


Low energy, low yield measurements underground: Problems and some solutions

Heide Costantini
INFN Genova Italy

Accelerator's requirements

$$\sigma(E) = S(E) \cdot e^{-2\pi\eta(E)} / E$$

Low energies

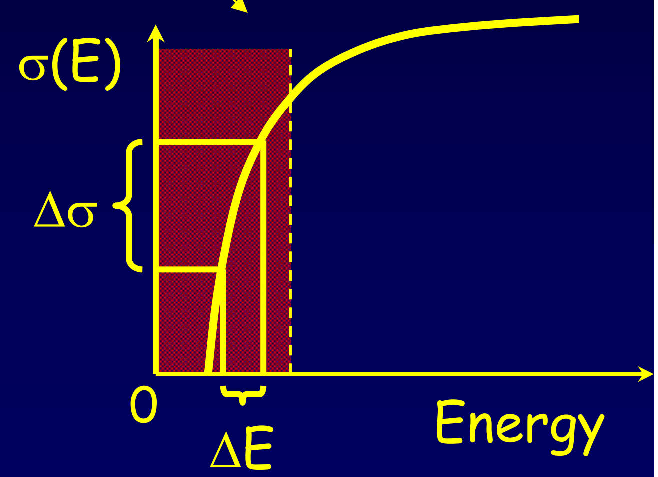
Low cross section

$$R_{lab} = \sigma \cdot \varepsilon \cdot I_p \cdot \rho \cdot N_{av} / A$$

high beam current to increase reaction rate

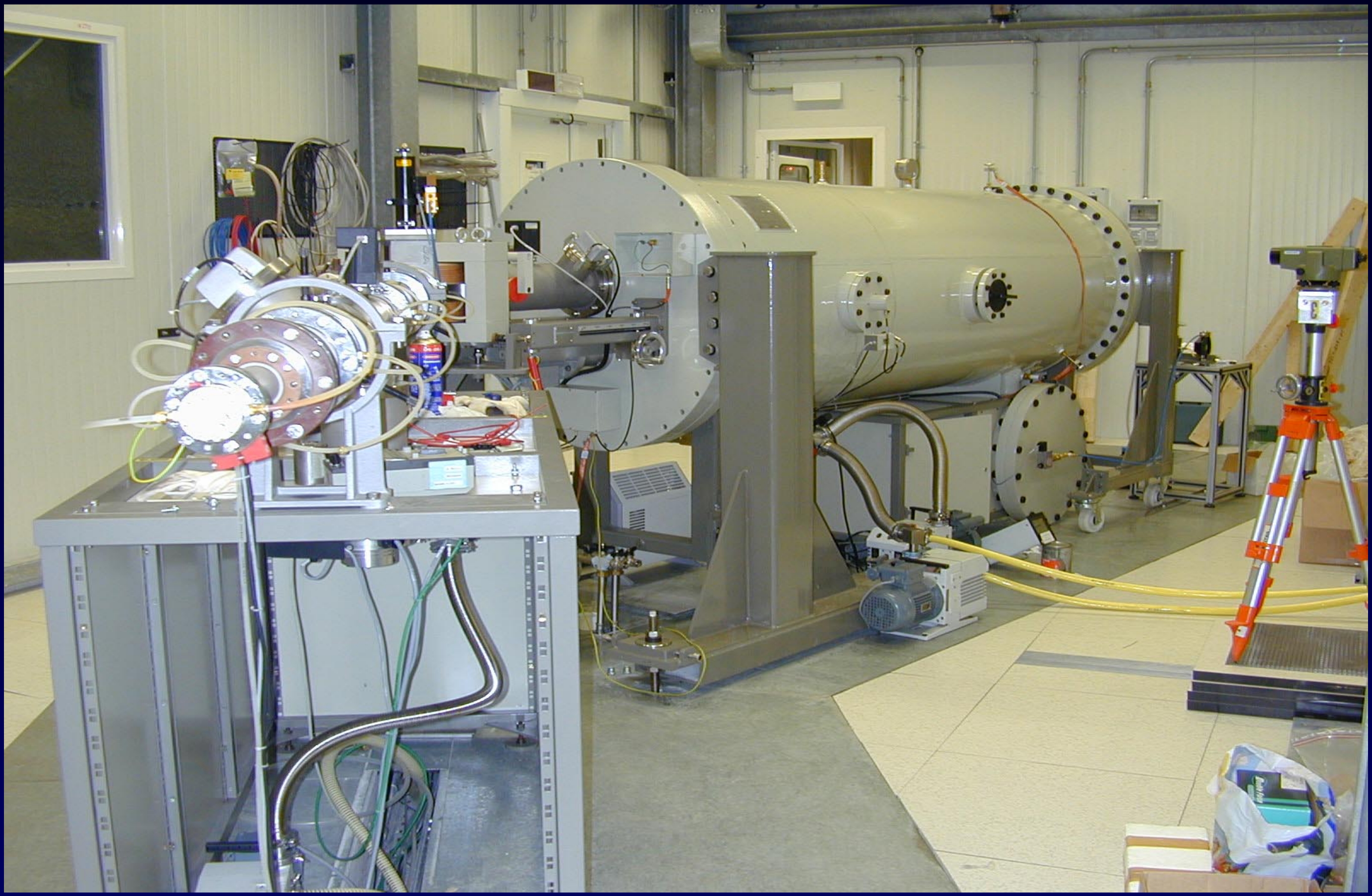
