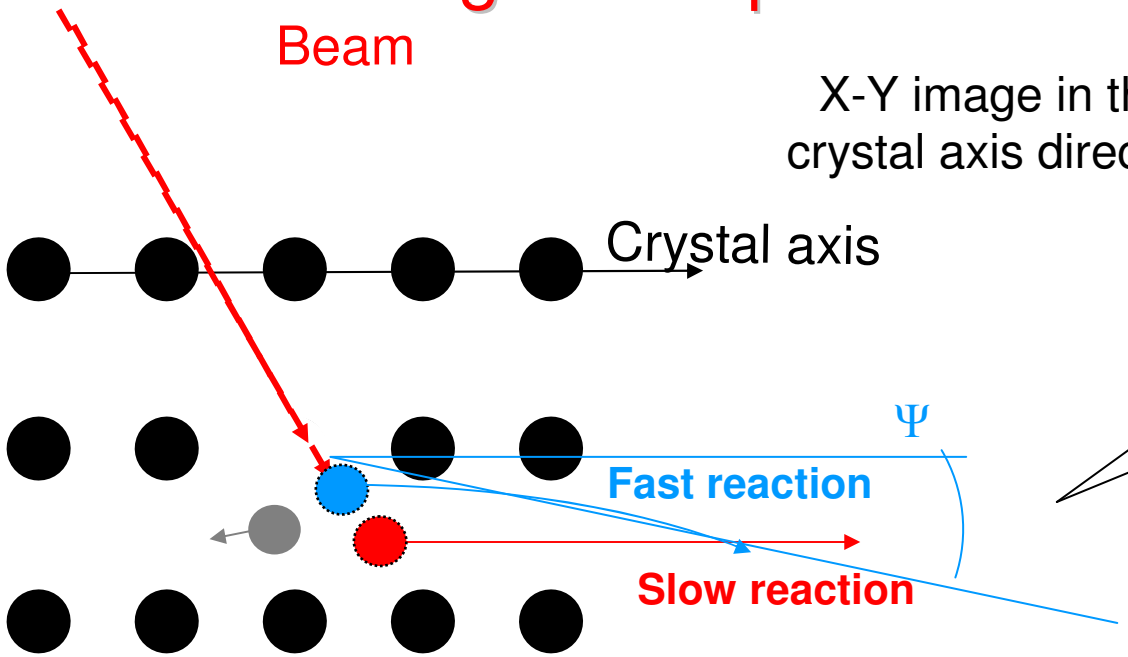
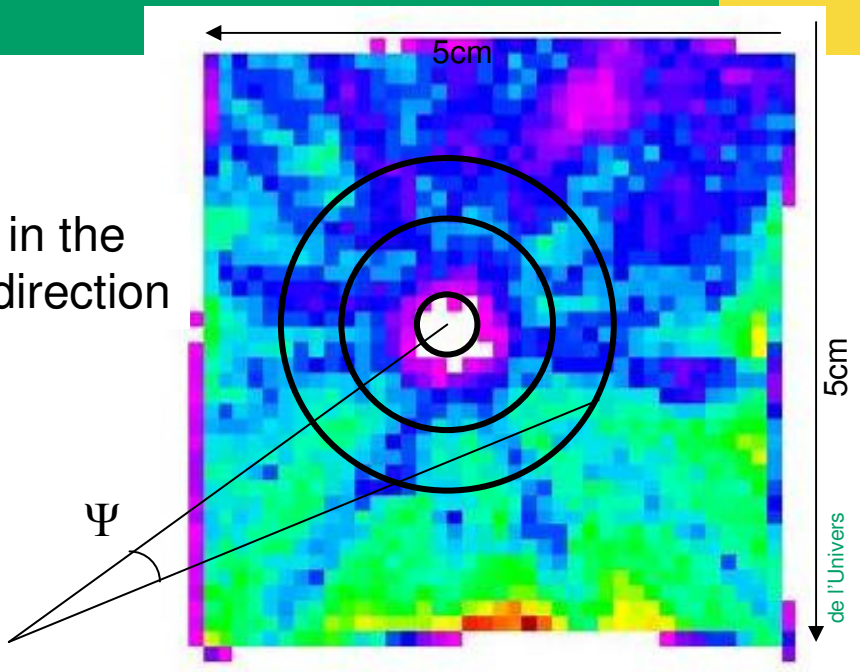
The Blocking technique



