# Measuring near- and sub-barrier fusion excitation functions with exotic neutron-rich beams

**A.M.Stefanini, L.Corradi, E.Fioretto, Pushpendra P.Singh**
INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy

**G.Montagnoli, D.Montanari, F.Scarlassara, C.A.Ur**
Dept. of Physics, Univ. of Padova and INFN-Padova, Italy

**F.Haas, S.Courtin, A.Goasduff**
IPHC, CNRS-IN2P3, Univ. de Strasbourg, Strasbourg Cedex 2, France

**C.L.Jiang, K.E.Rehm**
Physics Division, Argonne Nat'l Laboratory, Argonne, IL, USA

**S.Szilner,** D.Jelavic-Malenica, T.Mijatovic, M.Milin, N.Soic
Ruder Boskovic Institute, Zagreb, Croatia

**X.D.Tang**
Univ. of Notre Dame, Notre Dame, IN, USA

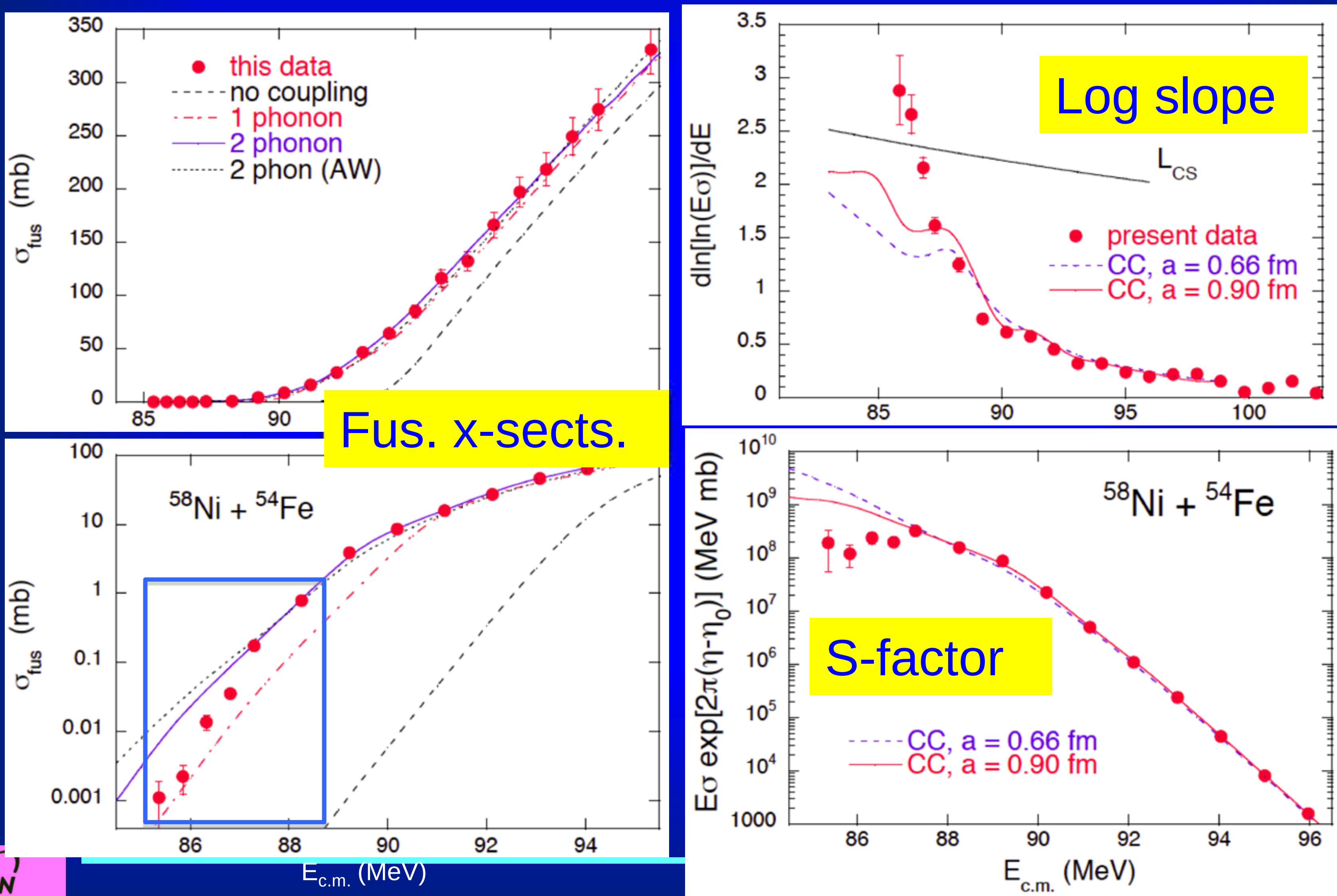
# Heavy-ion Fusion near the Coulomb barrier with SPES

