A gas-filled mode for the large-acceptance spectrometer VAMOS

- **Vacuum mode**
  - versatililty suited for direct, DI, transfer, fission reactions
    - variable distance to / angle around the target
  - fusion-evaporation @ 0° in very asym direct kinematics at high I_{beam}
    - poor beam rejection in sym and inverse kinematics

- **New complementary gas-filled mode**
  - powerful beam rejection and transmission for fusion-evaporation @ 0°
  - → relevant for multi-nucleon transfer, DIC and QF @ appropriate angle

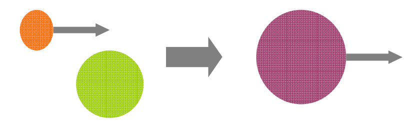
Flexible Inelastic Reaction Isotope Spectrometer with large (p, ϑ) acceptance operating in vacuum and gas

Ch.Schmitt, VAMOS group, GANIL

VAMOS: From vacuum to gas

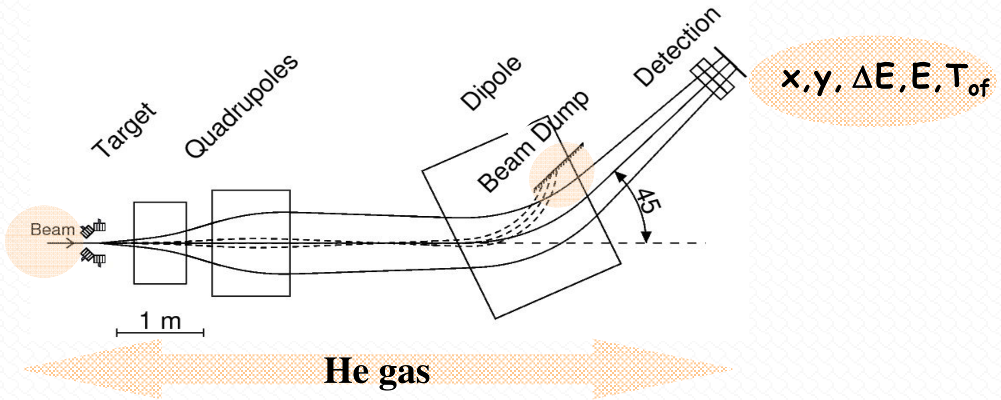
- **Tasks**
  - Discriminate/select efficiently the products of interest
  - **Reject the intense incoming direct (ϑ =0°) and elastic scattered beam ($\vartheta \neq$ 0°)**

- **How to optimize VAMOS for fusion-evaporation ?**
  - Beam rejection according to $B\rho_{vacuum}$ not sufficient
  - **Gas-filling**: $B\rho_{gas}$ ~ A and Q distribution narrow
    Powerful beam/ER separator and large transmission



Fusion-evaporation @ 0° ...

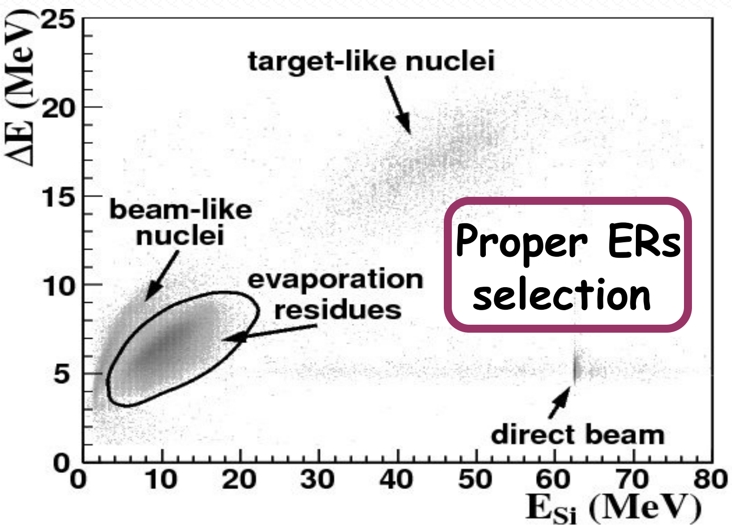
- **Set-up**
  - C foil before the target for vacuum/gas separation
  - He gas-filling ~(0.2–1.3)mbar
  - beam dump (Ta plate)



- **Measurement** ^{40}Ca (196MeV) + $^{150}Sm \rightarrow$ $^{190}Pb^*$ (σ_{ER} ~ 50mb)
  - ERs identified via prompt γ-rays in EXOGAM and/or radioactive α decay in Si
  - Poor beam rejection in vacuum