X-Y image in the crystal axis direction



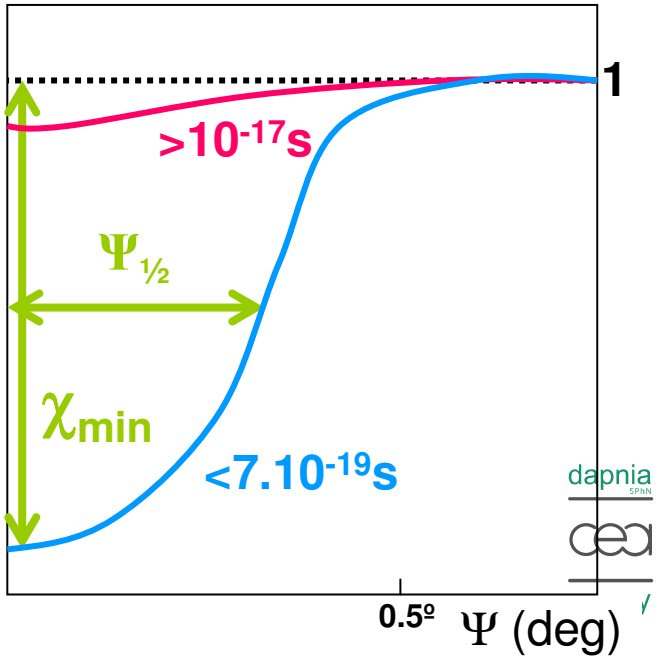
Collective effect of deviation Due to the crystal rows

Blocking dip (χ_{min}) ⇔ recoil distance of the CN

Limit : Thermal vibrations / velocity of nucleus

χ_{min} doest **not** depend on Z or E of nucleus but on the 1st order on:

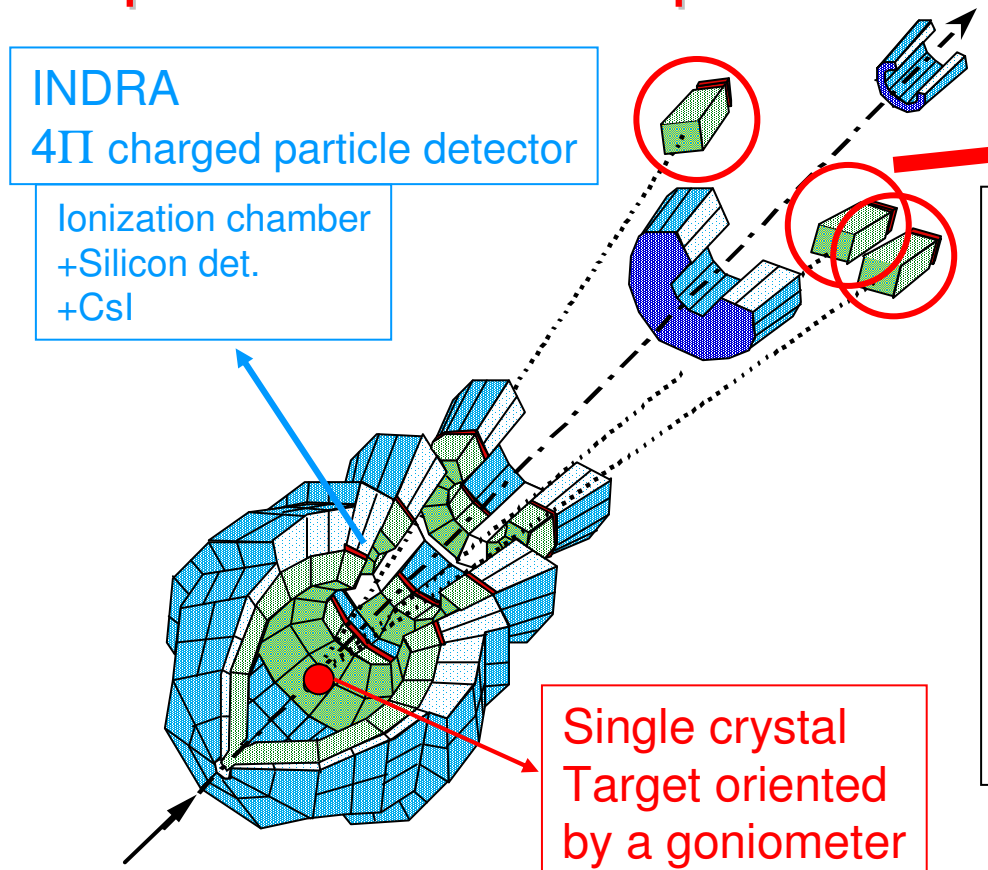
-crystal quality and **reaction time**



Experimental Set-up

INDRA
4Π charged particle detector

Ionization chamber
+Silicon det.
+CsI



3 Blocking Telescopes

In the crystal axes direction:
At 20° (x2) and 10°(elastic)

- ionization chamber (Energy loss)
- 2D resistive Si detector
  - → energy
  - → position $\delta x=\delta y=0.3$mm

Z identification, E measurement
Angular resolution : $\delta\Psi=0.02$deg

Single crystal
Target oriented
by a goniometer

E > E(Bass)
E*(CN) ~80 MeV

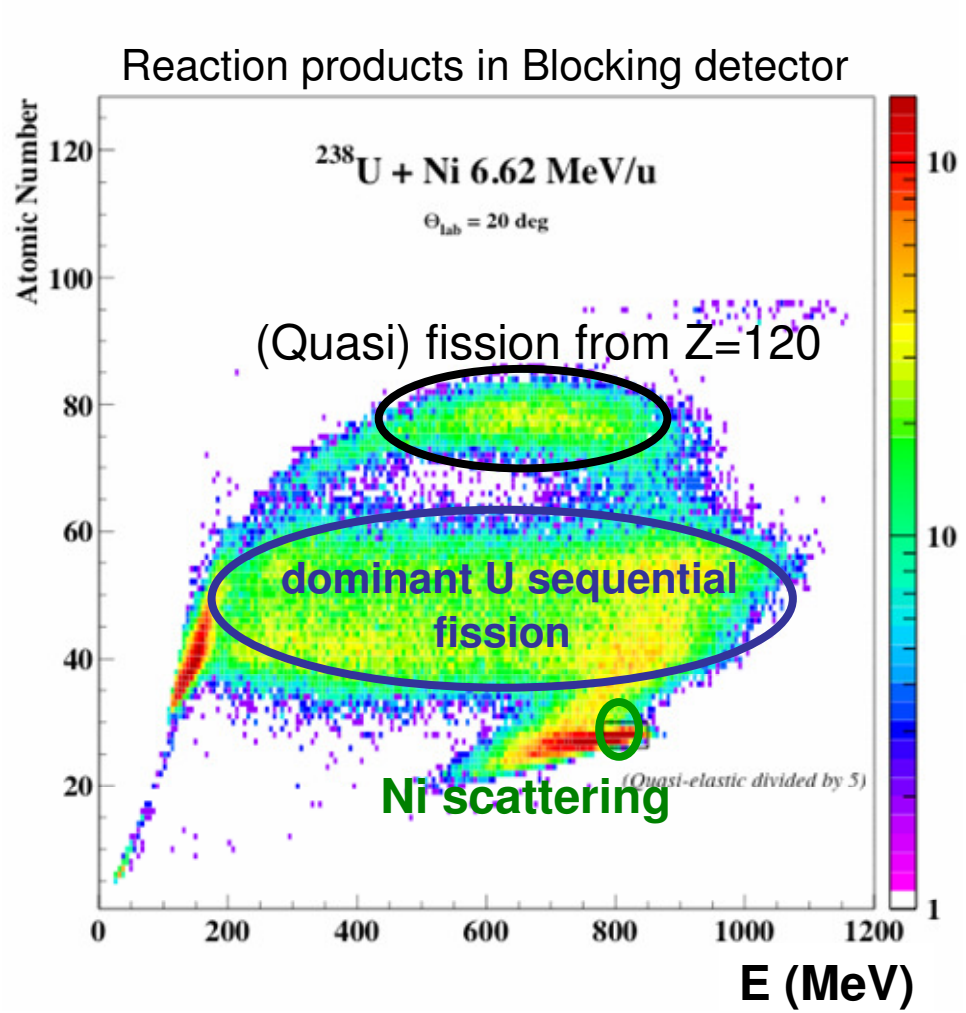
Selection of binary reactions
Estimation of Z (δZ=±2)
Detection of light charged particles