-heavy-ion fusion around the Coulomb barrier is governed by channel coupling effects

-the future availability of the exotic SPES beams will allow to study these phenomena in much deeper detail, allowing to test nuclear structure situations presently unavailable with stable beams (and targets)

- however, from the experimental point of view, measurements at $0^0$ and near-by angles are not simple, when the beam intensity exceeds $10^4$ – $10^5$ pps

# Fusion hindrance at low energies
## (recent LNL results on $^{58}Ni + ^{54}Fe$)

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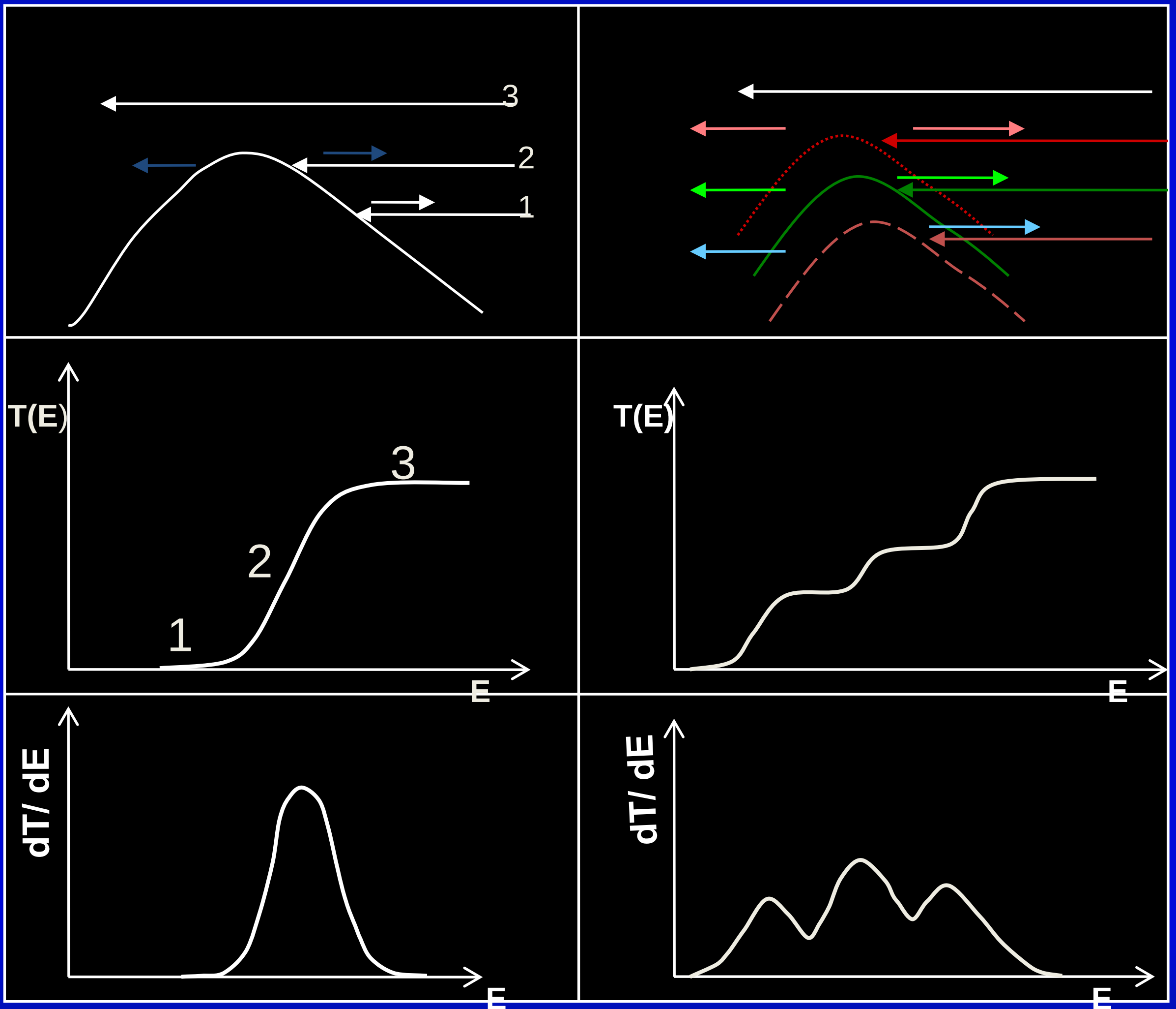
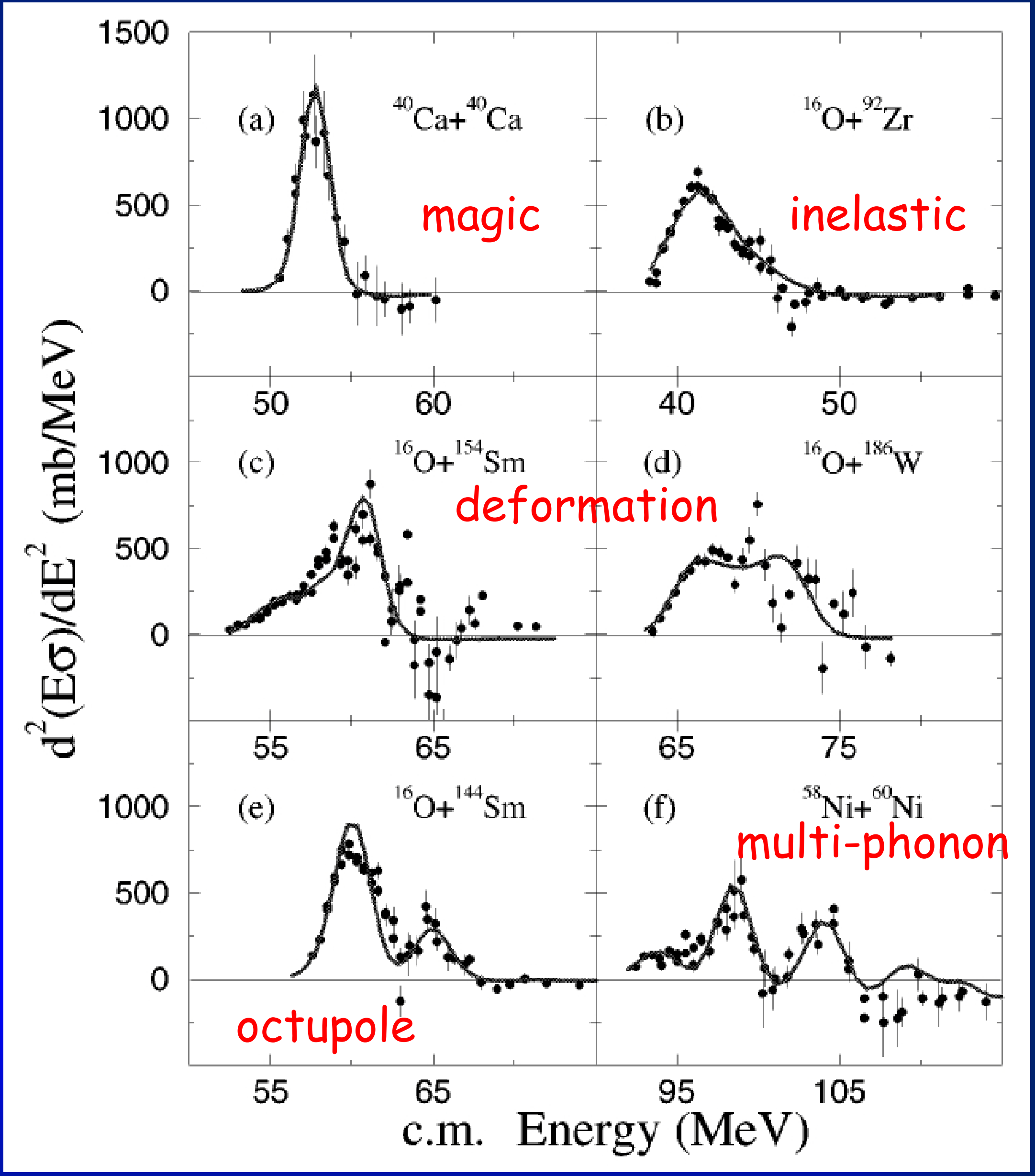
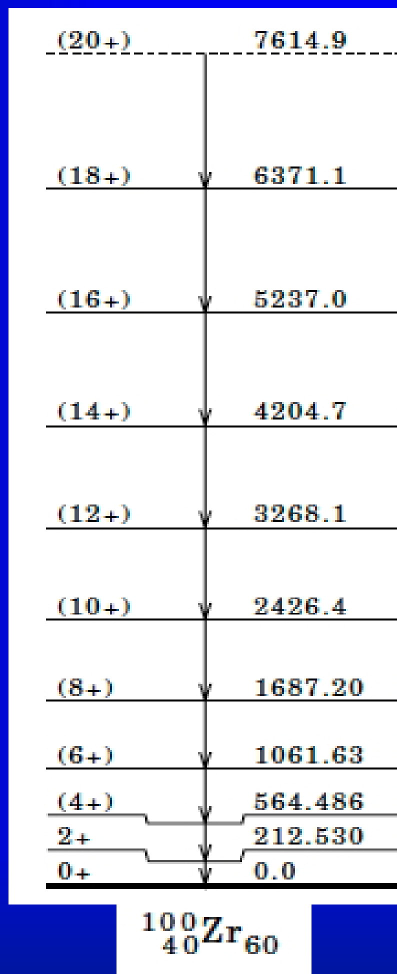
# Fusion barrier distributions: a pictorial view

