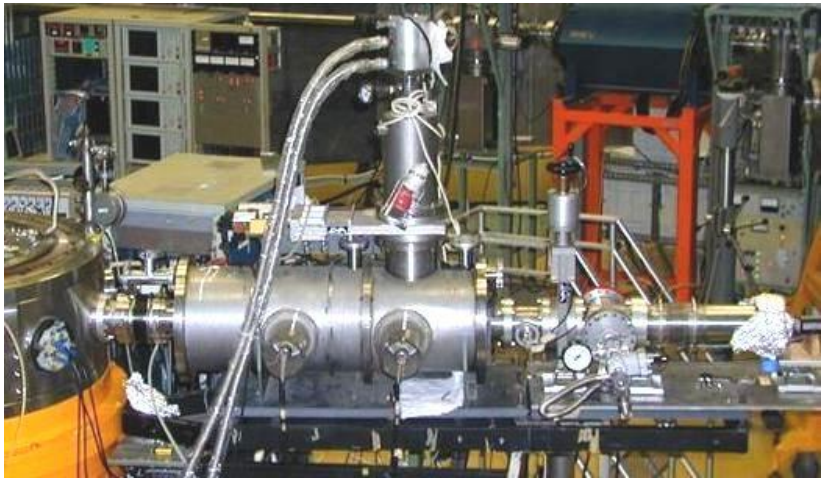
The PRISMA experiment at LNL

Traditionally, our group has always been involved in 2 lines of research:

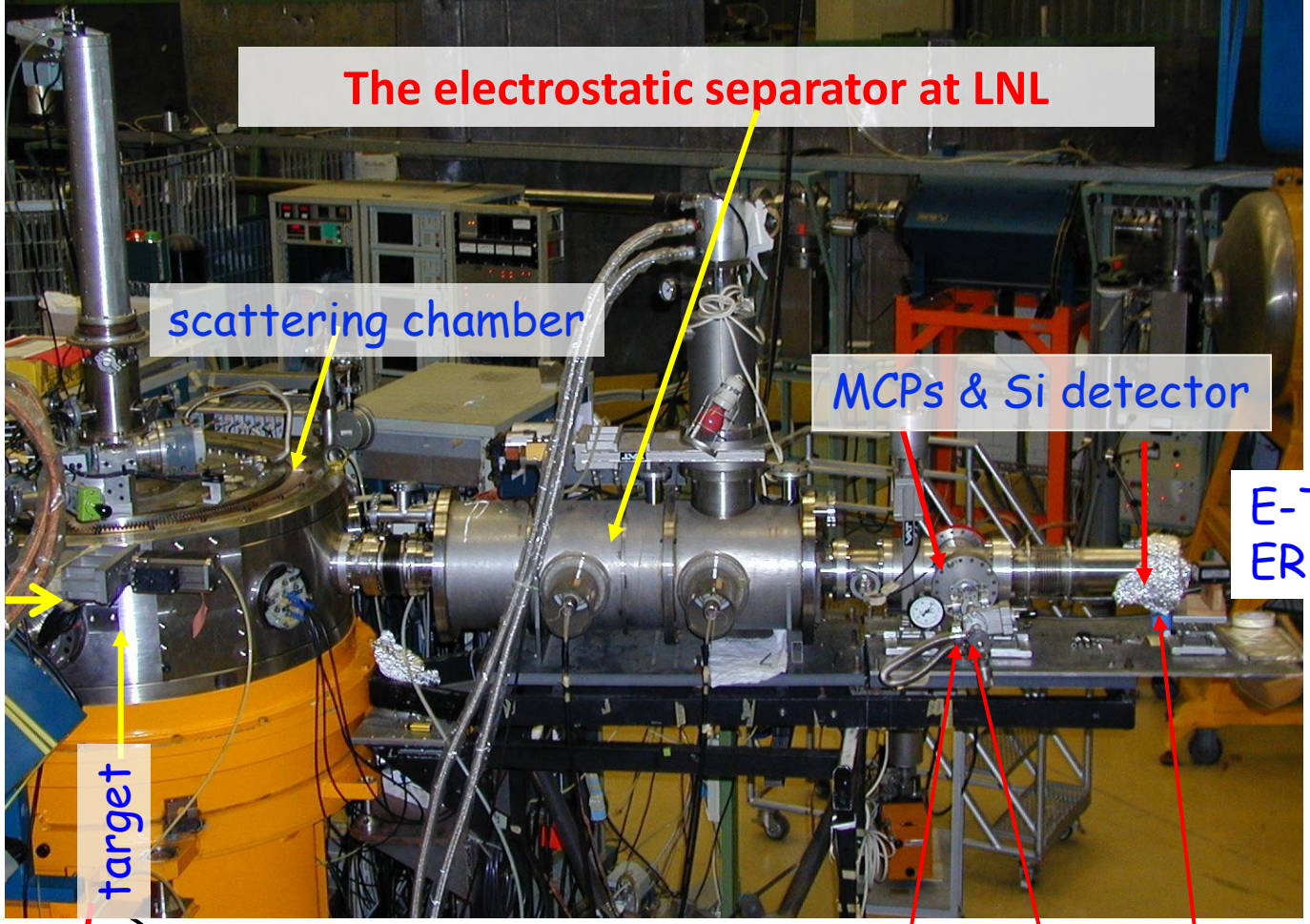


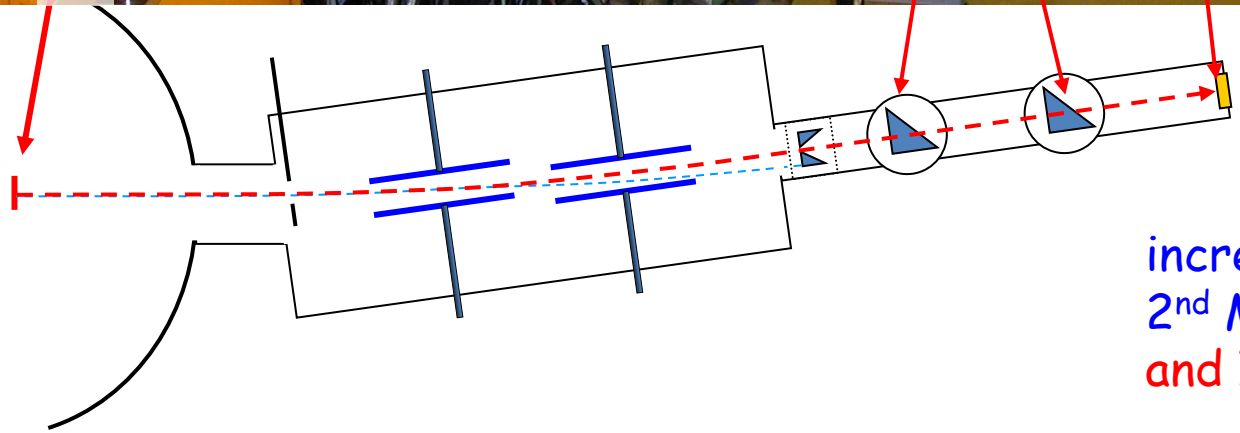
HI fusion reactions around V_B

presently focused at **$E << V_B$**

2-body reactions, the same energy

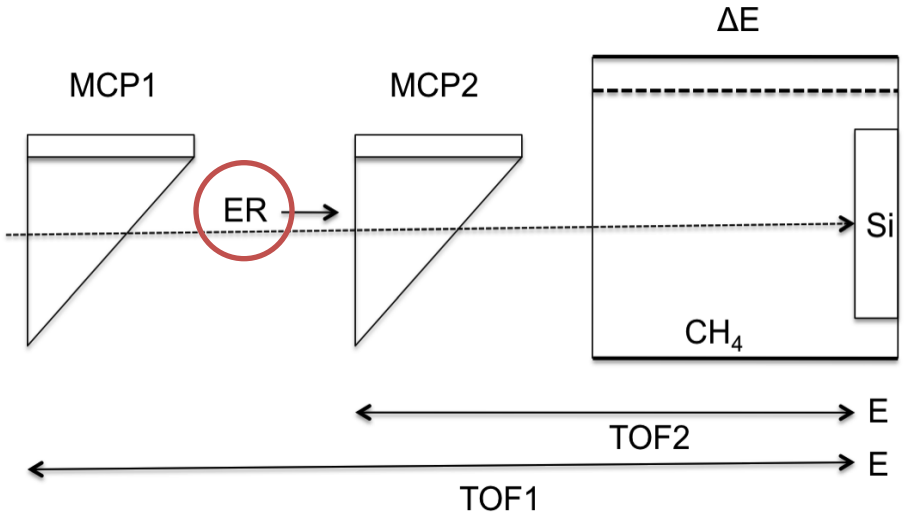
pair transfer enhancement
(transfer coupling to fusion
n-rich isotope production ....)

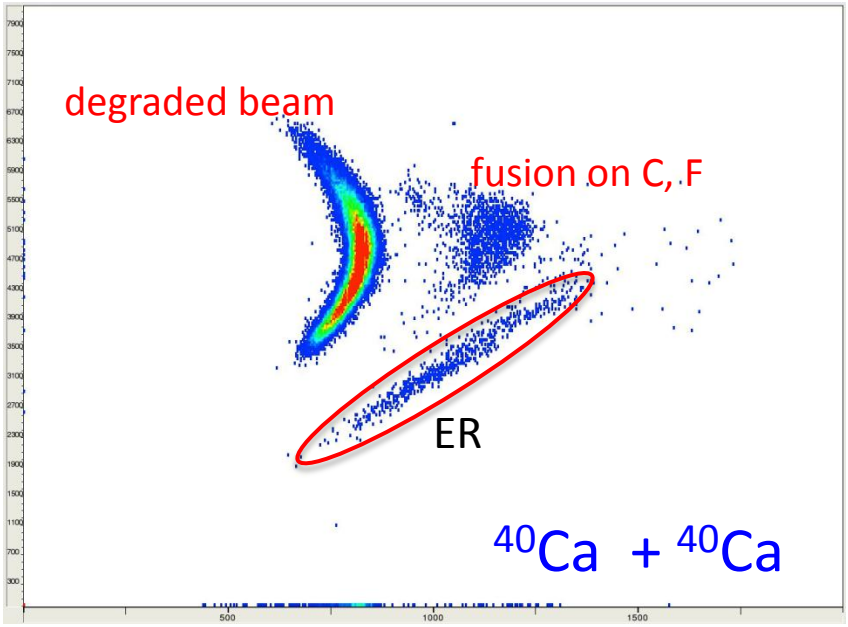


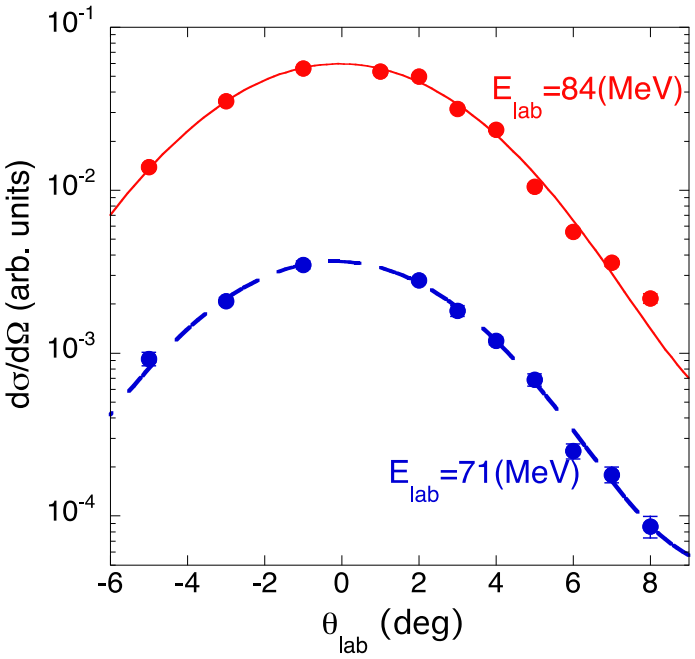


increased solid angle
2nd MCP-detector
and I.C.