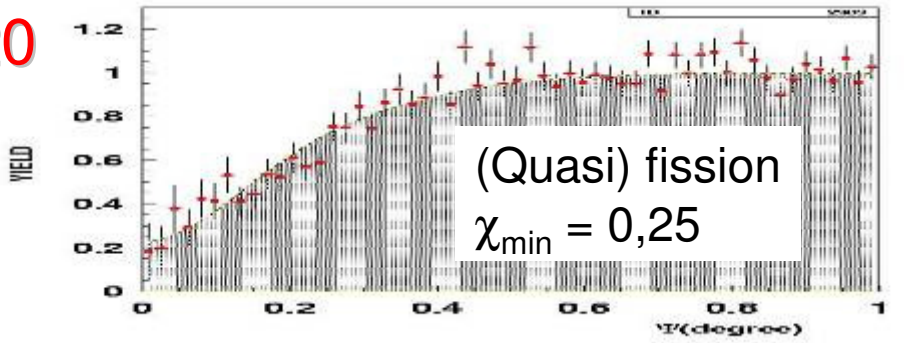
$^{238}U + Ni \rightarrow {}^{\sim 296}114$

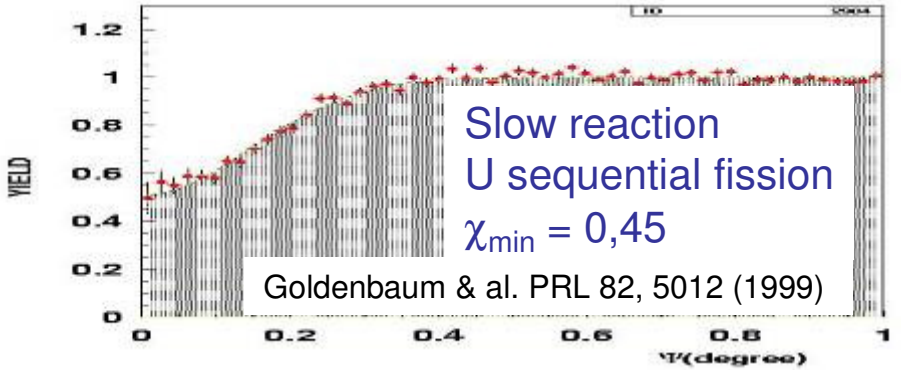
$^{238}U + Ge \rightarrow {}^{\sim 312}124$