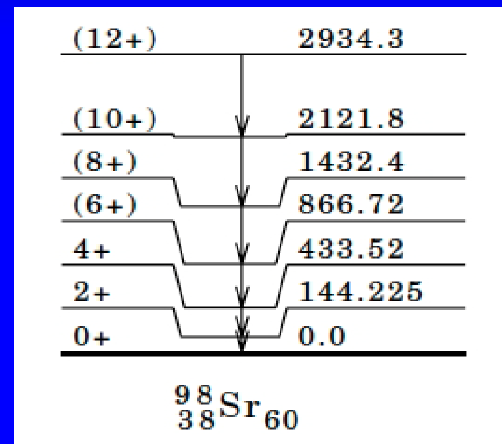


Several shapes of fusion barrier distributions found for various heavy-ion systems with stable beams and targets



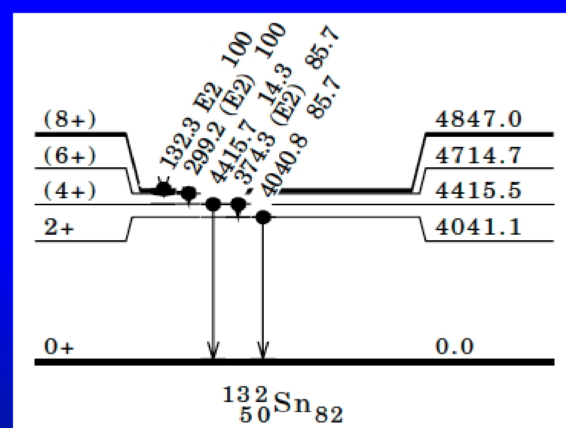
# Fusion of ($^{100}$Zr), $^{98}$Sr and $^{132}$Sn (SPES beams)with $^{40,48}$Ca. Low-Energy structure of the beams