Detector set-up, experimental matrix ΔE-ToF and angular distributions



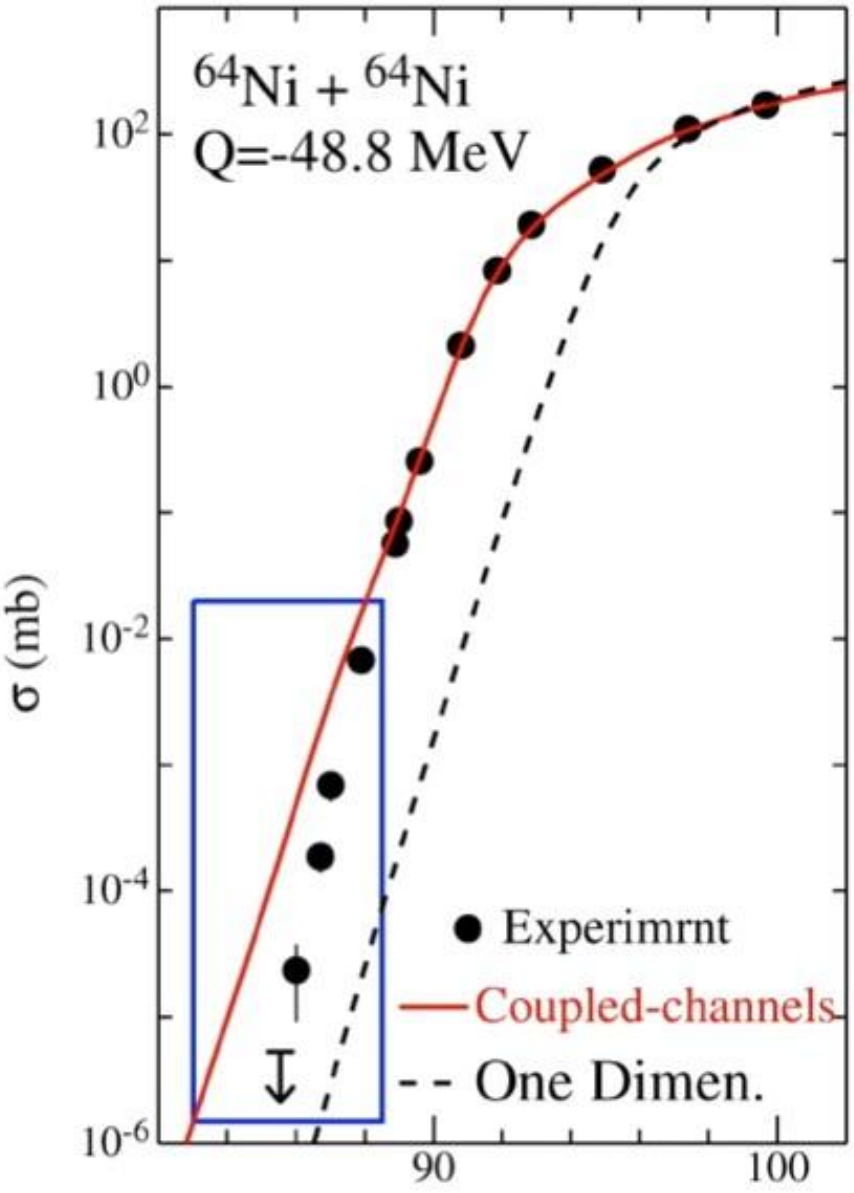




Experimental Angular Distributions

G.Montagnoli, NN2012

Low-energy fusion hindrance



Long known for its large enhancement in the near sub-barrier region ...

... fusion cross section drops below standard CC calculations at very low energies (and cross sections)
(C.L.Jiang, several)

deviation from "exponential-like": the slope gets steeper at lower energy, suggesting some kind of threshold effect

two ways to represent hindrance

C.L.Jiang et al. Phys.Rev.Lett. 93 (04) 012701

change of the logarithmic slope

$$L(E) = \frac{d \ln(E\sigma)}{dE}$$

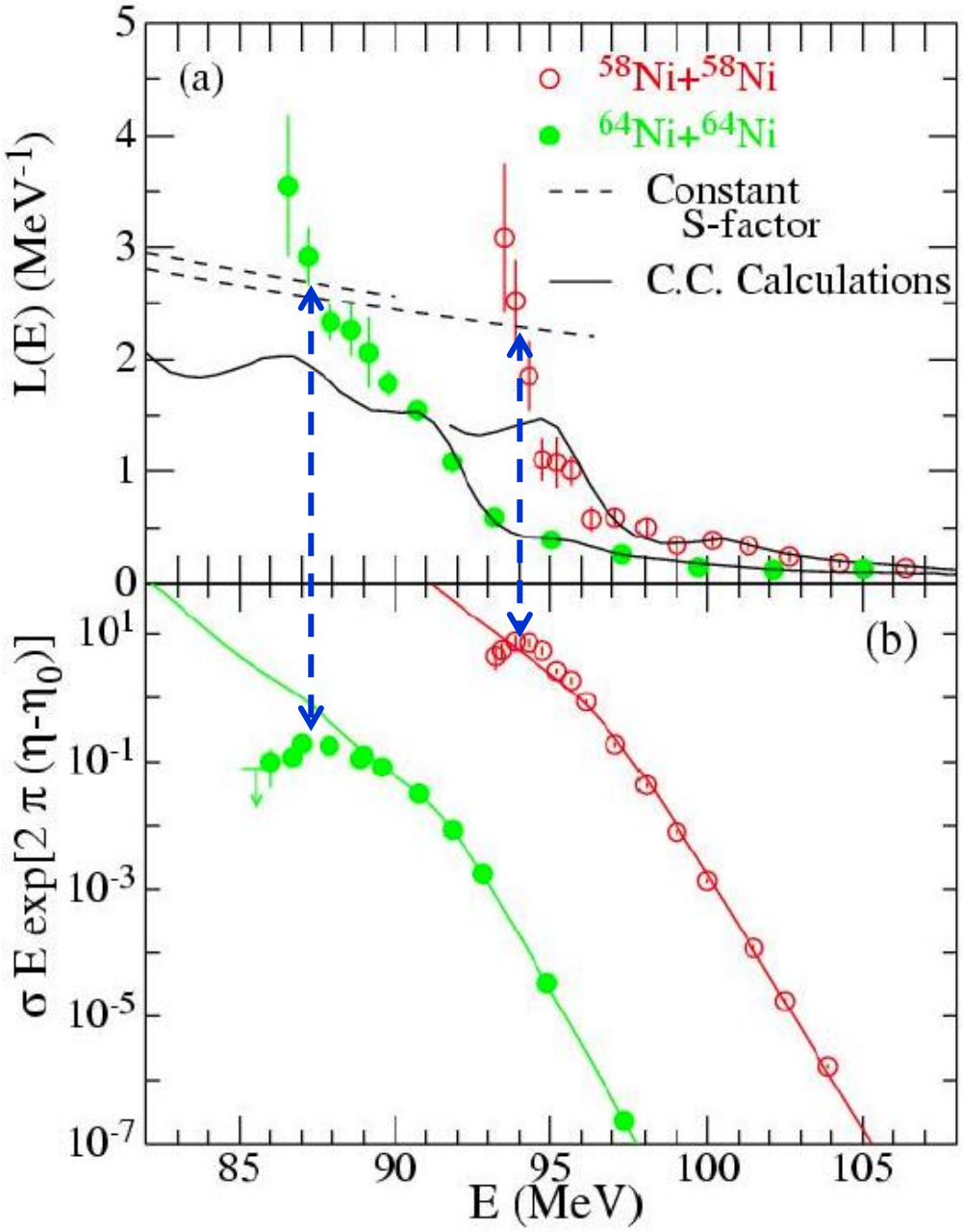
"deviation from the trend":
the astrophysical S – factor
may show a maximum

$$S(E) = E\sigma \cdot \exp(2\pi\eta)$$

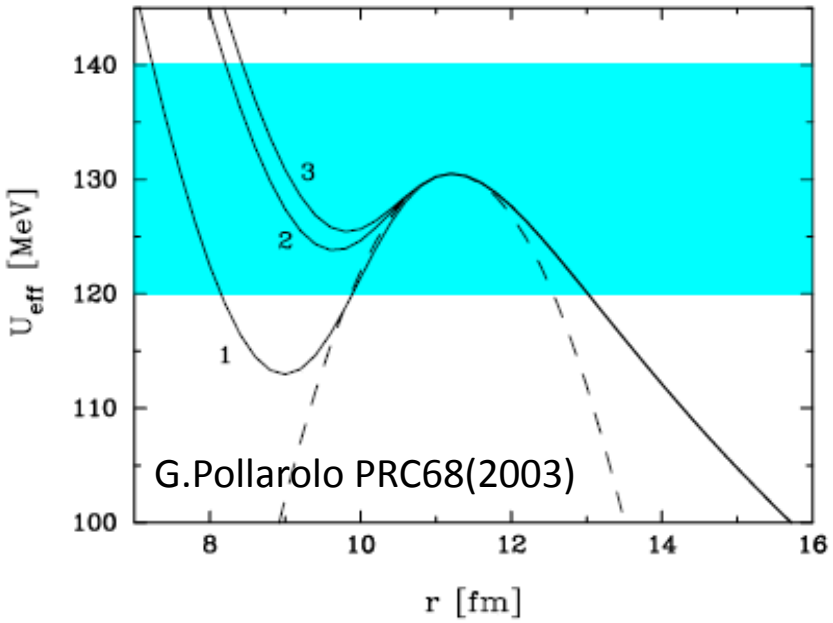
not independent:
if S(E) has a maximum

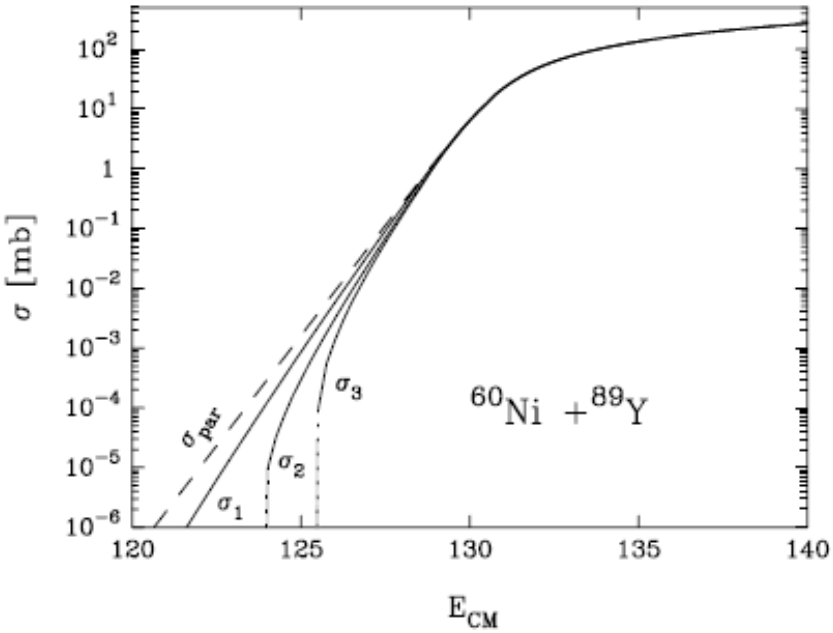
$$L(E) = L_S(E) = \frac{\pi\eta}{E}$$

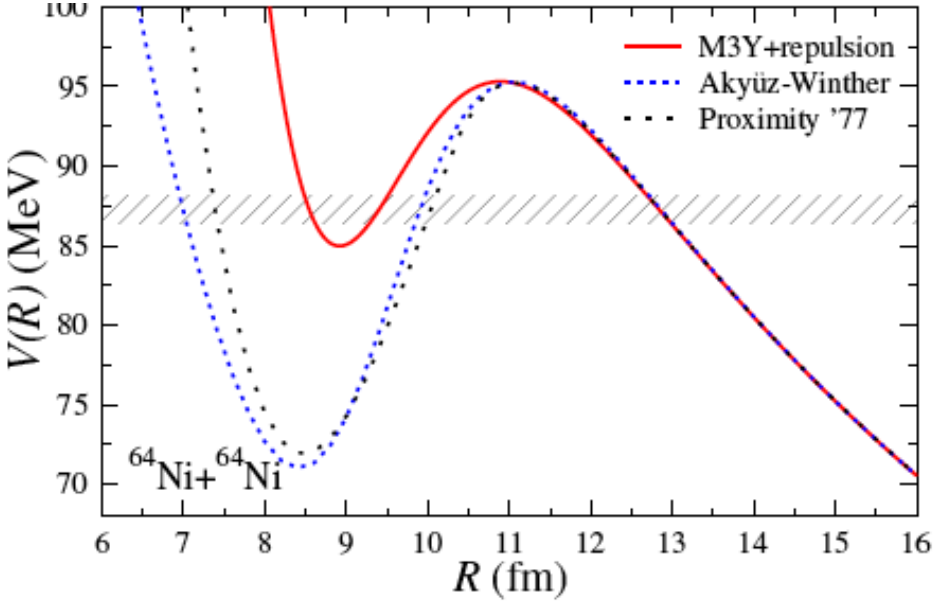
the energy E_S follows a systematic trend



A handle to probe the inner part of the nucleus-nucleus potential.