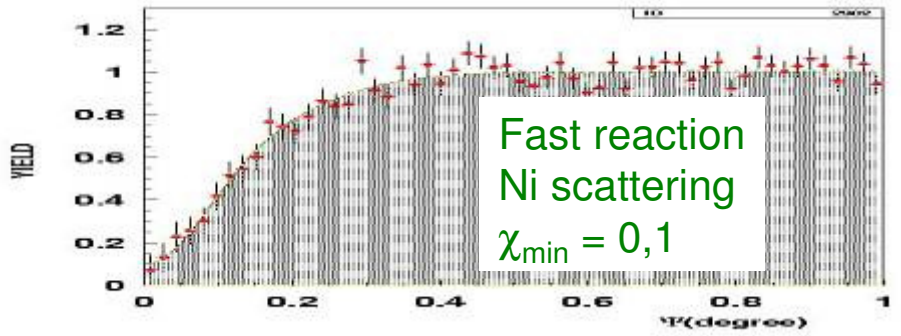
$^{208}Pb + Ge \rightarrow {}^{\sim 282}114$

Blocking Dip Measurements Z=120









Long fission time for Z=120 → Presence of stabilizing shell effects

Characteristics of fragments detected at 20° with $60 \leq Z_1 \leq 85$

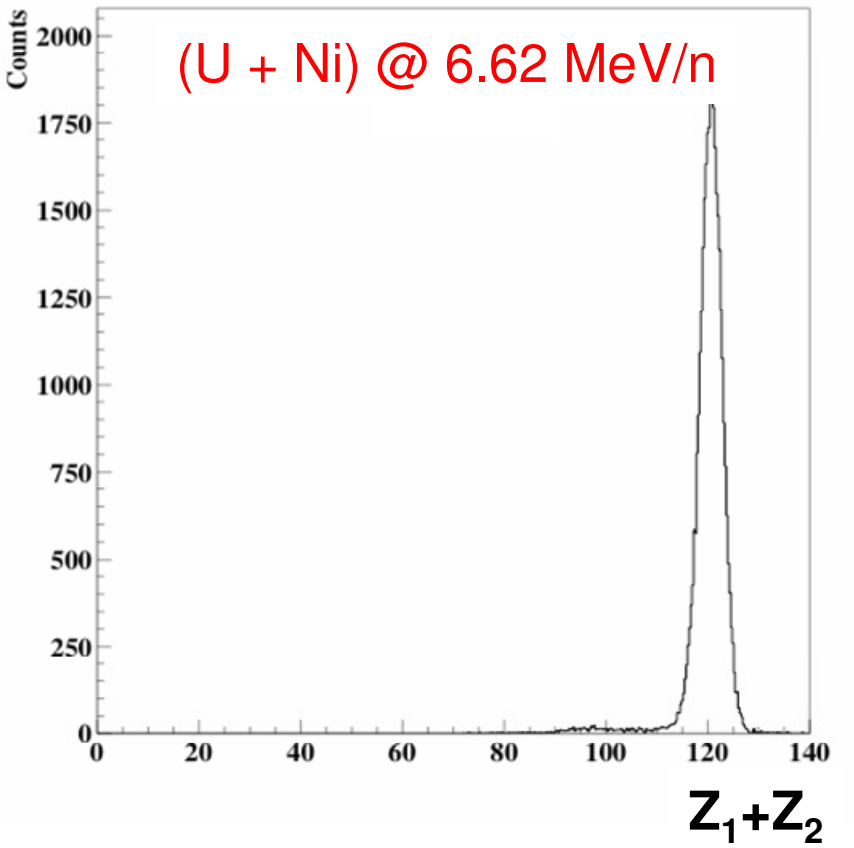
Coincidence with INDRA

➔multiplicity = 2; $Z_1 + Z_2 = 120$

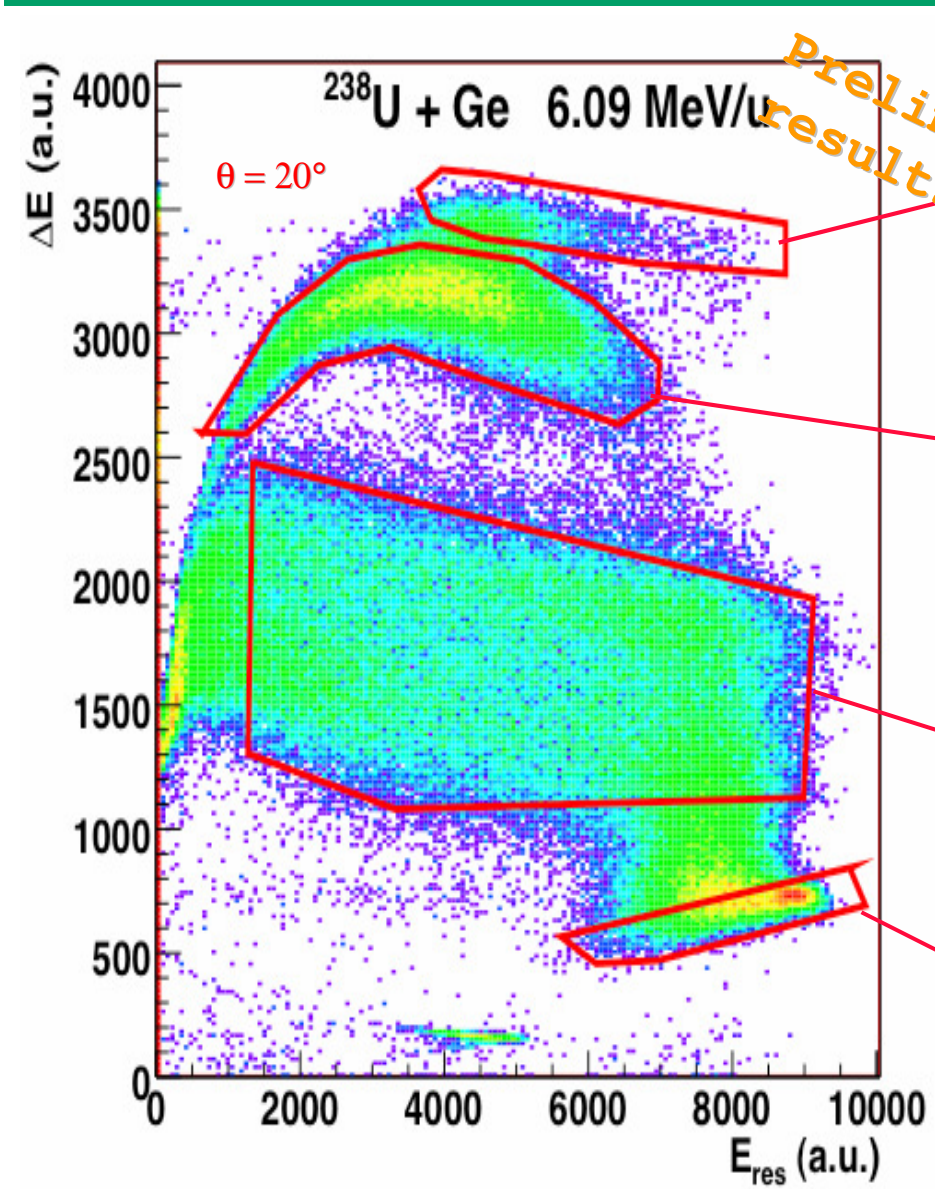
➔ Intermediate mass fragments
M ≈ 4×10^{-3}