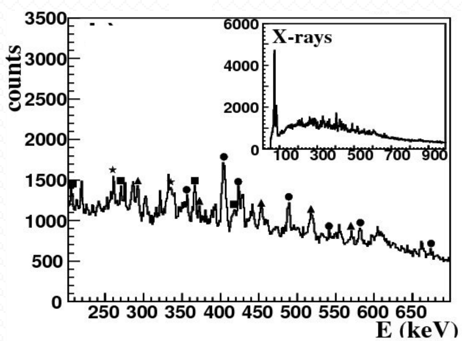
Selection and identification of the ERs

- Selection

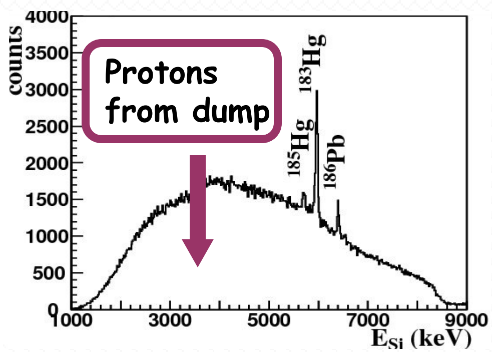


- Identification

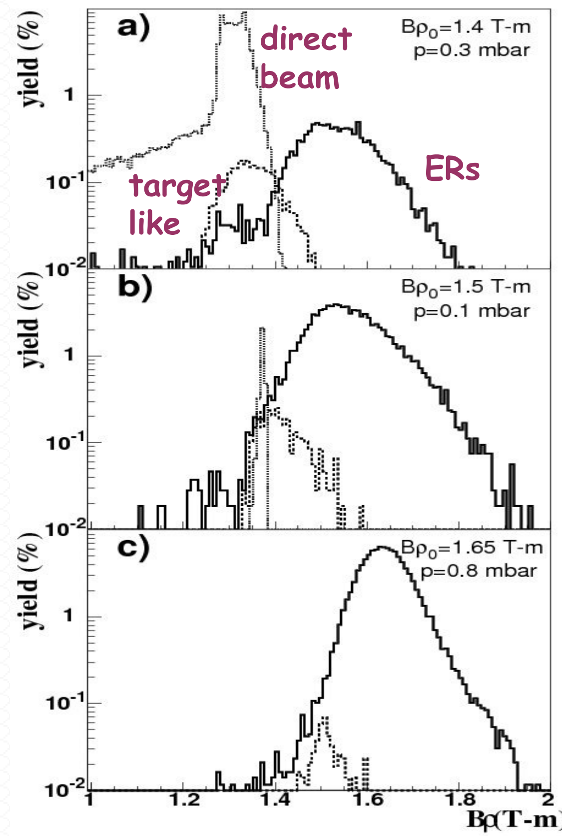
Prompt γ-radiation



Radioactive α-decay



- First measurement of B ρ @ a gas-filled magnet



- Velocity at the target available

(crucial for high velocity and $\vartheta \neq 0°$)

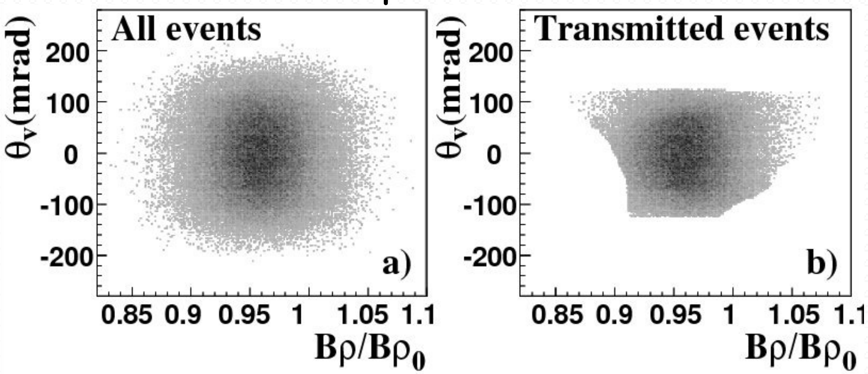
Performance of the gas-filled VAMOS

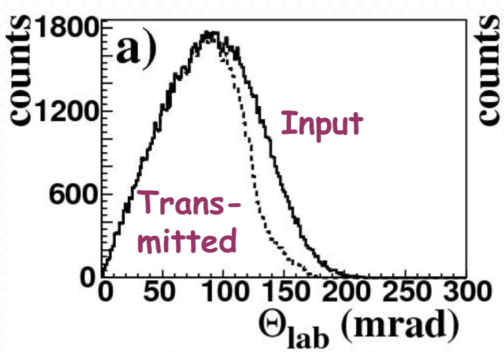
- Optimal conditions : **$B\rho_0$=1.65Tm and p ~ 1mbar** (with present simple set-up)