deformation

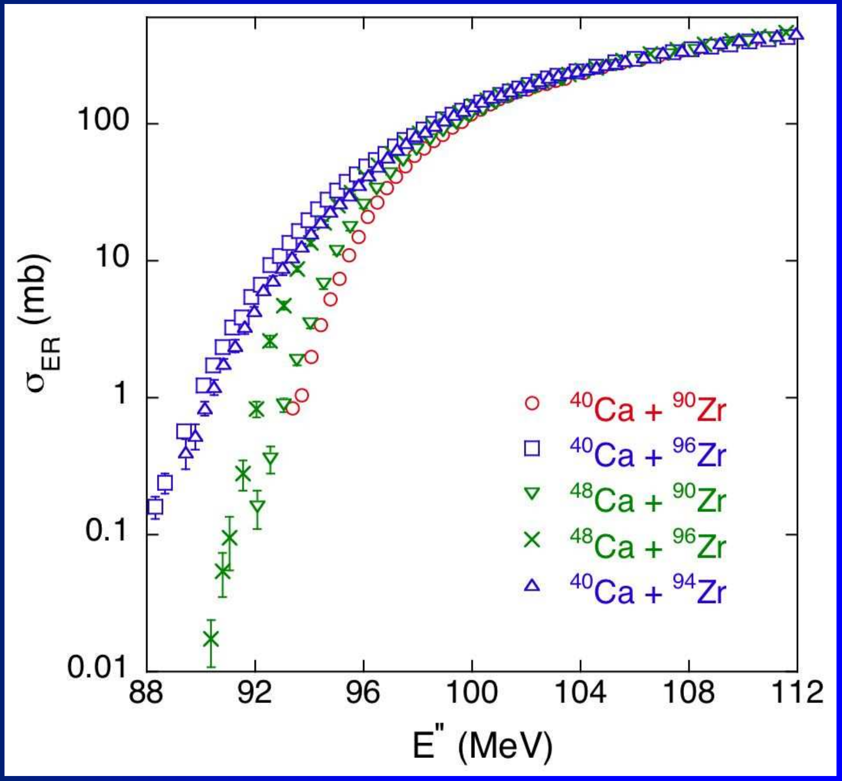
≈$10^5$ pps

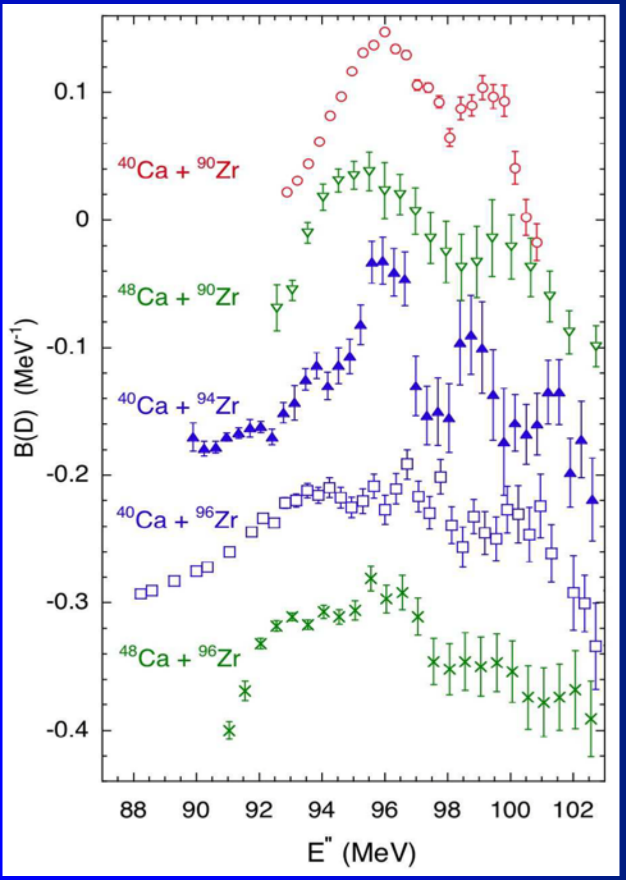



magic

≥$10^7$ pps

# The "old" Ca+Zr systems




The two systems $^{40}$Ca + $^{94,96}$Zr have larger fusion cross sections at low energies, with respect to the other three cases. This is mainly due to couplings to neutron pick-up channels with positive Q-values.