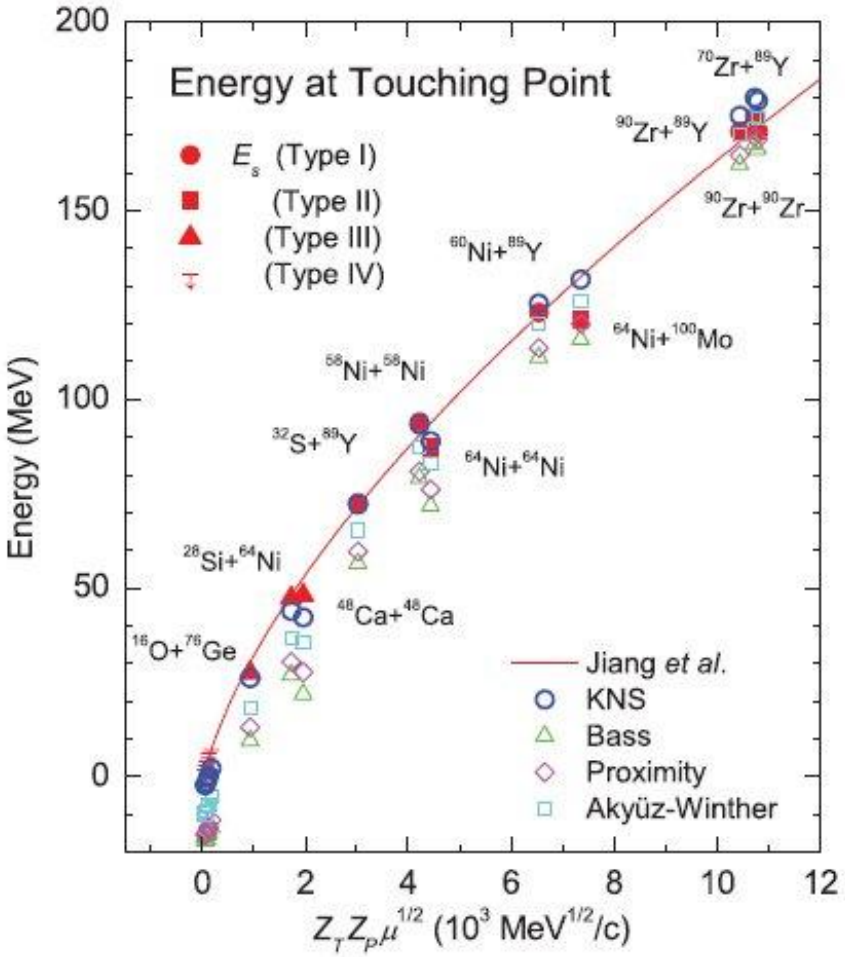
Esbensen and Misicu:
Phys. Rev. Lett. 96 (2006) 112701

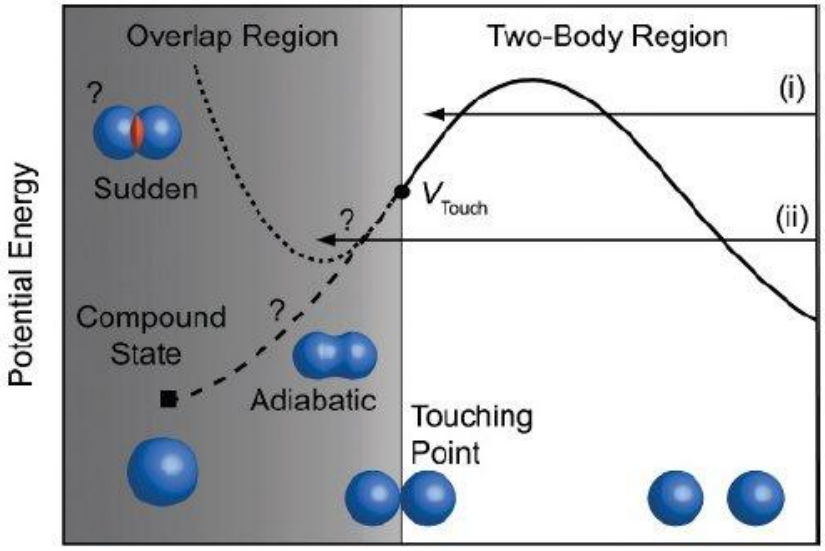
incompressibility of nuclear matter
+ Pauli excl. principle: M3Y + repulsion

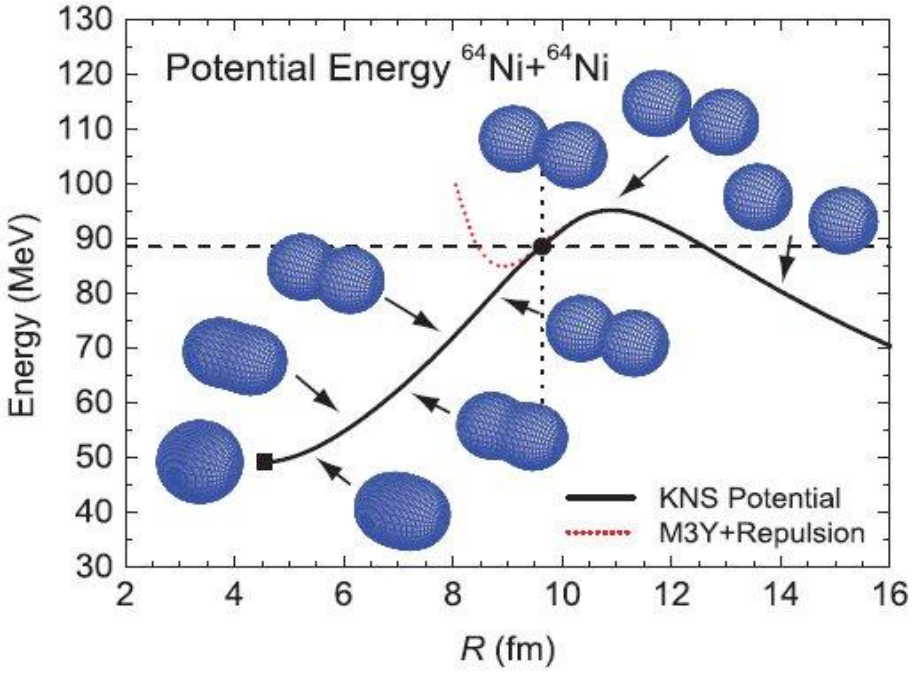
Sudden approximation

An alternative point of view:

Adiabatic approximation







2-step model

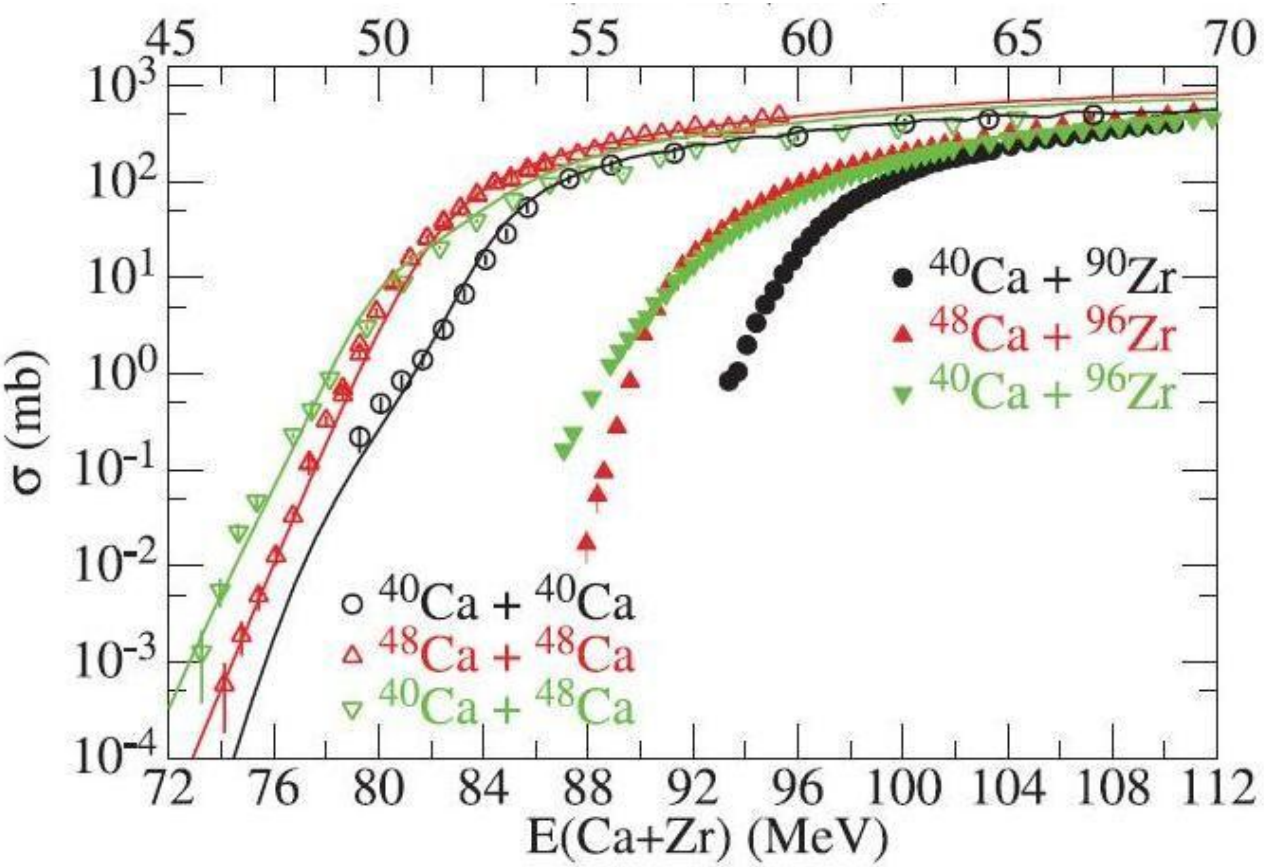
standard CC for **$r>R_{touch}$**
neck: dinuclear system (1b BP) for **$r>R_{touch}$**

Our measurements of Deep sub-barrier fusion

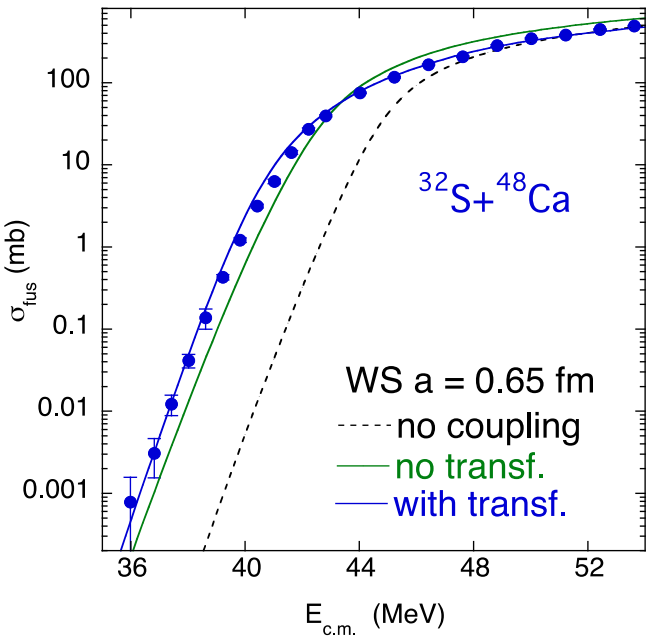
$^{36}S+^{48}Ca$ PRC78 (2008)
$^{48}Ca + ^{48}Ca$ PLB 679 (2009)
$^{36}S+^{6}4Ni$ etc. PRC82 (2010)
Ca + Ca systems. PRC82 (2010)

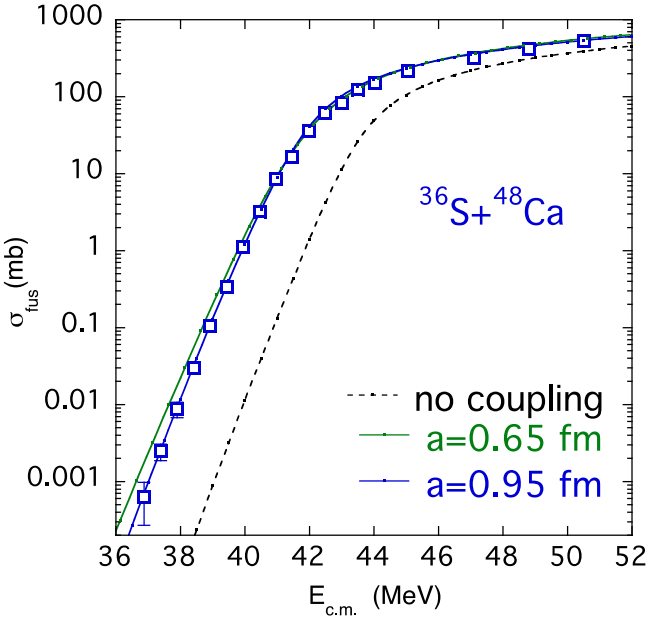
$^{58}Ni+^{54}Fe$ PRC82 (2010)
$^{40}Ca+^{40}Ca$, $^{36}S+^{64}Ni$. NPA 834 (2010)
$^{40}Ca+^{40}Ca$ etc. PRC85 (2012)

