A program for the study of reaction mechanisms in the *GeV* range

Physics program

ACTAR Meeting

Bordeaux - Gradignan

16th of June, 2008

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Experimental method of investigation

- **Energy range ~ 1 *GeV* per nucleon**

→ nucleon – nucleon collisions as the dominant process for energy deposition in the target / projectile nuclei

- **Inverse kinematics**

→ 1 *GeV* energy + target / projectile mass asymmetry allow for a localisation of the CoM low-energy products at forward angles
→ No detection threshold, especially for heavy residues

- **Coincidence measurements**

→ Low CoM energy products ≈ de-excitation fragments of the projectile
→ Coincidence measurements of light particles & heavy residues allow for mass / charge / energy balances to estimate the violence of the collision → study of the mechanisms with the excitation of the nuclei

- **Detection**

→ High detection efficiency of neutrons & charged particles
→ ~ 100 % geometrical efficiency for fragments of charge ≥ 3

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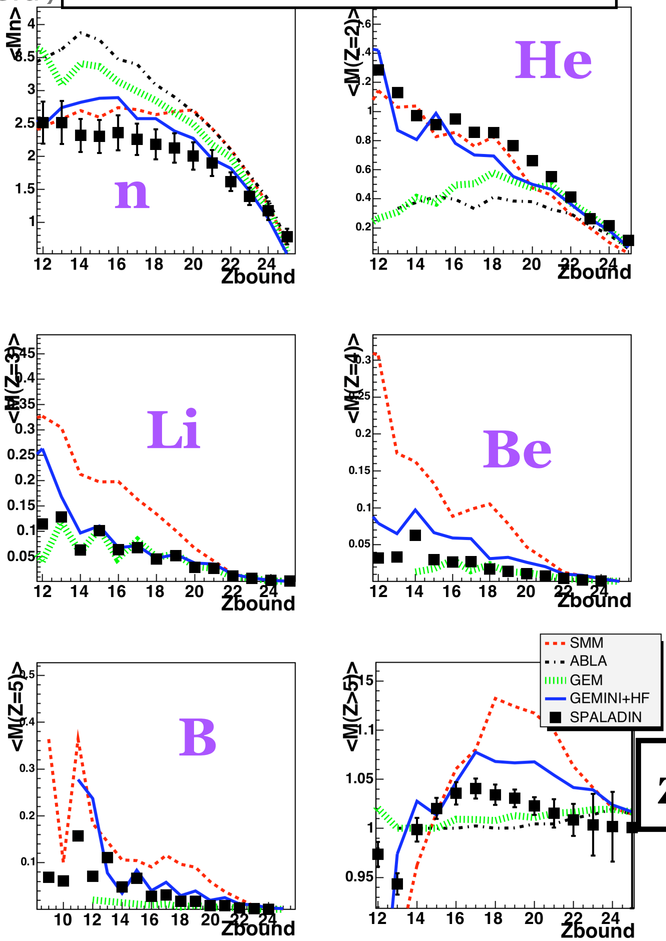
Example: first results of SPALADIN

Average multiplicities

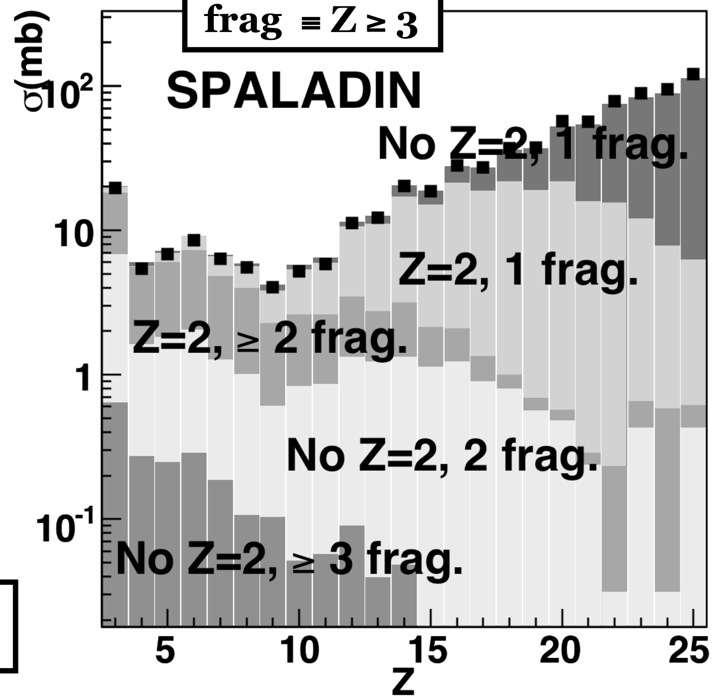


$$Z_{bound} \equiv \Sigma_{Z \geq 2} Z$$

$^{56}Fe+p$, 1 *GeV* per nucleon

Contributions to the cross-section

$frag \equiv Z \geq 3$



É. Le Gentil *et al.*, PRL **100**, 022107 (2008)