Beam rejection factor > 10^{10}
No direct beam on the detectors for $1.2 \cdot 10^{10}$ ^{40}Ca per sec sent in VAMOS

- Transmission from ion-optical calculations

α3n evaporation channel





~ 80% for α evaporation channels
~ 95% for neutron/proton channels

Performance of the gas-filled VAMOS

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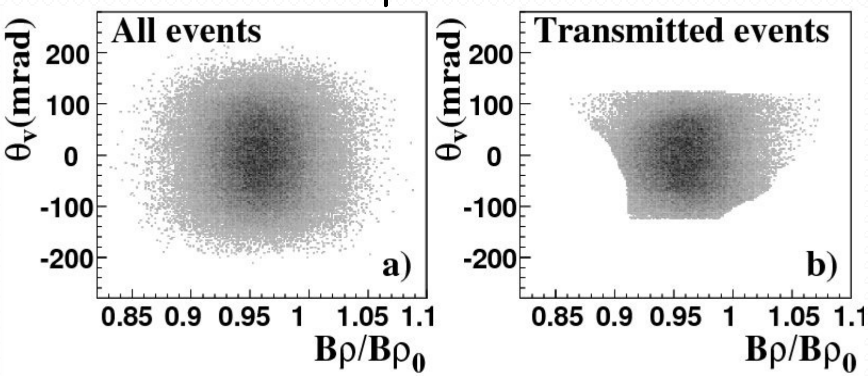
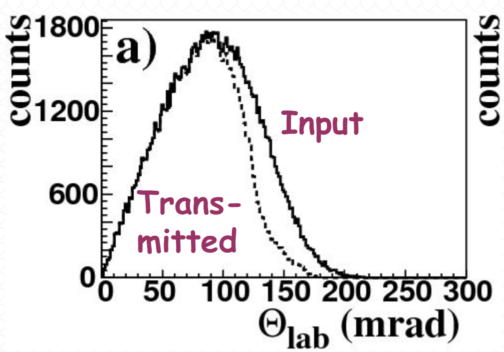
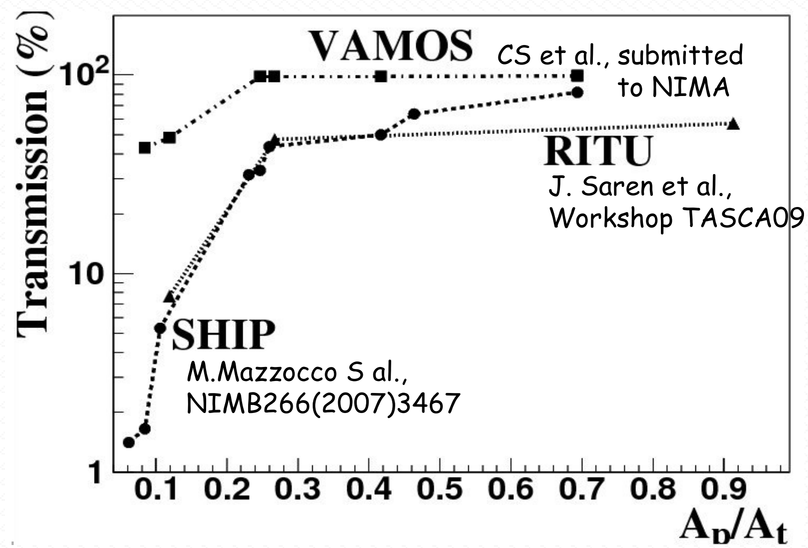