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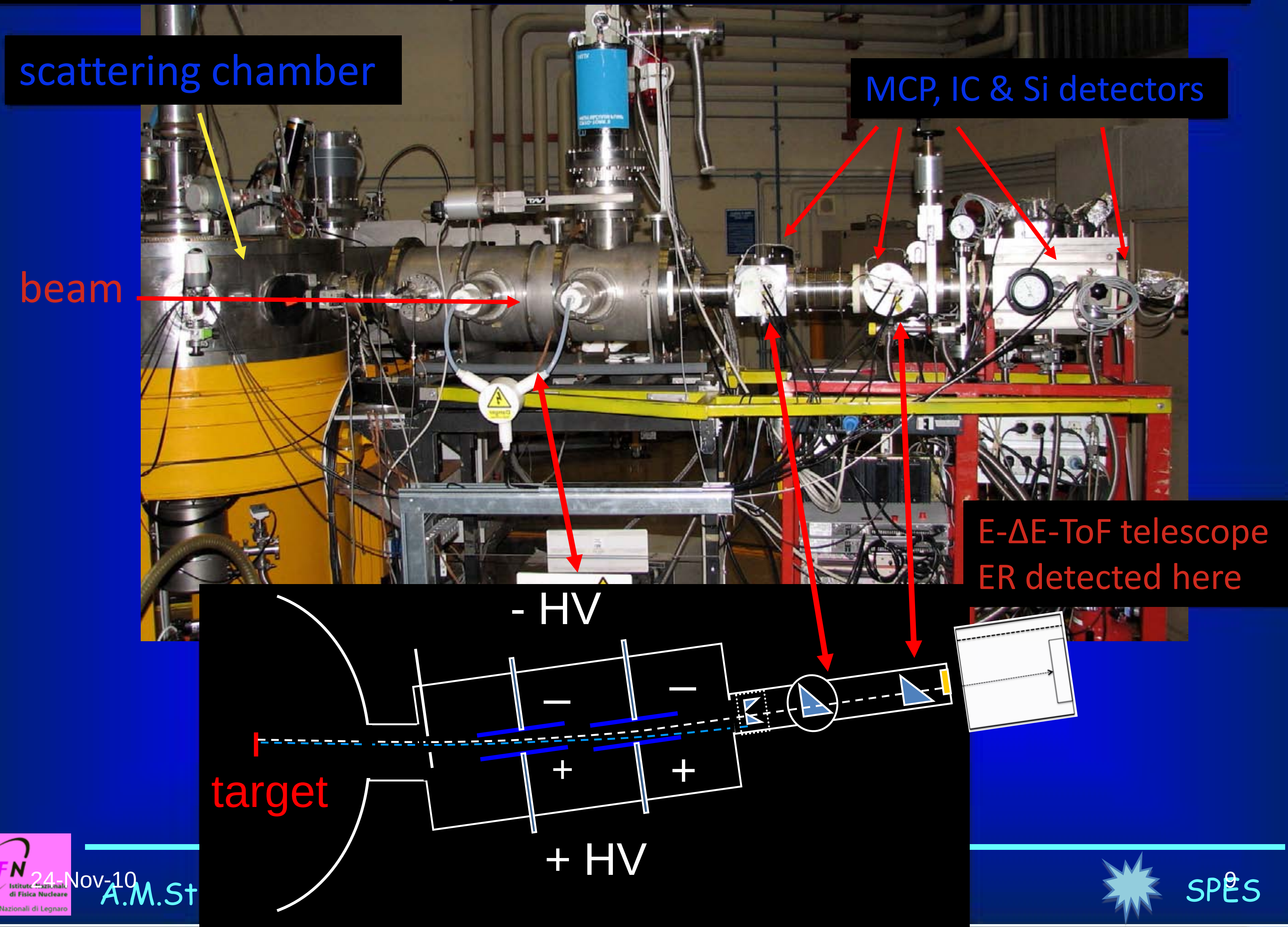
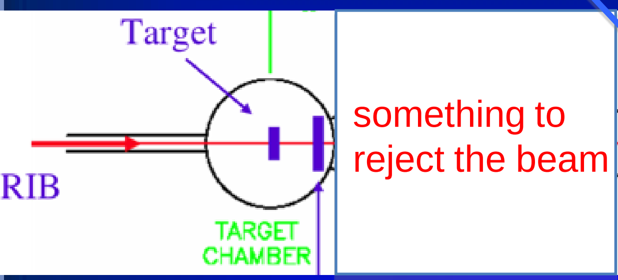
# Systematics of neutron transfer Q-values