Long measurements to collect statistics

energy stability during measurement



Good energy resolution

LUNA:400 kV accelerator



- ✓ U_{max}= 50 – 400 kV
- ✓ I ~ 500 μA for protons

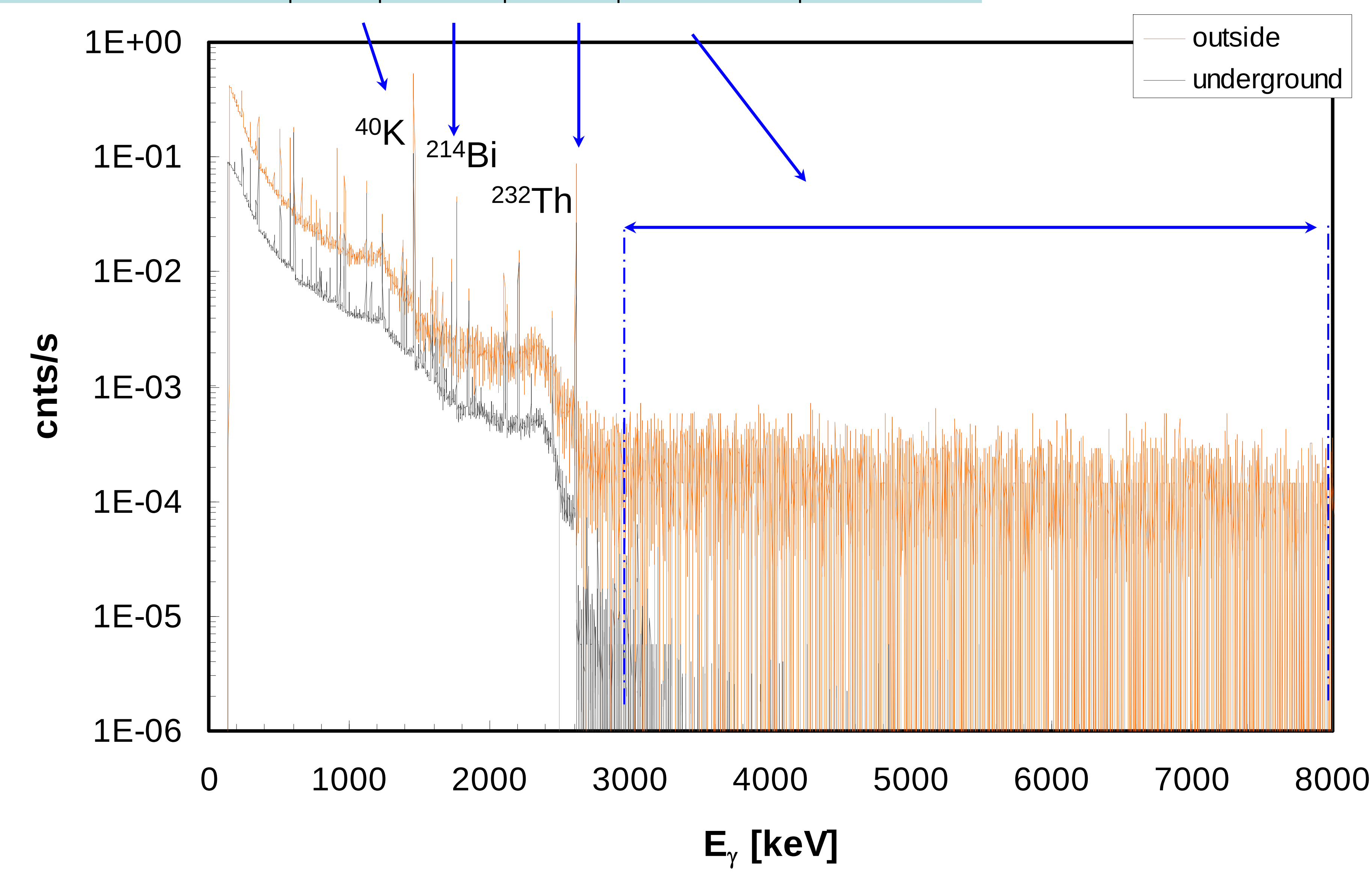
  I ~ 250 μA for alphas

- ✓ Energy spread : 72eV
- ✓ Total uncertainty is ±300 eV

  between Ep = 100 ÷ 400keV

outside	1.5	0.15	0.34	0.64	counts/s
underground	0.3	0.13	0.11	0.0009	counts/s