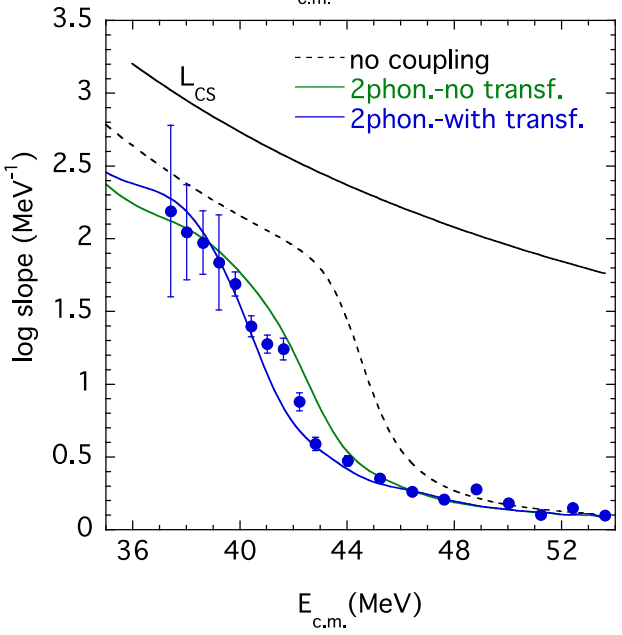
An interesting systematics:

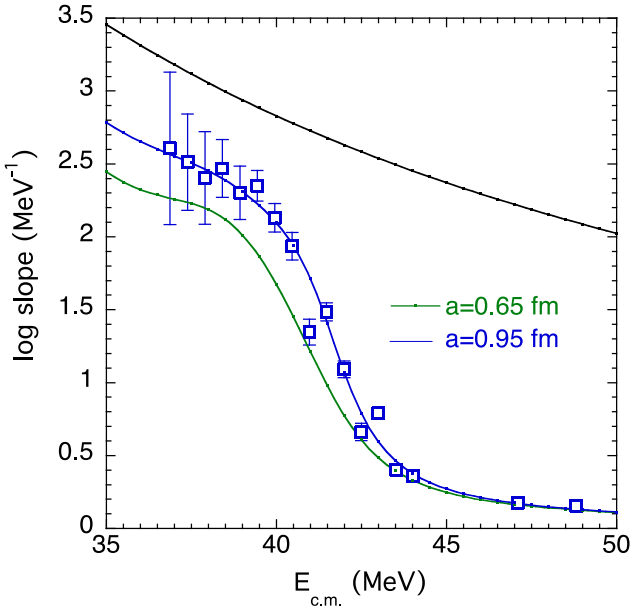


other recent results





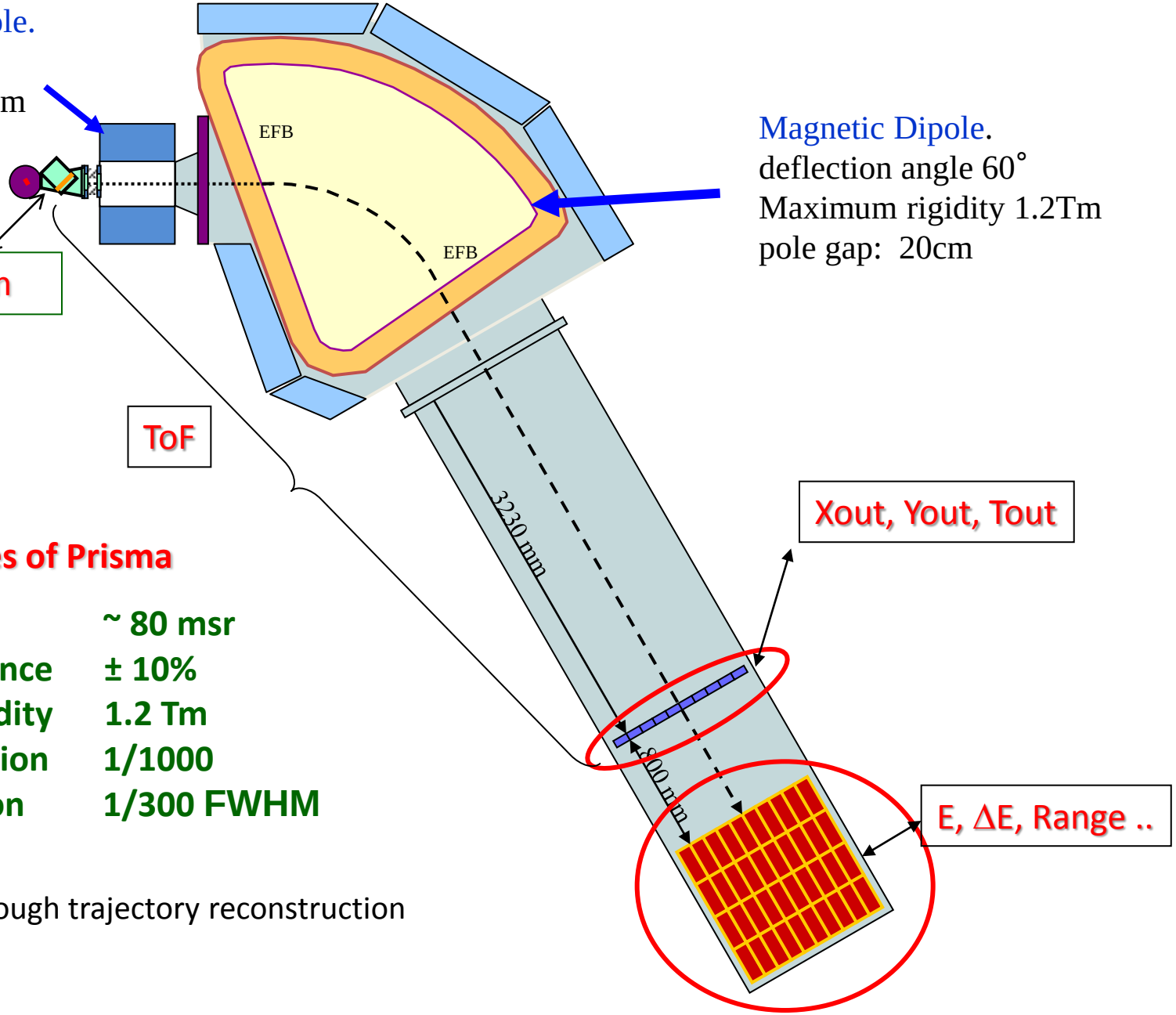




$$L(E) = \frac{d\ln(Es)}{dE}$$

G.Montagnoli, NN2012

Magnetic Quadrupole.
diameter 30cm
effective length 50cm



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

Deisgn features of Prisma

Solid angle	**~ 80 msr**
Mom. acceptance	**± 10%**
Maximum rigidity	**1.2 Tm**
Energy resolution	**1/1000**
Mass resolution	**1/300 FWHM**

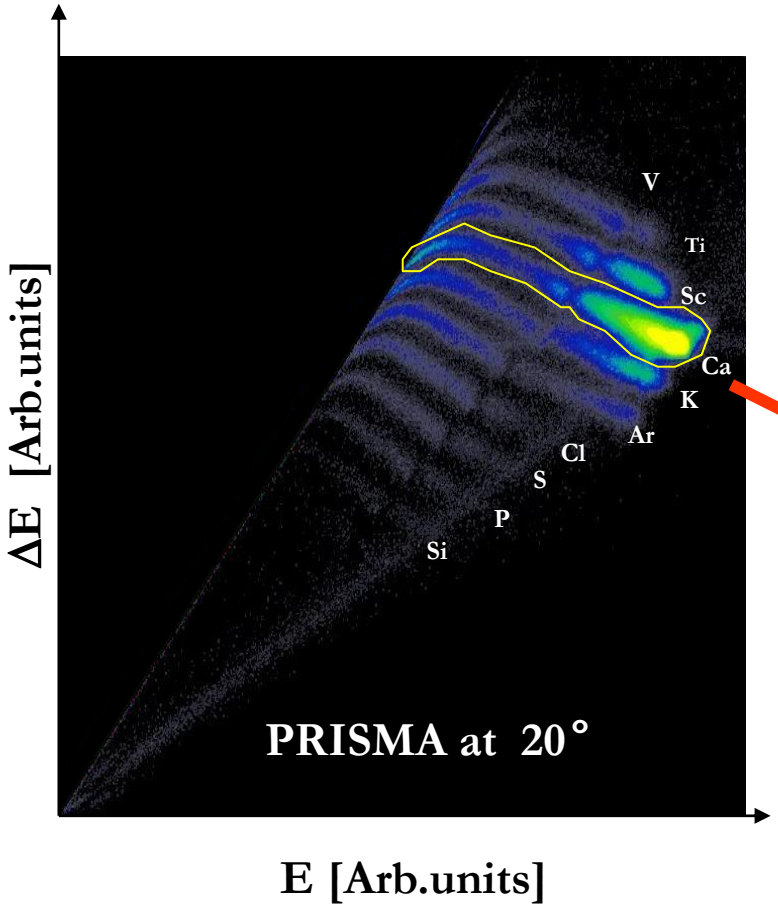
Only possible through trajectory reconstruction