➔Light Charged Particle
M ≈ 7×10^{-2}

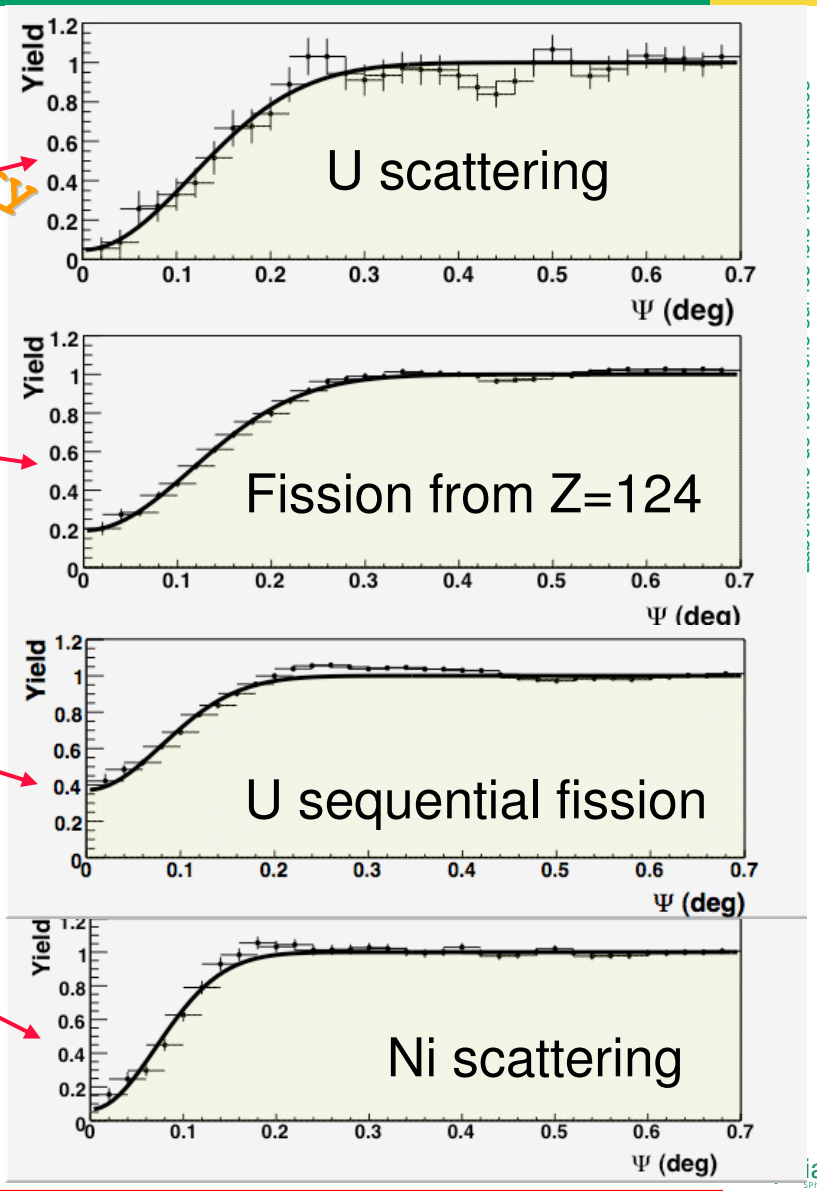
➔"Good behaviour" for fission frag.
Kinematics OK
Viola systematic OK