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Physics program of the spallation group

- **Experiments in Cave C of GSI**

→ S304: Study of the spallation of $^{28}Si+p$ & $^{136}Xe+p$ at 1 *GeV*

→ S293: Study of the fission channels of spallation with the excitation energy of the prefragment and with the fissility parameter of the projectile (^{238}U, ^{208}Pb & ^{181}Ta at 1 *GeV*)

R3B

- **Spallation experiments at R3B**

→ Coincidence measurements of $^{208}Pb+p$ & $^{238}U+p$ at 1 *GeV*

→ *A+He* & *A+C* for a comparison with *A+p* at the same CoM energies

→ Kinematics reconstruction at the target point

- **Fission experiments at R3B**

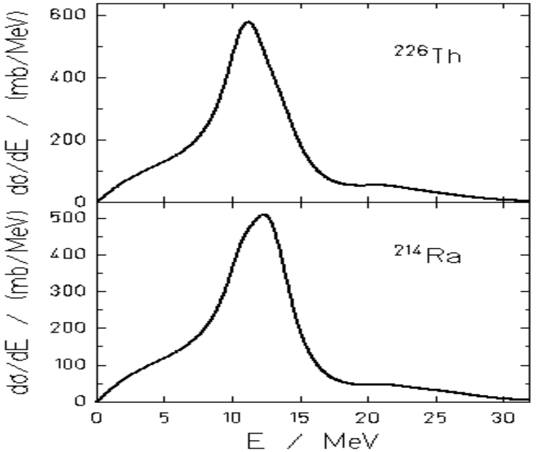
→ Coulomb excitation of the projectile which leads to fission

→ Study of the low-energy fission of radioactive actinides

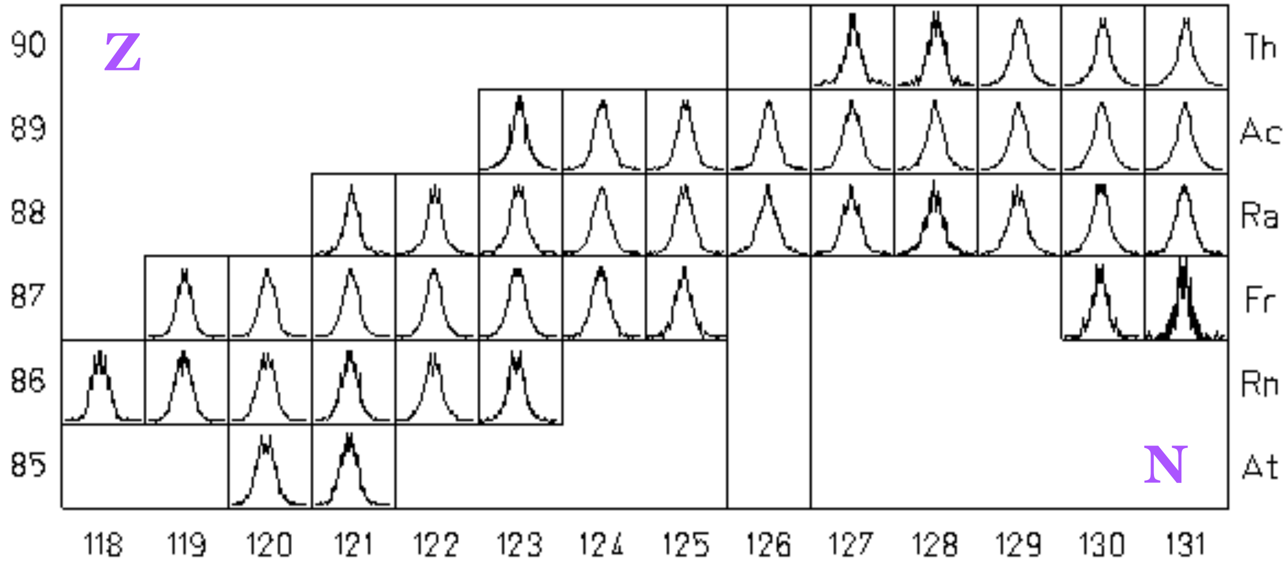
Low-energy fission studies

- **Actinide secondary beams from the fragmentation of ^{238}U**
- **Electromagnetic fission of the fragment in the Coulomb field of a heavy target (*Pb* / *Au*)**