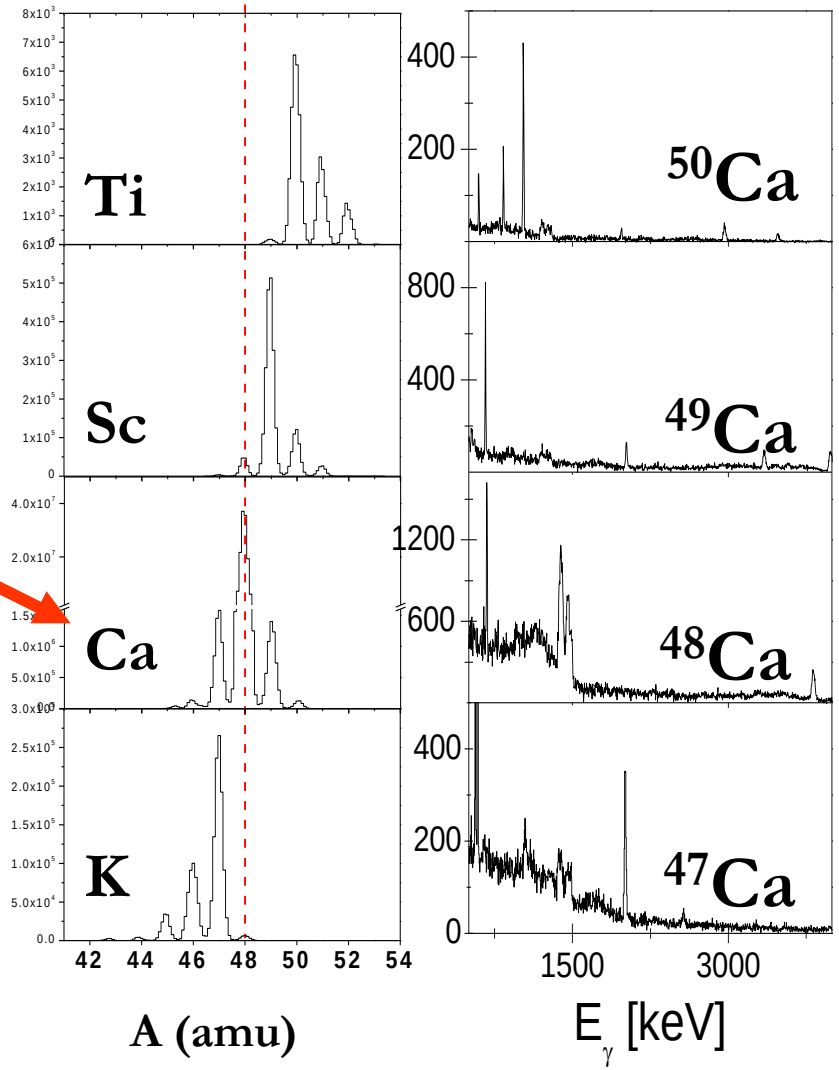
Isotope Selection

Mass distributions
Reaction studies

Gamma spectra
Nuclear structure

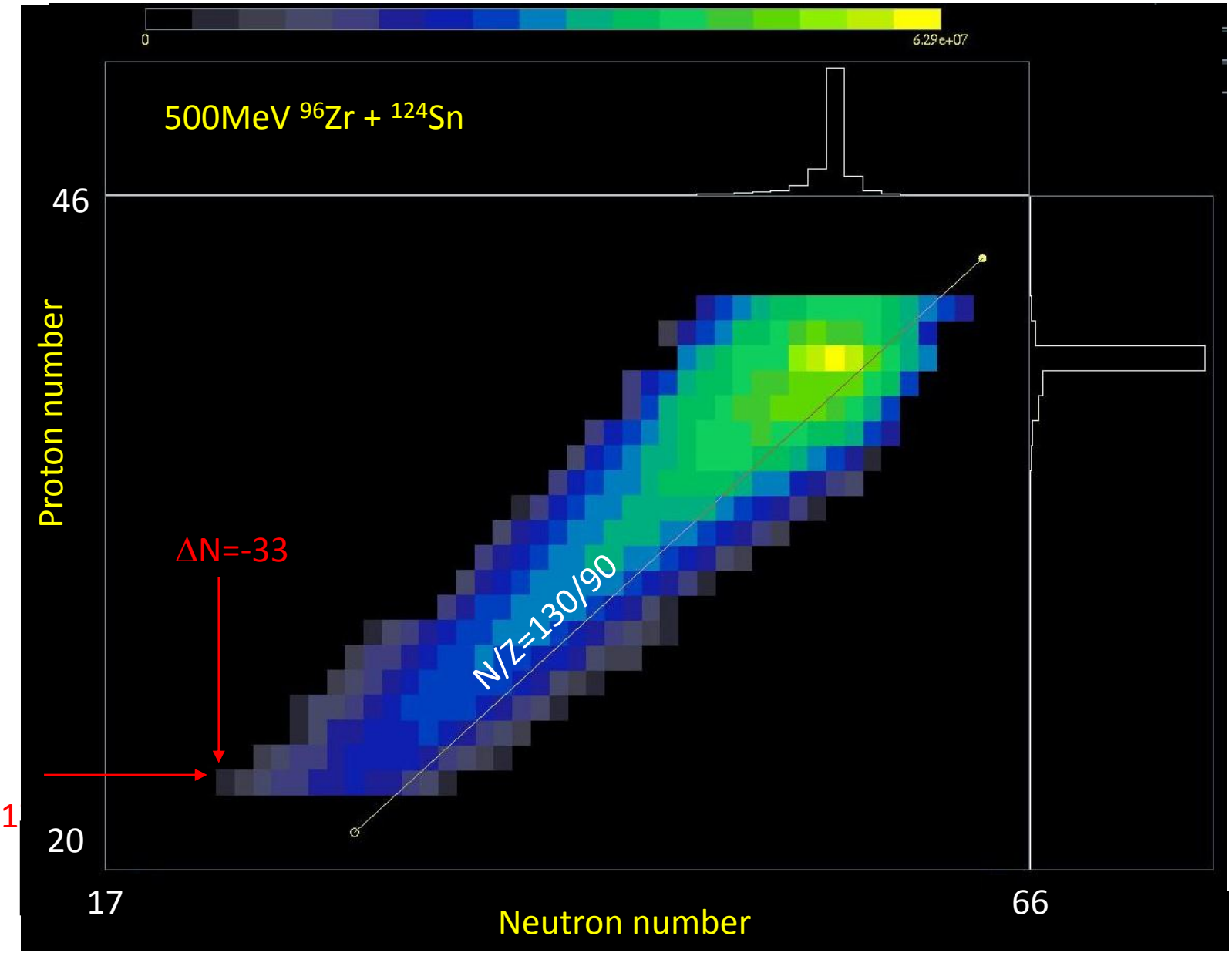
$^{48}Ca + {}^{64}Ni$ at 282 MeV





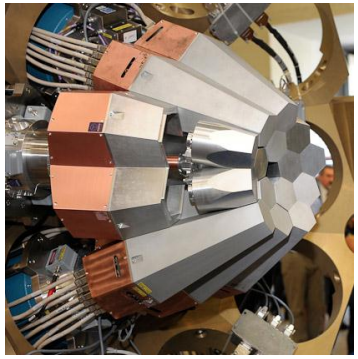
D.Montanari

N-Z yields



Paolo Mason, Giugno 2007

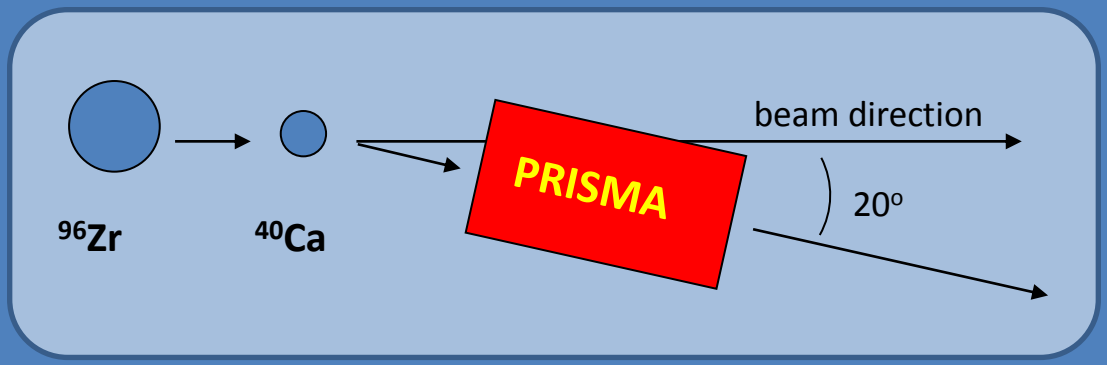
LNL experiments in the n-rich region

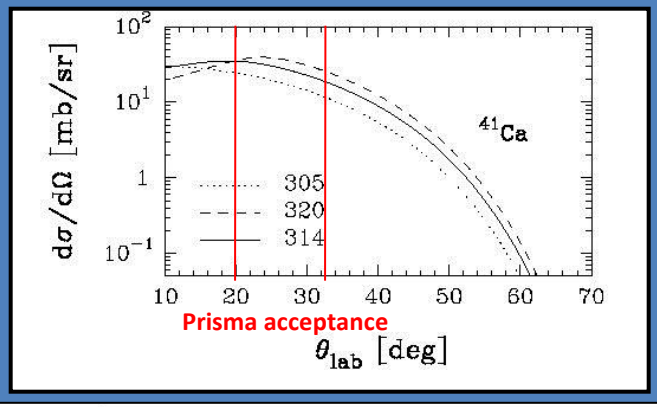


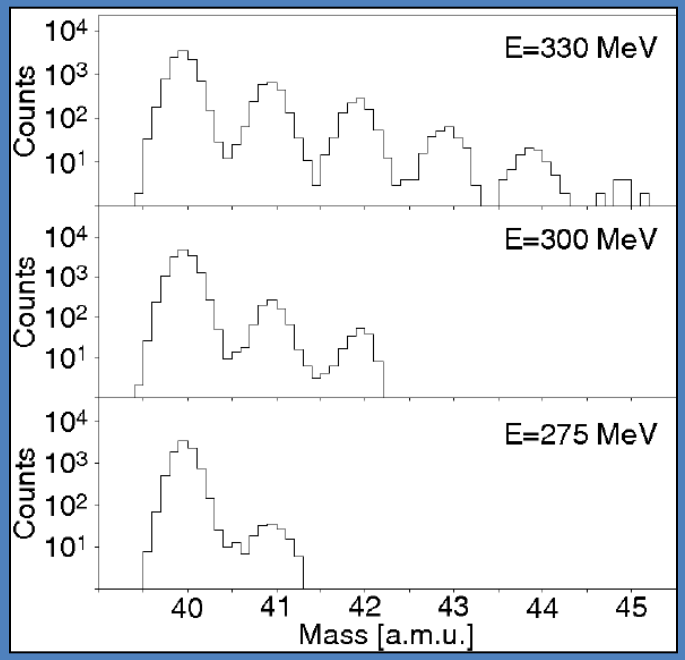
AGATA Demostrator

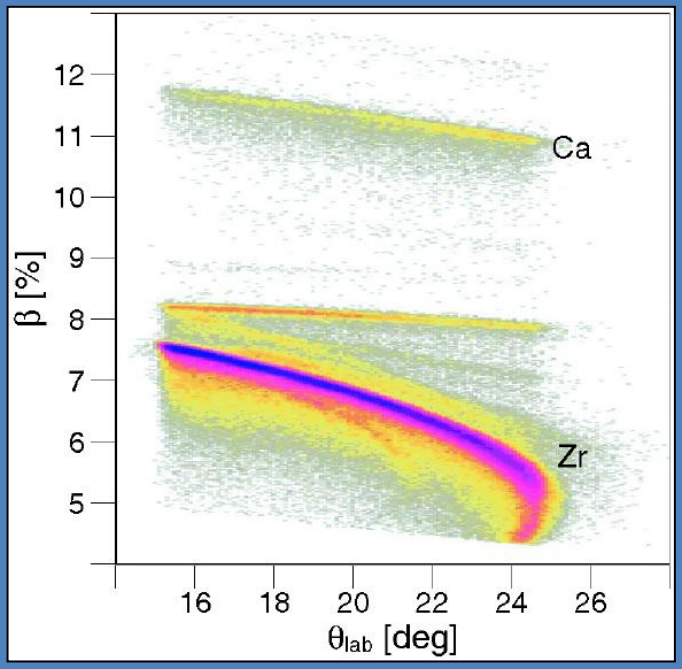
J.Valiente-Dobon. 2012

Reaction in inverse kinematics with PRISMA





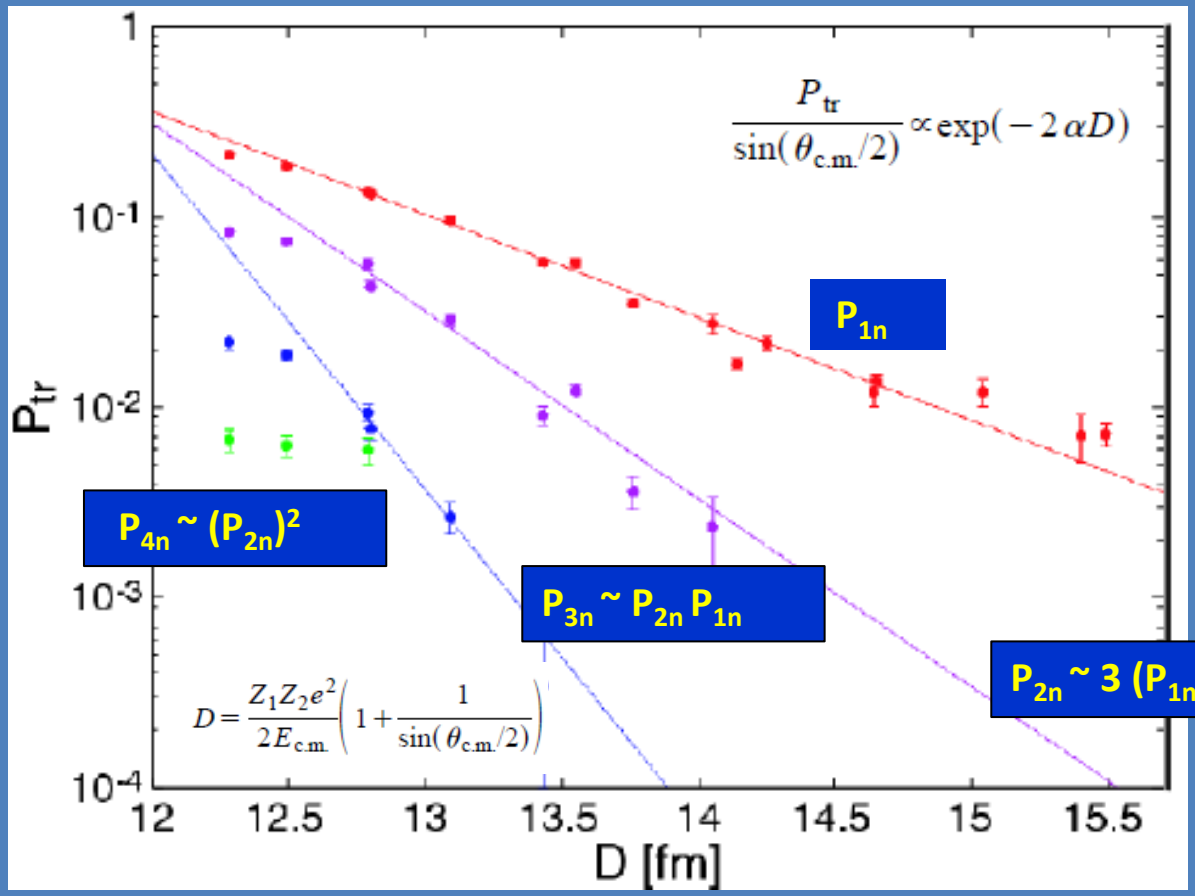




below barrier: no interference («slope anomaly»)
only the tails of the wavefunction overlap
semiclassical approximation valid