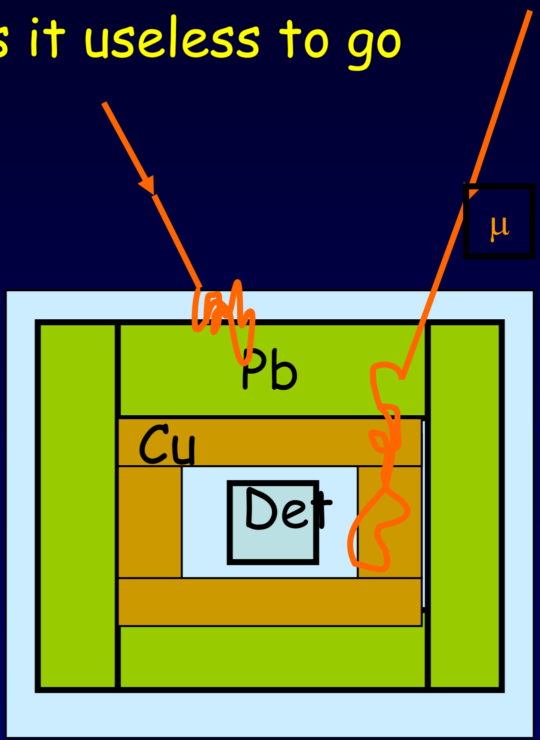
Clear advantage of high Q value reactions



What about low Q values?

If the Q-value of the nuclear reaction is < 3MeV, is it useless to go underground ?

Environmental radioactivity is present underground (Rn)



Detectors can be shielded passively with proper Pb-Cu shield as on surface

BUT underground passive shielding is more effective since μ flux, that create secondary γs in the shield, is suppressed.