→ Study of the fission-fragment distribution



E* distributions after EM excitation in a Pb target at 430 A MeV calculated by K.H. Schmidt *et al.*, Nucl. Phys. **A665**, 221 (2000)



Fission fragment charge distributions measured for nuclei between ^{205}At and ^{221}Th by K.H. Schmidt *et al.*, *Nucl. Phys.* **A665**, 221 (2000)

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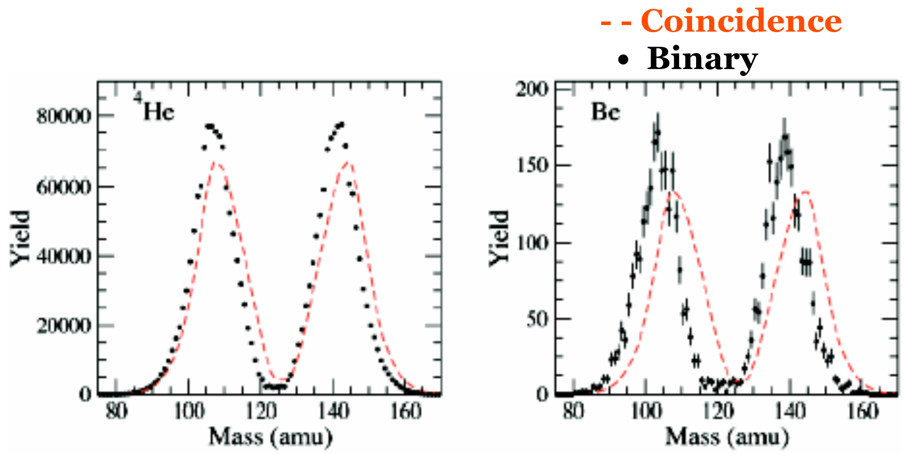
Low-energy fission studies

- **Additional information with R^3B**

→ Mass & charge of the fragments
→ Fission-fragments in coincidence
→ De-excitation neutrons or charged particles in coincidence
→ Kinematics of the fission fragments

- **Well defined fissioning system (A , Z , E^*)**
- **Mass & charged splitting as a function of M_n or E^***
- **Ternary fission ?**
- **For all nuclei below ^{238}U**