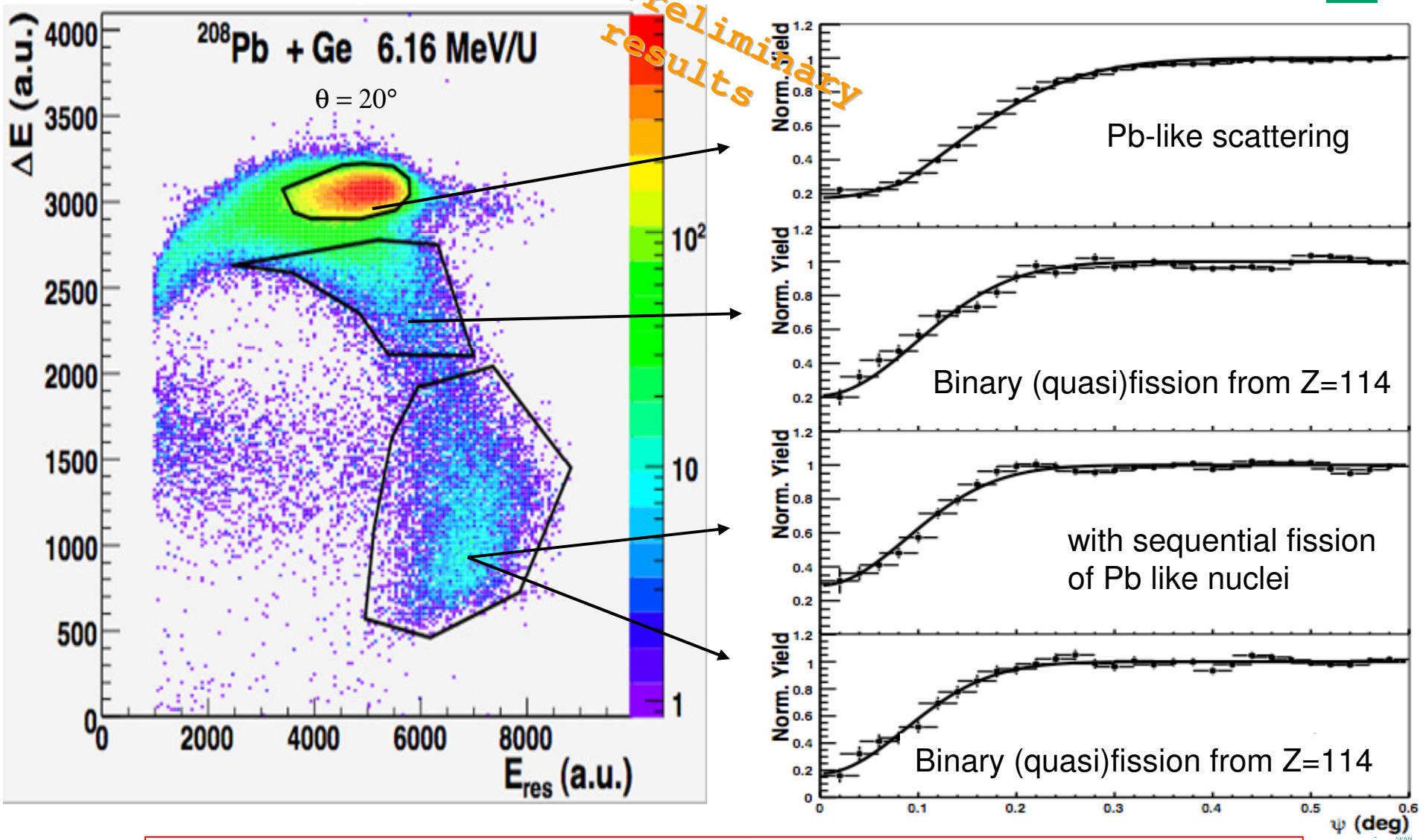
At least 10% of fission times > 10^{-18}s



Preliminary results



Long fission time for Z=124➔Presence of stabilizing shell effects



- long lifetimes for sequential fission of projectile-like fragments
- **no hint for long lifetimes for Z = 114 , A = 282**

Conclusions

Evidence of long lifetime (> 10^{-18}s) CN of Z=120

Similar results for Z=124

➔Existence of high fission barriers

➔ possible localization of Superheavy stability island

No or less long lifetimes for the Z=114 nucleus

Need of additional data to define the stability zone

Study according to excitation energy of CN

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Réferences

A. Drouart & al., *International Symposium on Exotic Nuclei (EXON 2004)*, Peterhof : Russian Federation (2005)
M. Morjean, AIP Conference Proceedings (2005) Volume 798, pp. 194
D. Jacquet & al., AIP Conference Proceedings (2006) Volume 853, pp. 239
M. Morjean & al., The European Physical Journal D -Volume 45, (2007).
M. Laget & al., Ph D Thesis (2007)