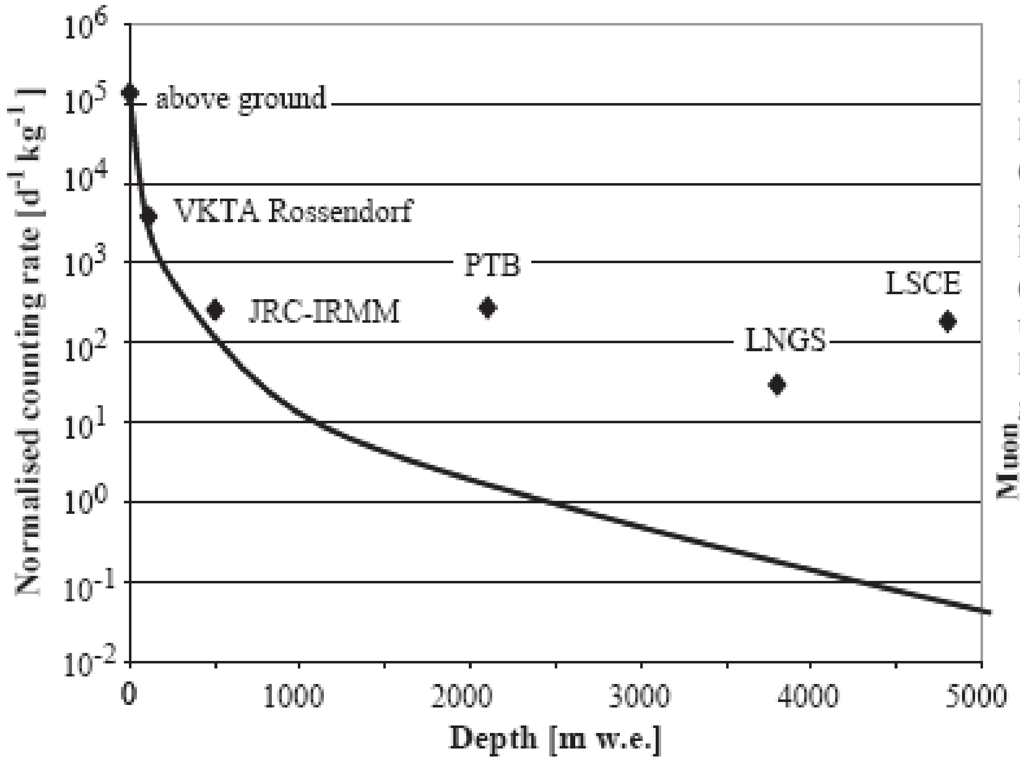
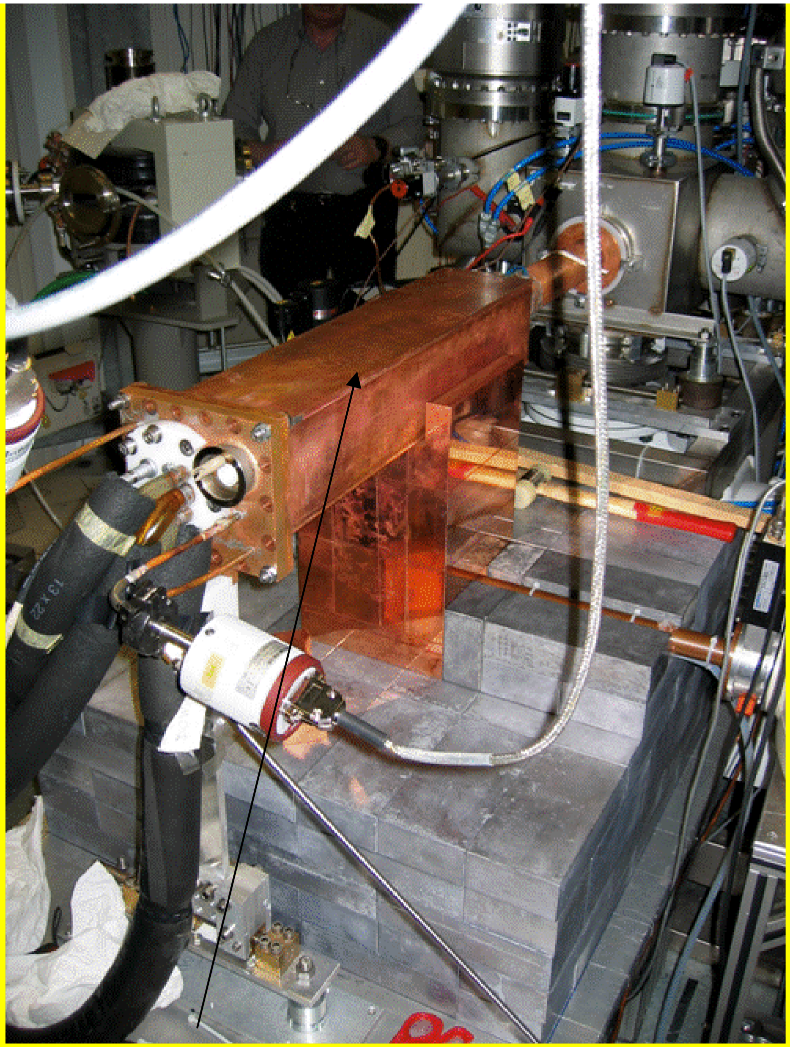


Fig. 1. The integral background counting rate from 40 to 2700 keV divided by the mass of the Ge-crystal for the best HPGe-detectors in some CELLAR laboratories. The solid line shows the muon fluence rate in arbitrary units normalised to the background counting rate above ground. All detectors have only passive shielding.