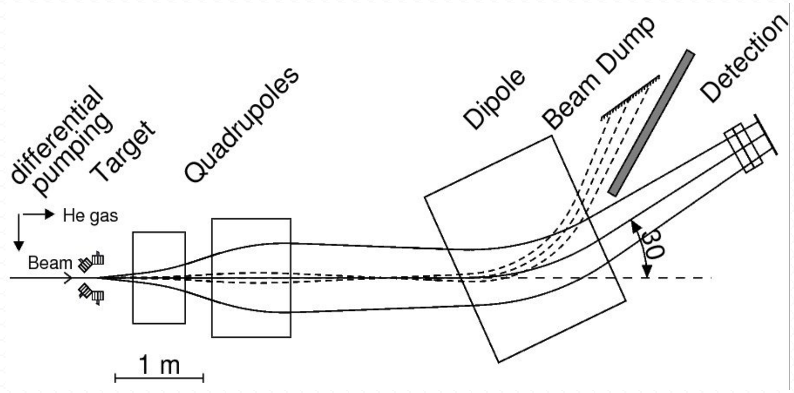


Large ϑ aperture
Big detectors



Developments

- Beam dump behind VAMOS and shielded
  (↓ scattering from there)
- Differential pumping system
  (↓ γ-background)
- Recoil Decay Tagging with MUSETT
  (ER-decay correlation)



→ Larger beam rejection and transmission

Complementary vacuum and gas-filled modes of VAMOS
towards getting ready for SPIRAL2

A versatile large-acceptance vacuum and gas-filled spectrometer
for multi-nucleon transfer (MNT) reactions ?

MNT reactions : Test cases

- **Examples**

^{18}O (98MeV) + ^{254}Es → ^{260}Lr (σ_p ~ 300nb)
Schädel et al., Phys. Rev. C 33 (1986) 1547

^{136}Xe (744MeV) + ^{208}Pb → $^{202}Os_{126}$ (σ_p ~ 200nb)
Zagrebaev et al., J. Phys. G 35 (2008) 125103

^{136}Xe (952MeV) + ^{208}Pb → ^{262}Sg (σ_p ~ 1pb)
hypothetical…

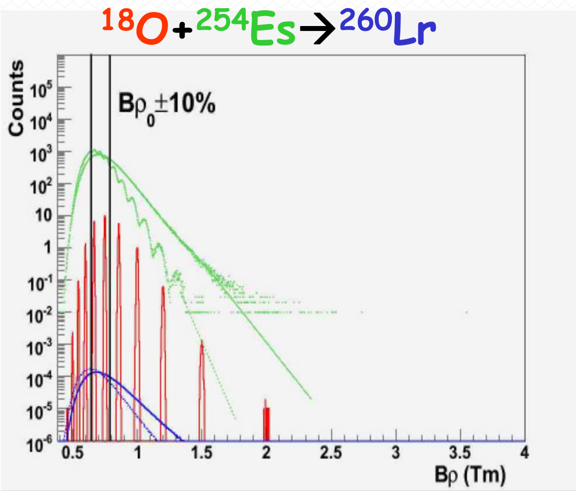
- **Exercise**

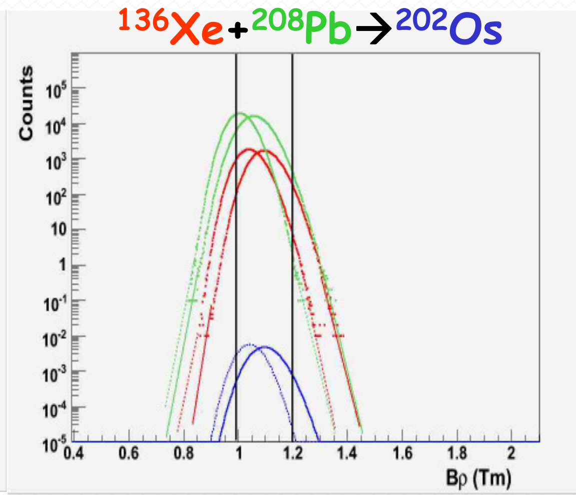
→ Can unwanted particles be rejected ?
→ Compare the Bρ of elastic scattered beam, target and transfer products as obtained at a vacuum and a gas-filled magnet

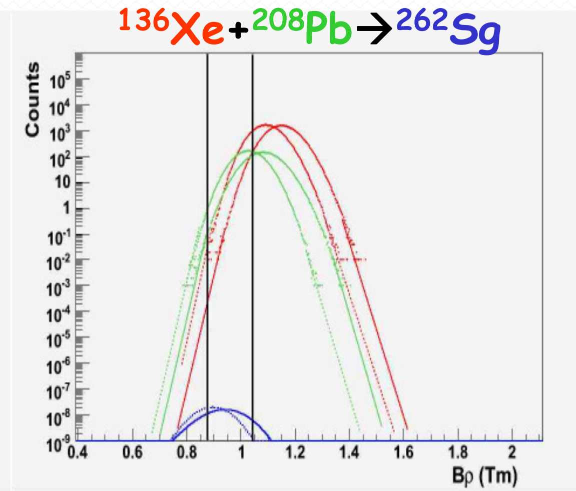
Assumptions:
- device @ grazing angle of the transfer product
- beam intensity of 10^{12}pps
- target thickness (25-500 $\mu g/cm^2$)