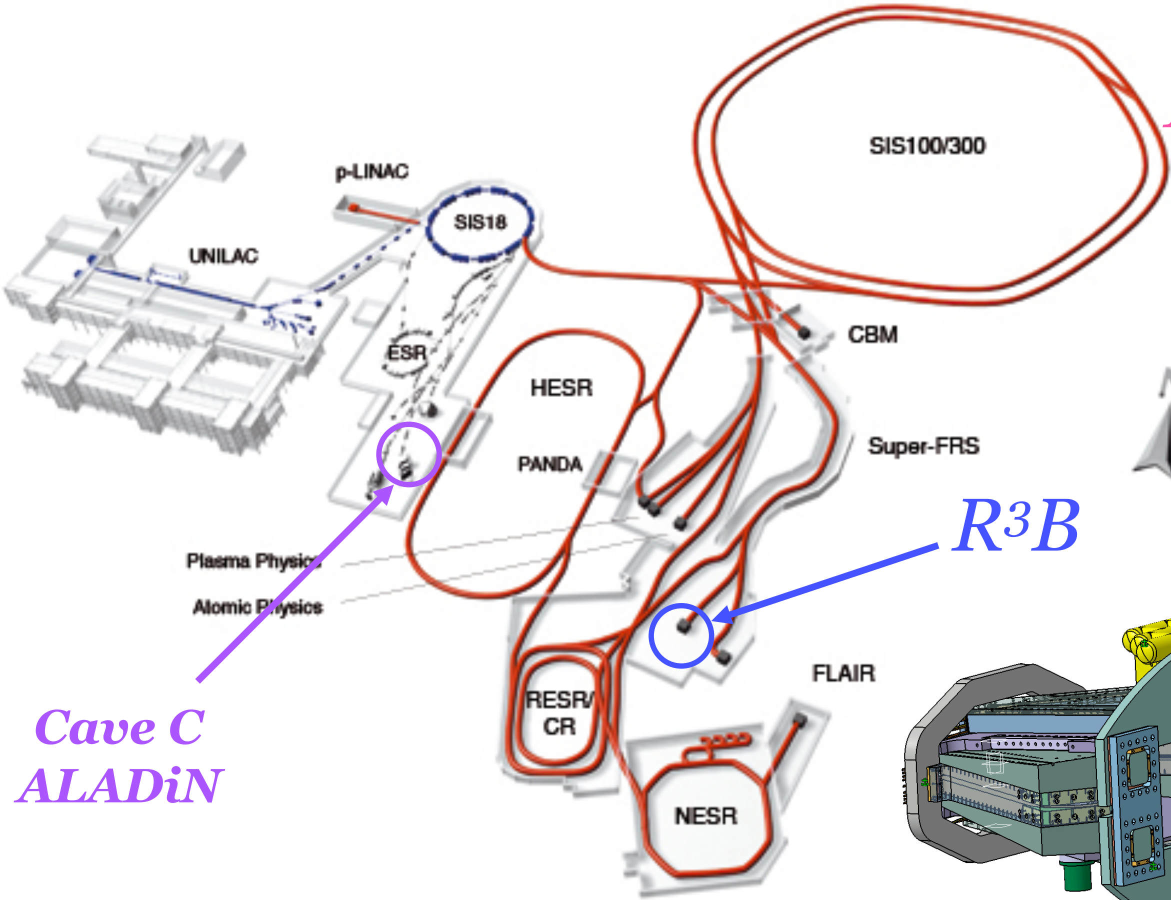


Fragment mass distributions in ternary fission of ^{252}Cf with ^4He and Be as the light charged particles. From F. Gönnenwein *et al.*, Nucl. Phys **A734** (2004) 213

R3B hall in the FAIR facility

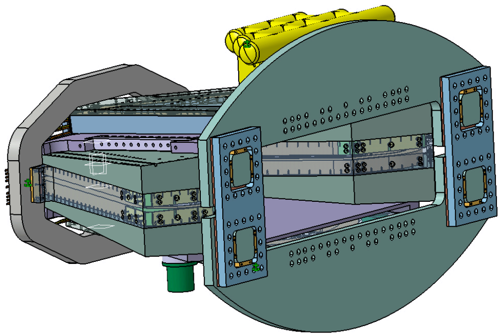
GSI

FAIR



R3B

Cave C
ALADiN



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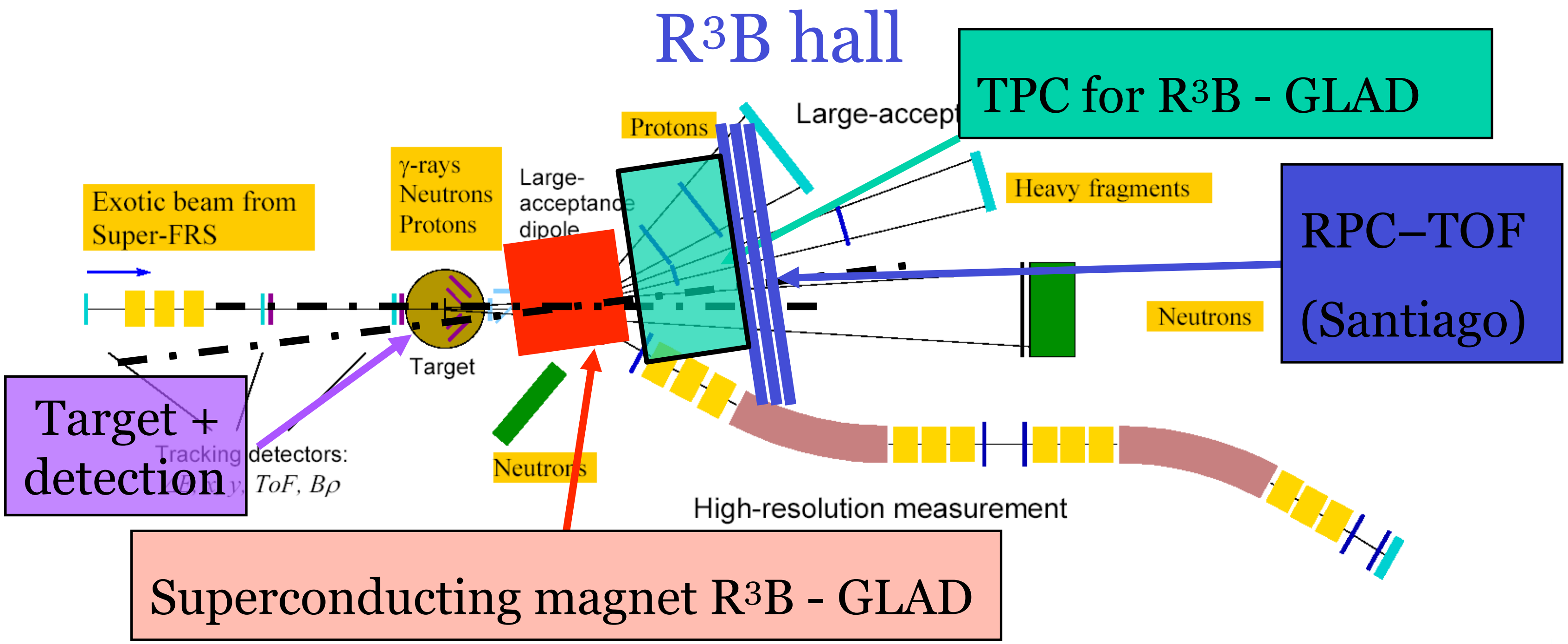