forward focusing
low cross sections

Previous experiment - $^{96}Zr+^{40}Ca$

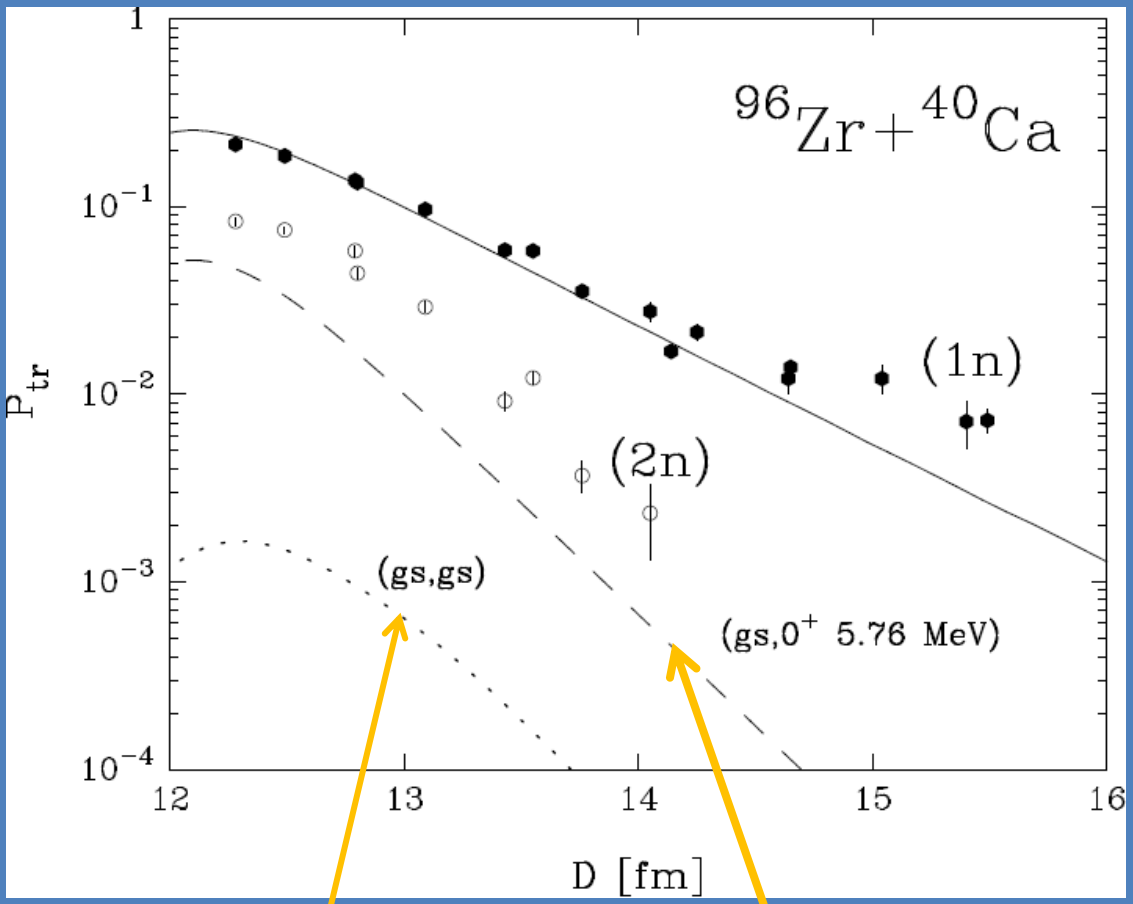


slopes in nice agreement with expectations from the binding energies

L. Corradi, FUSION11, St. Malo – France

D.Montanari. NN2012

Previous experiment - $^{96}Zr+^{40}Ca$



+1n well reproduced by theory in slope and absolute value

Same slope of +2n between theory and experiment

+2n enhancement due to the presence of other excited states?

Absorption reproduced by theory

L. Corradi et al., Phys. Rev. C 84, 034603 (2011)

2n transfer to g.s.

2n transfer to 0^+ (5,76MeV)
(2n in p3/2)

D.Montanari. NN2012

The experiment – ^{60}Ni +^{116}Sn

PRISMA + AGATA

Direct kinematics

Angular distributions

θ_{lab} = 50° and 70°

(D ≈ 14.5 fm and 16.7 fm)

PRISMA only

Inverse kinematics

Excitation function

E_{beam} = 410 – 500 MeV (θ_{lab} = 20°)

(D ≈ 12.3 to 15.0 fm)

Gamma-rays used to estimate the population of excited states

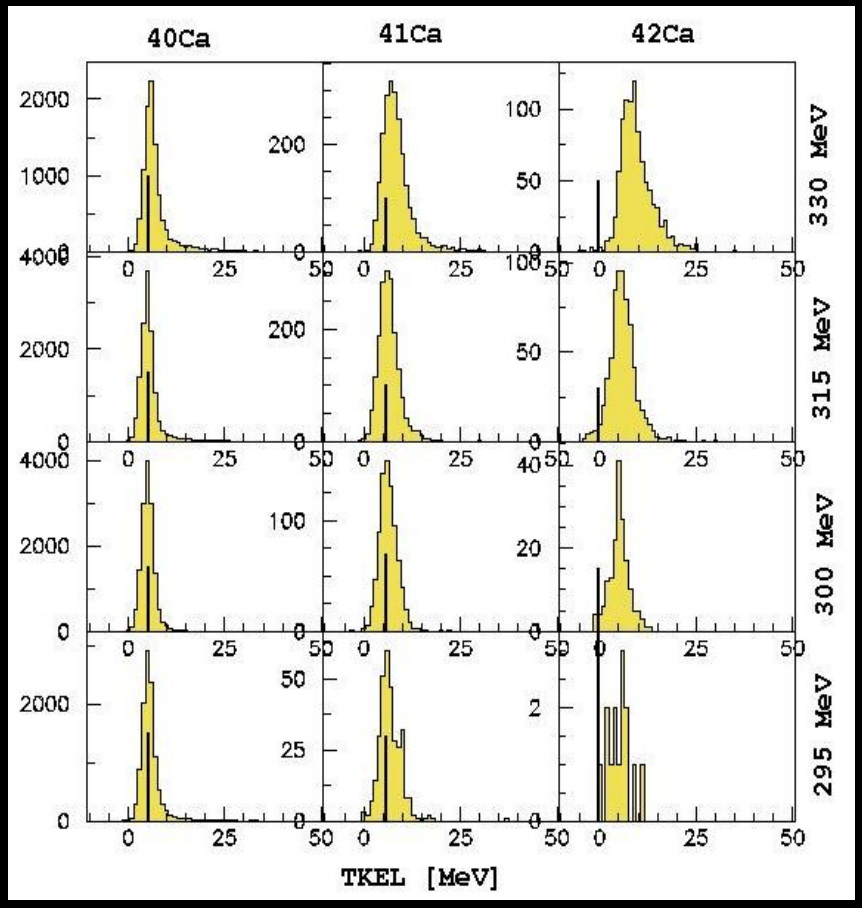
Ground state Q-values

	+1n	+2n	+3n	+4n
Closed-shell ^{96}Zr + ^{40}Ca	+ 0.51	+ 5.53	+ 5.24	+ 9.64
Superfluid ^{116}Sn + ^{60}Ni	- 1.74	+ 1.31	- 2.15	- 0.24