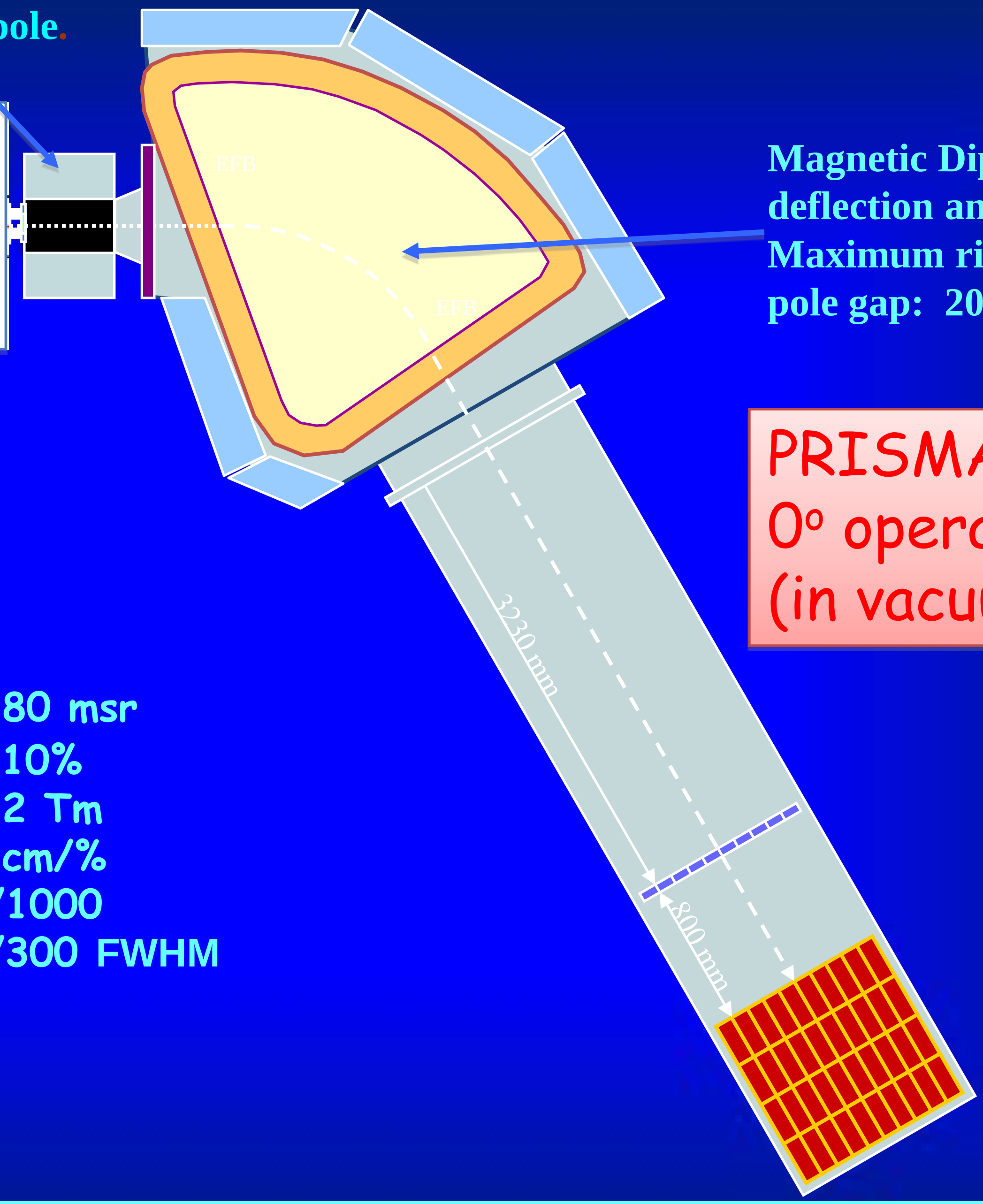
| System | +1n | +2n | +3n | +4n | +5n | +6n |
|---|---|---|---|---|---|---|
| $^{40}Ca + ^{90}Zr$ | -3.61 | -1.44 | -5.86 | -4.17 | -9.65 | -9.05 |
| $^{40}Ca + ^{96}Zr$ | +0.51 | +5.53 | +5.24 | +9.64 | +8.42 | +11.62 |
| $^{40}Ca + ^{98}Sr$ | +2.60 | +10.10 | +12.16 | +18.97 | +19.60 | +24.76 |
| $^{40}Ca + ^{90}Kr$ | +2.05 | +8.43 | +9.31 | +14.93 | +12.48 | +15.76 |
| $^{40}Ca + ^{132}Sn$ | +1.05 | +7.28 | +7.58 | +13.32 | +12.86 | +17.70 |
| $^{40}Ca + ^{140}Xe$ | +2.97 | +10.81 | +12.93 | +20.03 | +19.46 | +23.40 |