Combination of upstream and downstream detection

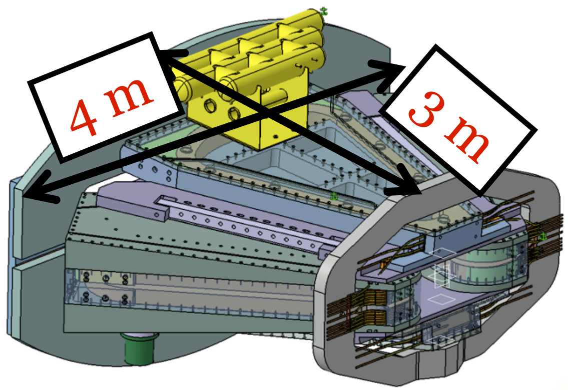
→ Improved A, Z et E* balances

→ **Spallation, fragmentation**

→ Identification (γ) of de-exciting nuclei

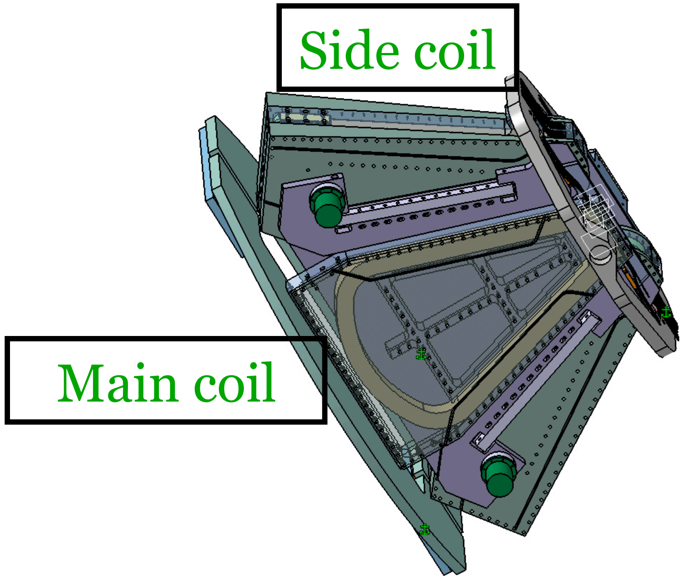
→ **Fission of radioactive actinides**

TPC: Multi-purpose detector



R^3B GLAD magnet

GSI Large Acceptance Dipole



- **R³B GLAD funding**

→ 3.5 M€ from EU CNI contract
→ 1.5 M€ from the collaboration
→ ~ 2 M€ from Saclay (manpower)

- **R³B GLAD built in Saclay**

→ Study started in 2001 (5th FP)
→ 35 persons involved
→ 30 *m.y* over 4 years

- **Basic equipment of R³B**
- **Parameters**

→ $\int B.dl = 4.8\ T.m$
→ +/- 80 *mr* in V & H planes for neutrons & charged fragments

- **To be delivered in 2012**

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Magnet acceptance definition & optimisation

Parameters of the magnet:

- Angular aperture **+/- 80 mr** horizontally and vertically
- Transparency to neutrons & to transport of **1 GeV** proton with HI
- → Very low fringe field at the target (< 25 mT)
- Free space: > 1 *m* from the target to the magnet, for detectors
- → Active shielding

Final geometry after **optimisation**:

- Distance from the target to the magnet entrance = **1.450 m,**
- A horizontal angle of the beam direction with respect to the magnet axis = **14°**
- Vertical and horizontal angles of the coils = **5°** & **18.6°**
- Simpler geometry without additional winding (as in the first drawings) ➔ less expensive, less risky