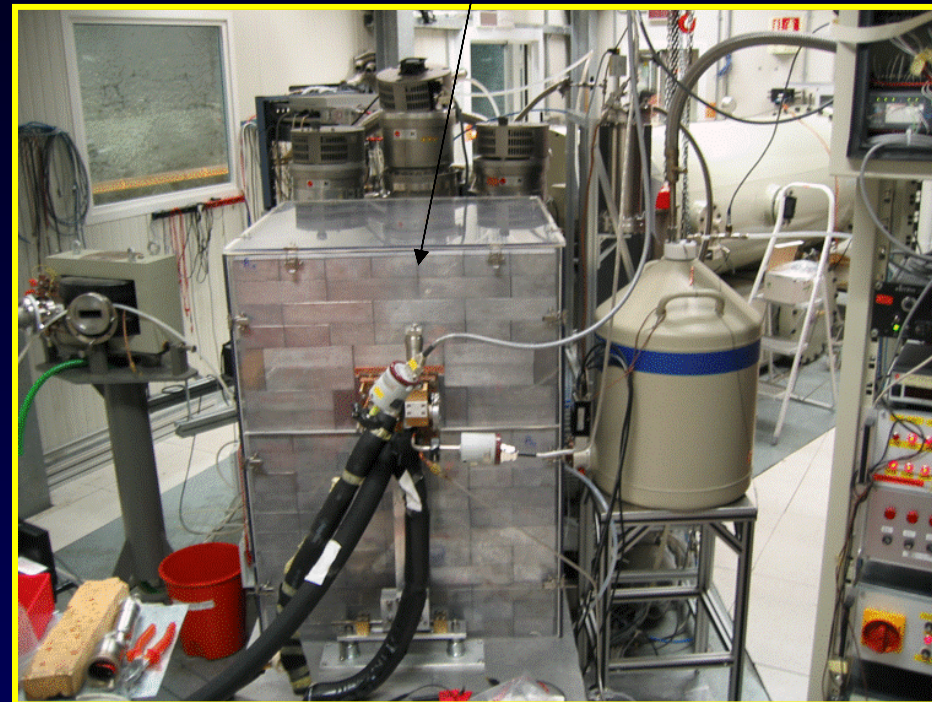
The shield of an HPGe-detector in an underground laboratory is typically composed of a thick (15–25 cm) lead shield of which the inner 2–5 cm are low in ^{210}Pb ($< 5\,Bq\,kg^{-1}$). Often there is an inner lining of freshly produced electrolytic copper. If the radioactivity of the lead is very low, the copper shield need not be very thick (~ 1 cm), but it is possible to use 15 cm copper deep underground as the activation of the copper there is very low. Above-ground copper linings increase the background for energies above 100 keV.

exponentially. This is a clear indication that othe sources which become more important are environmen tal radioactivity, neutrons from spontaneous fissio and (α,n)-reactions, and residual cosmogenic activatio from the above-ground production of the detector. I most underground laboratories, the radon gas i removed carefully from the environment around th detector.