SPES beams

# Electrostatic separator and E-ΔE-ToF telescope to detect evaporation residues at ≈ 0°





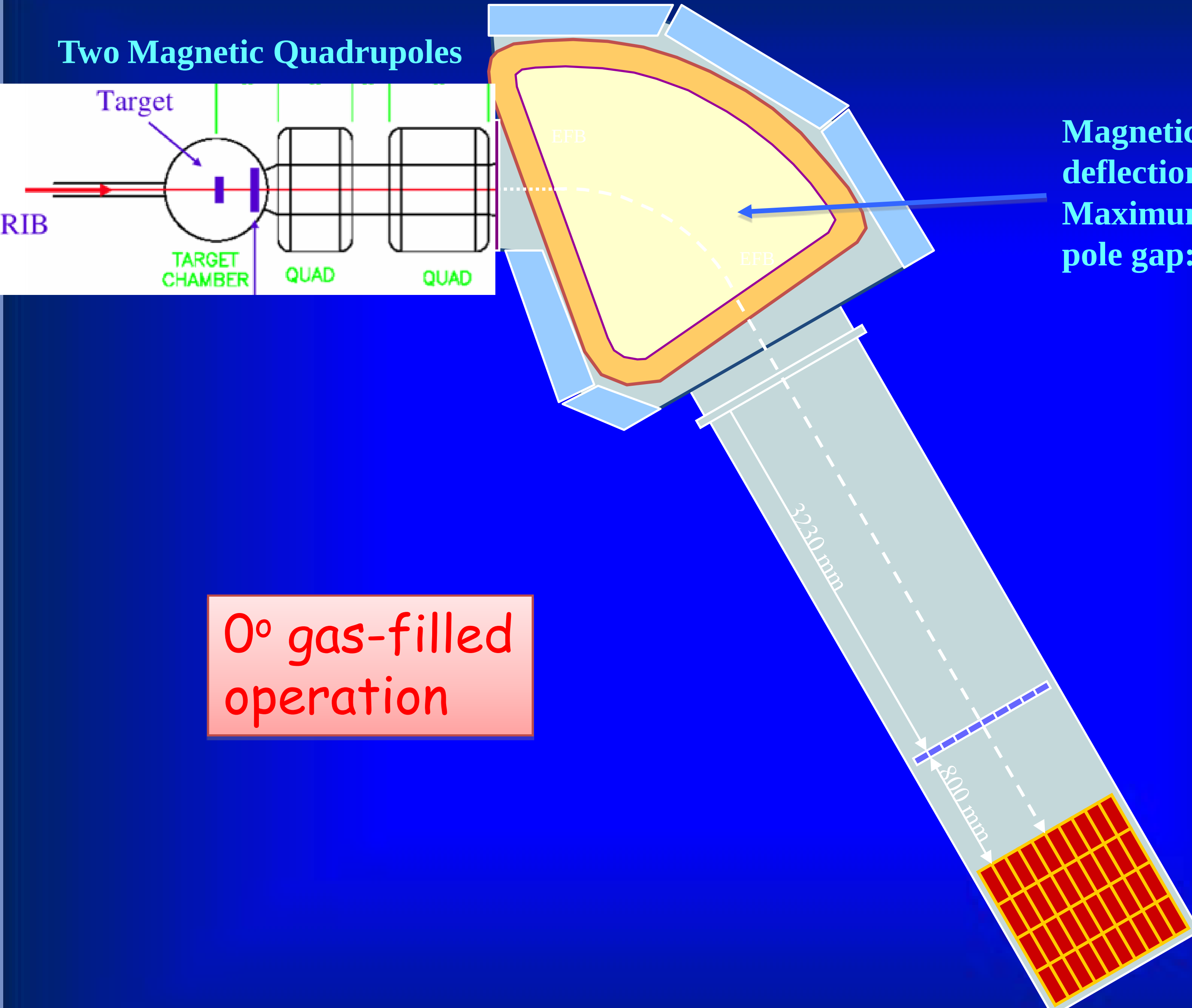




PRISMA
0° operation
(in vacuum)

# Features

| | |
|---|---|
| Solid angle | ~ 80 msr |
| Mom. acceptance | ± 10% |
| Maximum rigidity | 1.2 Tm |
| Dispersion | 4 cm/% |
| Energy resolution | 1/1000 |
| Mass resolution | 1/300 FWHM |

# Two Magnetic Quadrupoles




**Magnetic Dipole.**
**deflection angle 60°**
**Maximum rigidity 1.2 Tm**
**pole gap: 20cm**

0° gas-filled operation

# Summary

- we propose to perform systematic measurements of fusion cross sections near and below the Coulomb barrier, for a number of systems involving heavy-ion exotic beams produced by SPES

- typical cases are $^{90}Kr$, $^{98}Sr$, $^{132}Sn$ and $^{140}Xe$ accelerated on lighter targets like $^{40,48}Ca$

- very important information on channel-coupling effects can be extracted, in a close connection with the varying nuclear structure when going from stable to exotic neutron-rich nuclei

- upgrading the PRISMA spectrometer will be needed, and this is presently under study

End