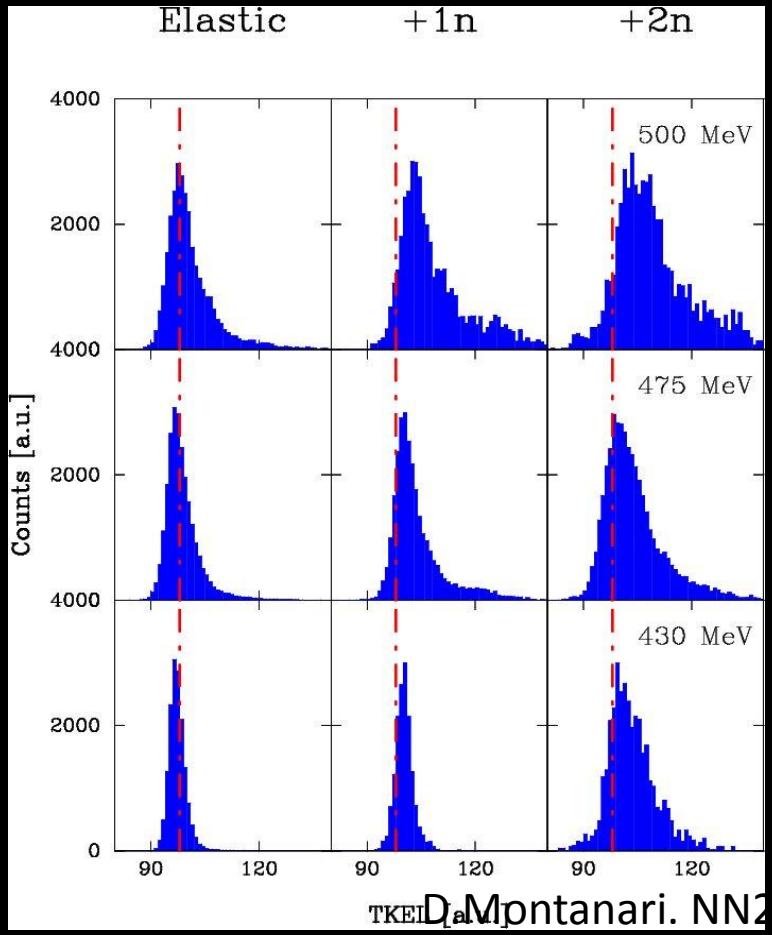
D.Montanari. NN2012

The experiment – ^{60}Ni +^{116}Sn

Qvalues for ^{96}Zr+ ^{40}Ca

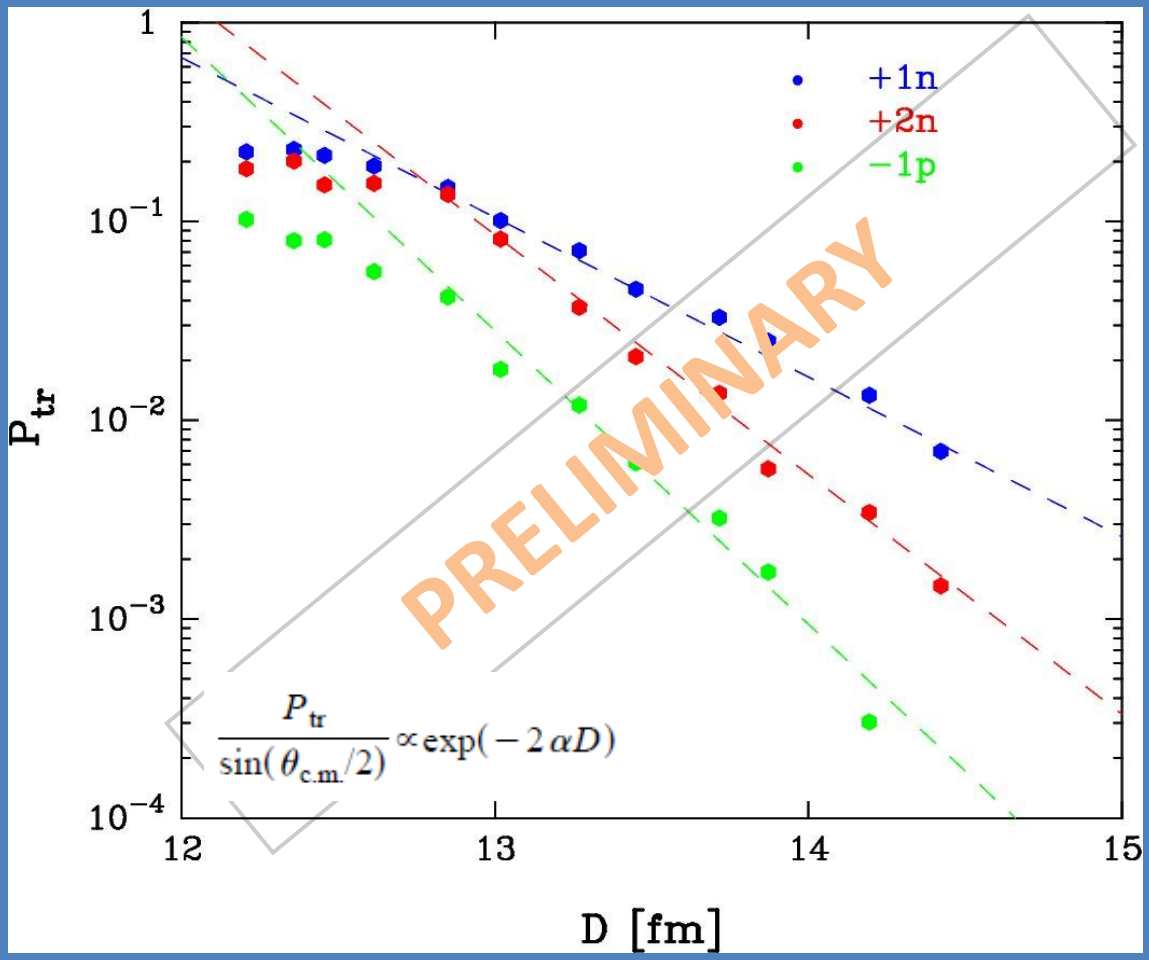


Qvalues for ^{116}Sn + ^{60}Ni



The experiment – ^{116}Sn + ^{60}Ni

Slopes for ^{116}Sn + ^{60}Ni



Preliminary data
Data under analysis

+1n and +2n slopes are in agreement with those expected from binding energies

$$D = \frac{Z_1 Z_2 e^2}{2E_{c.m.}}\left(1 + \frac{1}{\sin(\theta_{c.m.}/2)}\right)$$

D.Montanari. NN2012

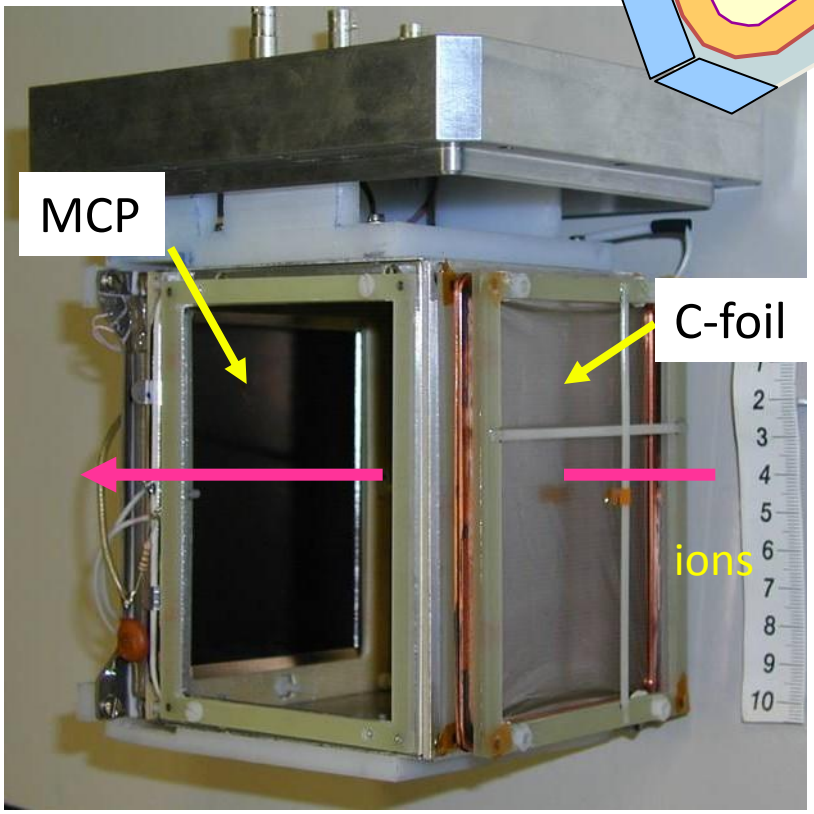
Present limitations and possible improvements

MCP start detector

X,Y resol. < 1 mm

negligible straggling

Xin, Yin, Tin

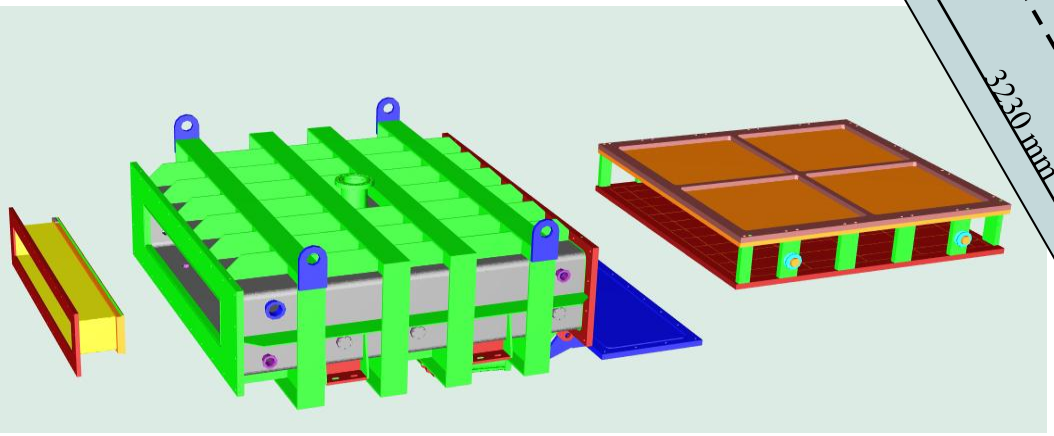


Anode readout based on 2 orthogonal delay lines. Home-made delay lines of 70 μm Cu-Be

DT ~ 350 ps

G.Montagnoli et al. Nuc.Instr.Meth. A547(2005)455

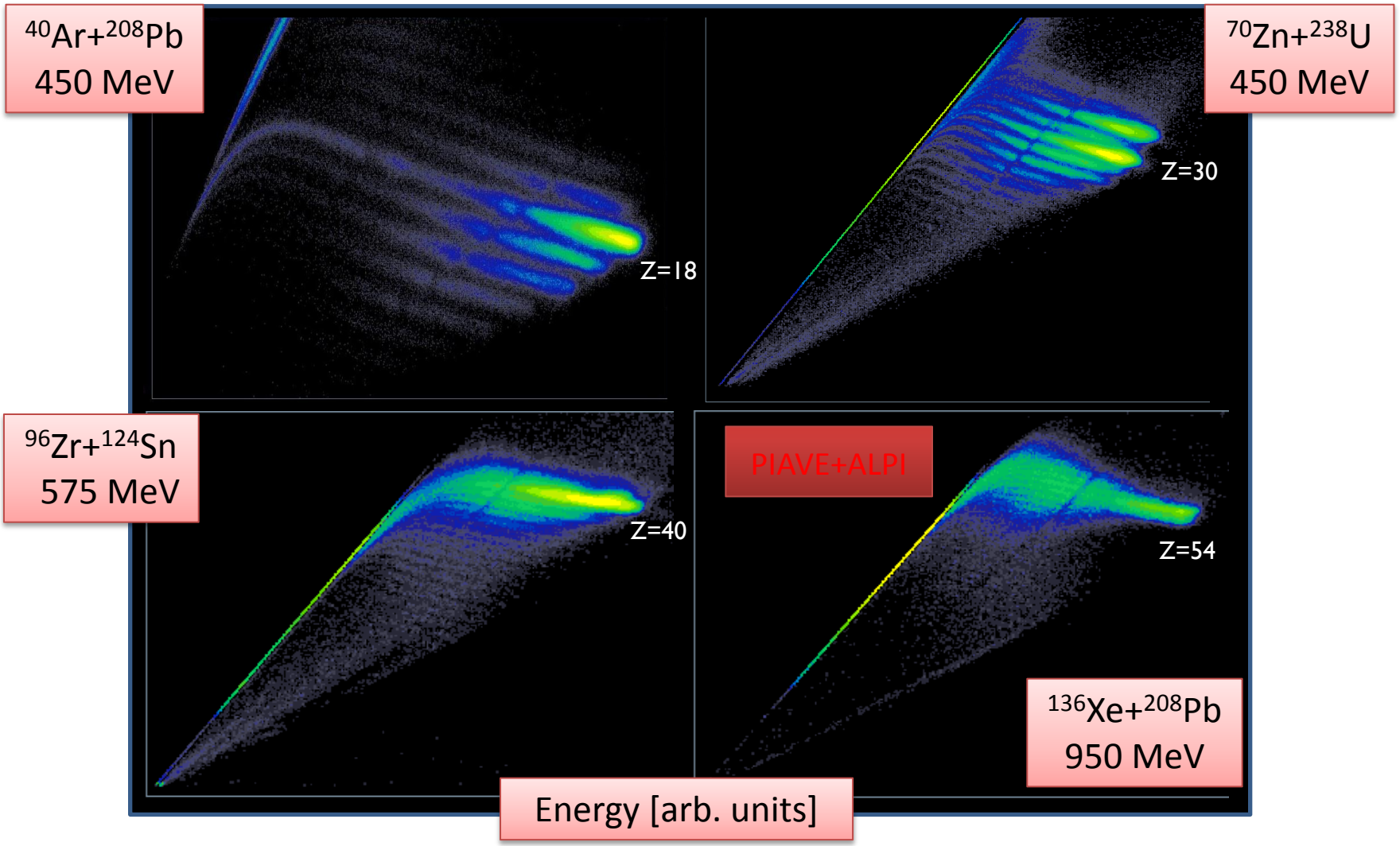
S.Beghini et al. Nucl.Instr.Met. A551 (2005)187