MNT reactions : Experimental strategy

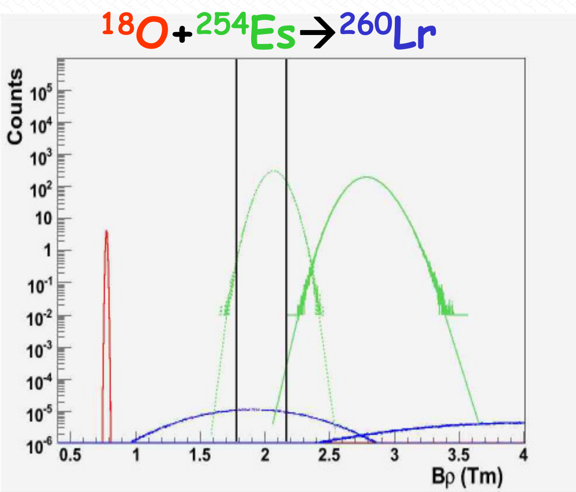
❍ Vacuum mode (Q parameterisations from Shima and Sagaidak)

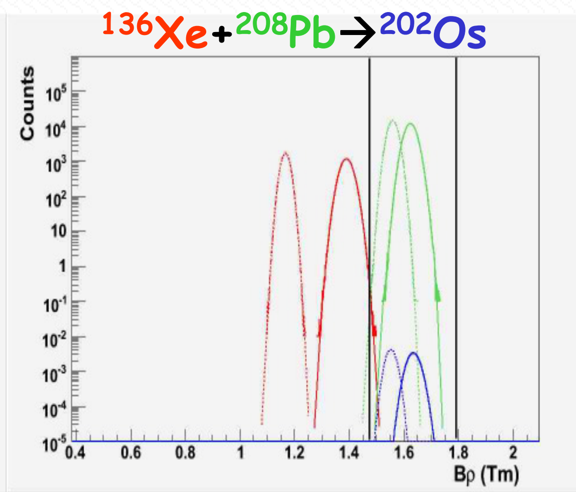


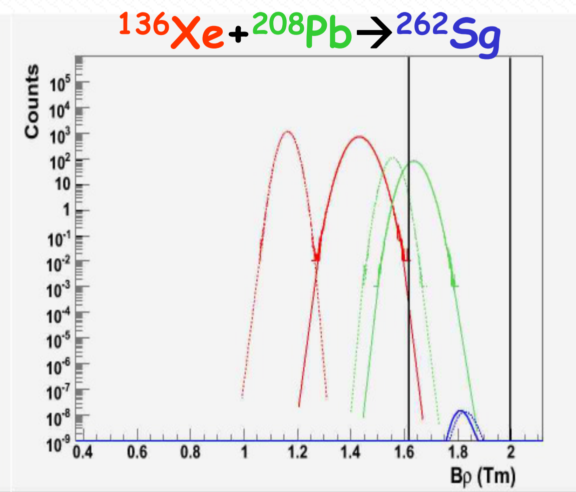




❍ Gas-filled mode (Q parameterisations from Ghiorso and Oganessian)







* σ_p for transfer product and σ_{Ruth} for beam and target
** $B\rho$ acceptance of $\pm 10\%$ assumed ($\forall$ angle)

→ **Gas-filled mode useful**

… Detailed design study, case-by-case evaluation → compromise

Remarks

on the study of heavy nuclei produced in MNT, DIC and QF reactions

- Scattered particles to be at minimum
- Direct (A, Z) identification of the heavy recoil not possible
- Complementary methods (Recoil [Decay] Tagging)
  γ-rays, LCPs, heavy fragments, X-rays at target and/or focal plane
- Low rate in the implantation detector (for ^{260}Lr : $T_{1/2}^{\alpha}$ = 3min)
- Large variety of potentially interesting products by DIC and QF covering a wide range both in angle and momentum

Conclusion

- Experiments @ VAMOS* proved the « viability » of a powerful double operation mode

* Originally designed as a large-acceptance vacuum spectrometer for low-intensity RIBs

IRIS
- versatile spectrometer
- wide-acceptance in (p, ϑ)
- vacuum and *gas-filled* mode
- rotation around the target