CH_4 or CF_4 @ < 100 hPa

Ionization Chamber.
entrance window 100x13cm
10x4 sections 10x25cm2 each

Z resolution / discrimination

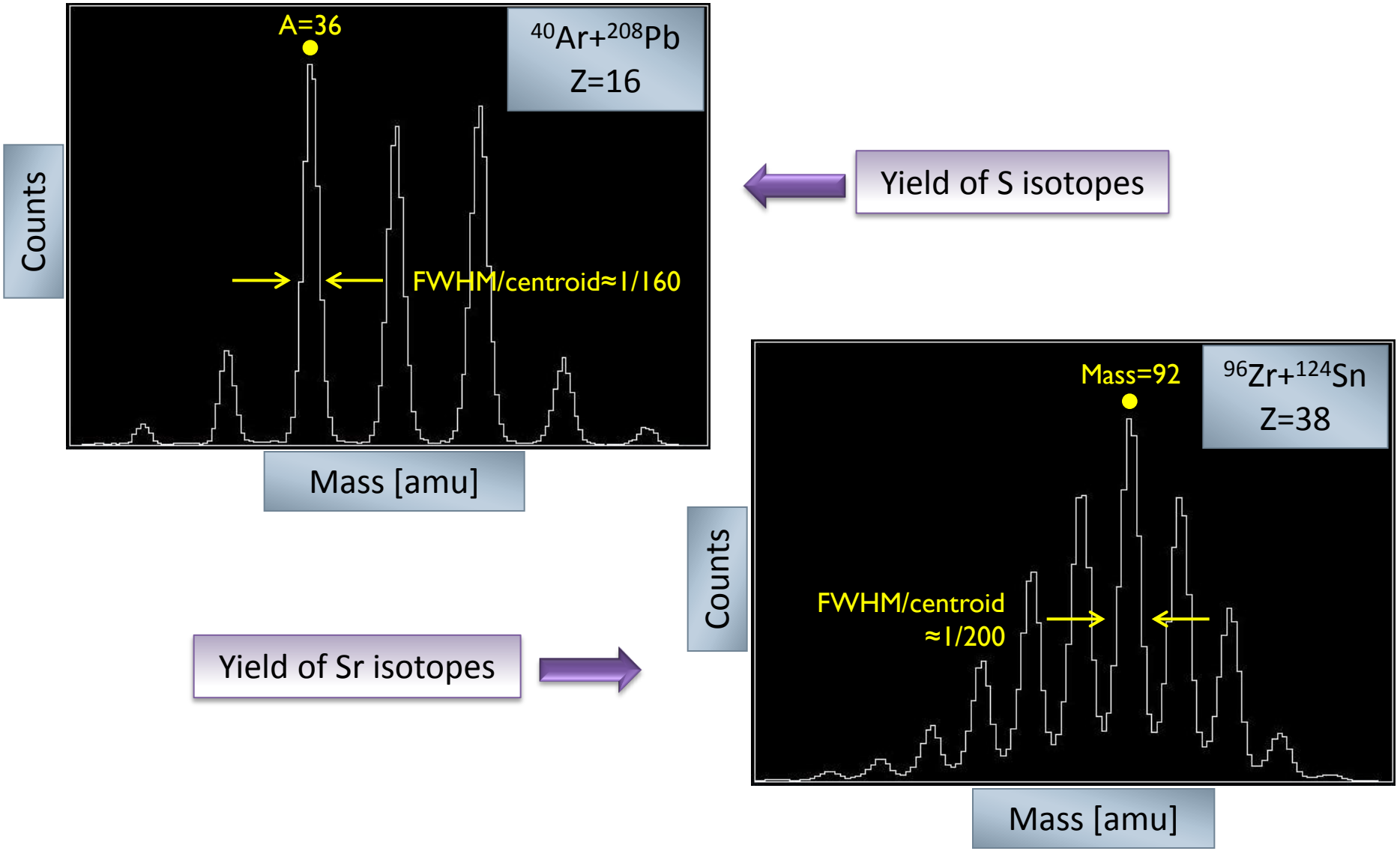


Below the Bragg peak no Z-separation can be obtained

E/A > 2-3 MeV for A ~200

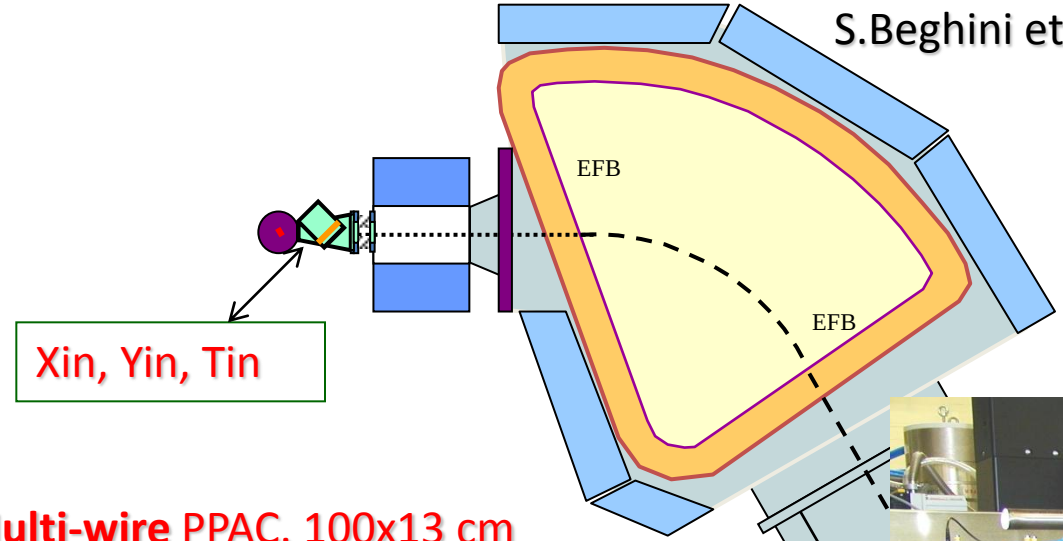
E. Fioretto

Mass resolution

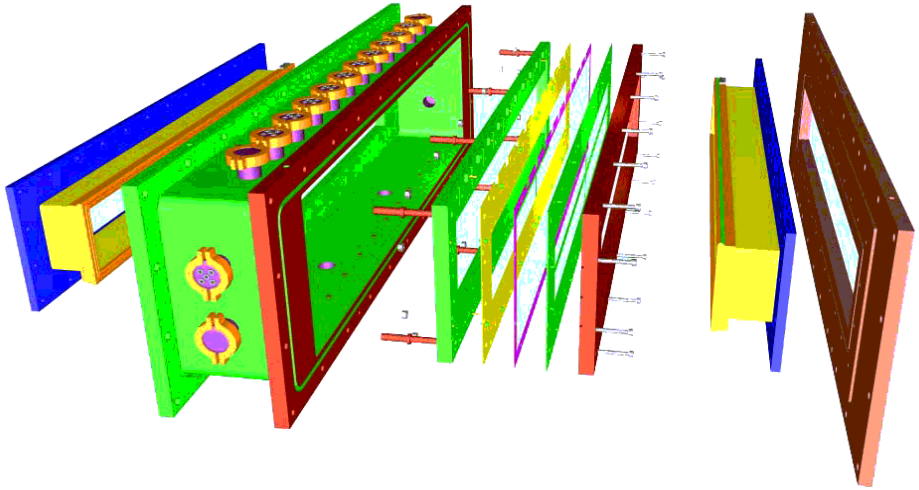


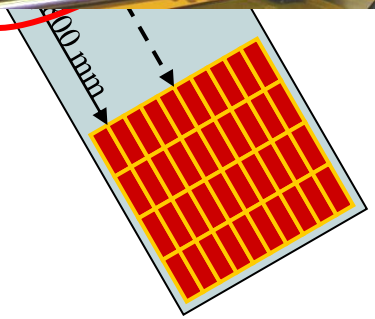
P. Mason

S.Beghini et al. Nucl.Instr.Met. A551 (2005)187

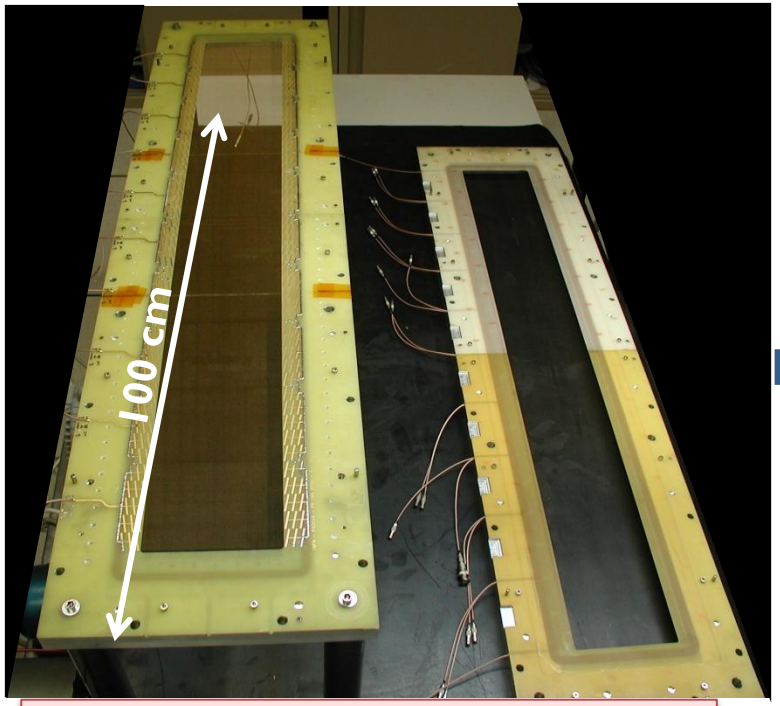


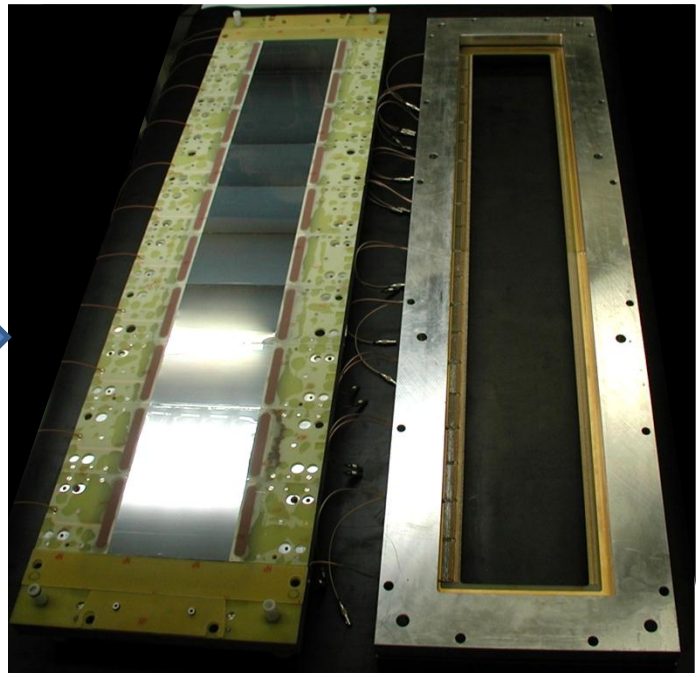
Multi-wire PPAC. 100x13 cm
10 sections, 10x13 cm
1mm X res.
2mm Y res.
Gas : C_4H_{10} @ 7 hPa

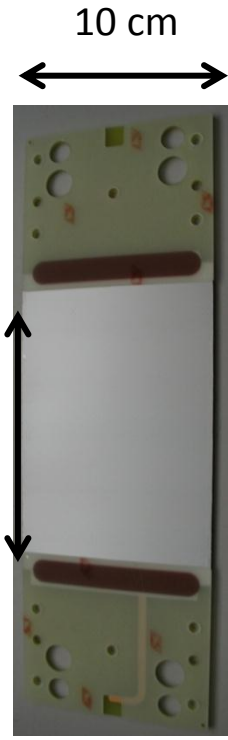




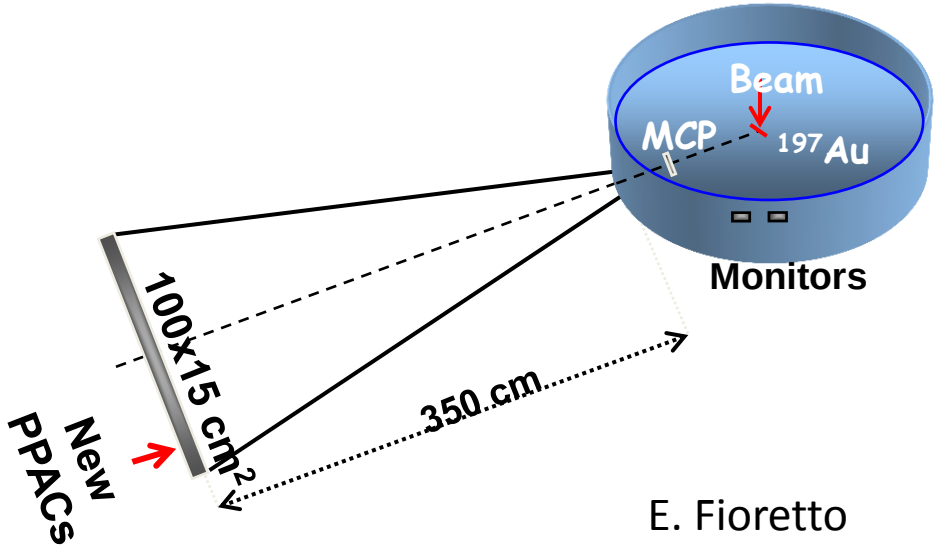
A more efficient focal-plane detector





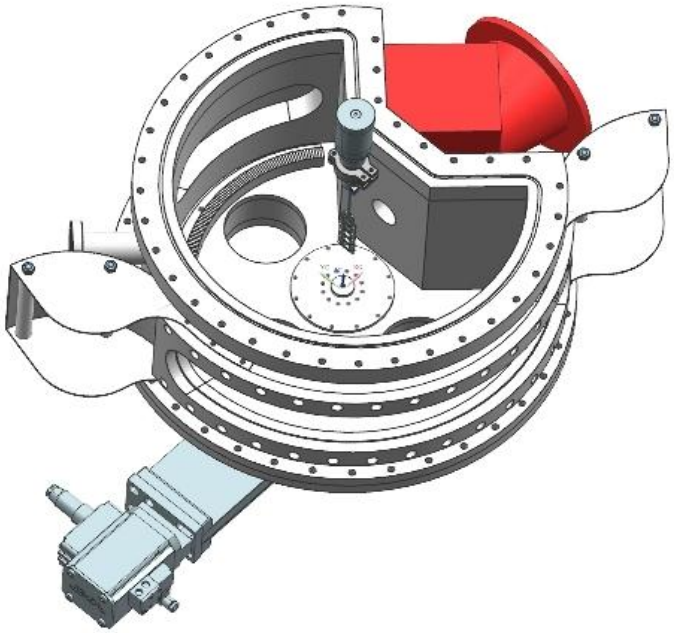


10 μm diameter Au plated Tungsten wires



E. Fioretto

New sliding seal scattering chamber



New large angle «coincidence arm»

MCP + PPAC + IC?