M. Laubenstein et al. Applied Radiation and Isotopes 61 (2004) 167–172

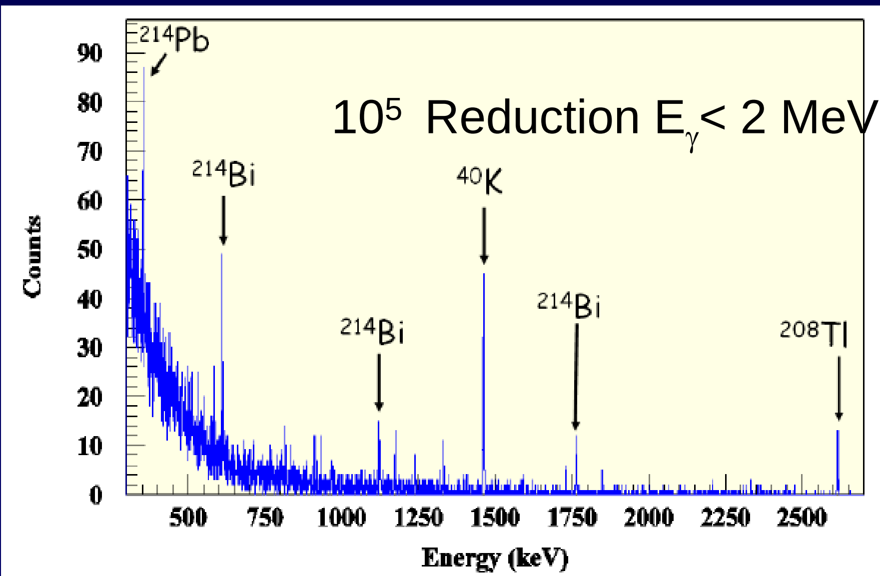


Radon box

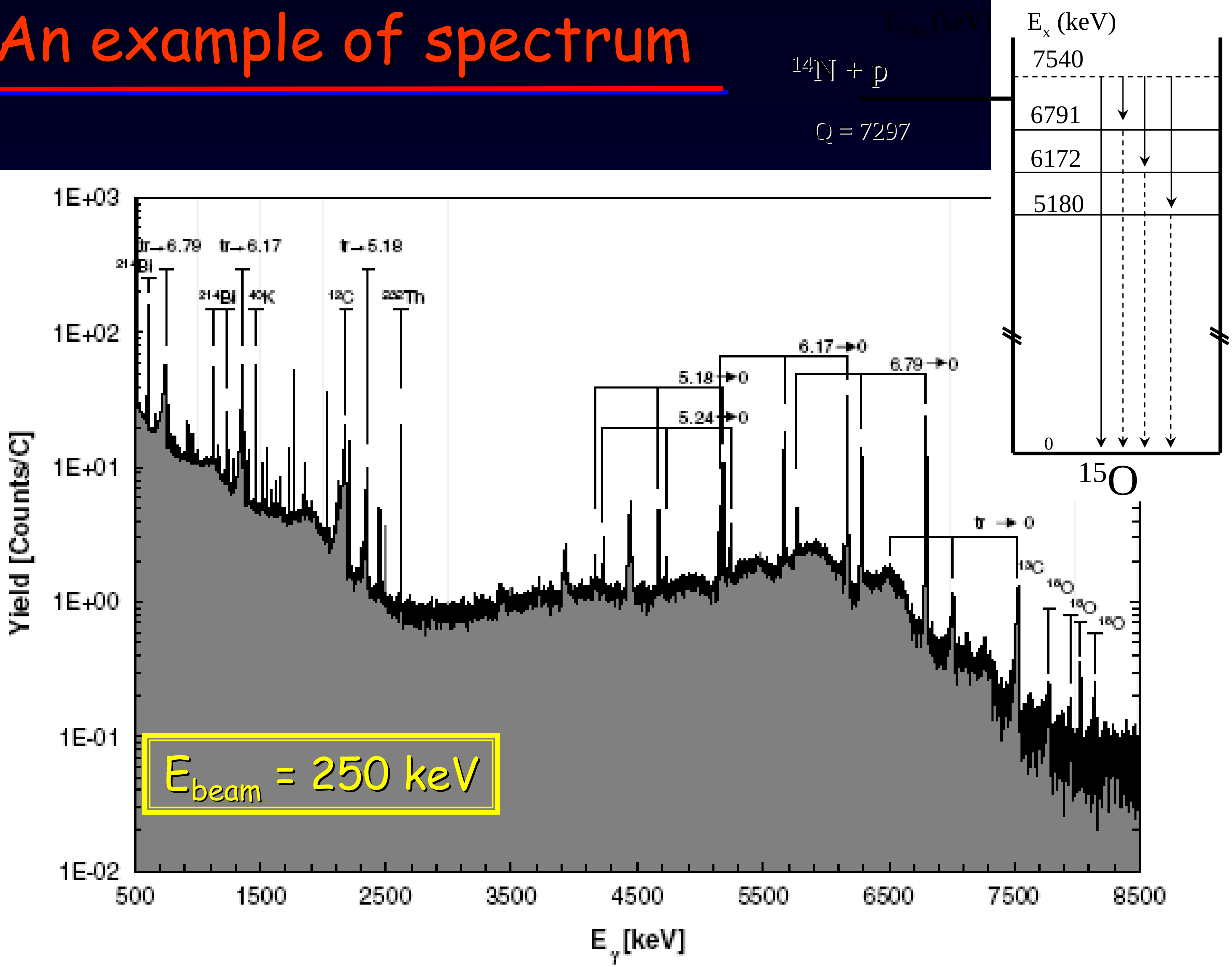


Low activity materials (Oxygen free copper)

22 days



An example of spectrum

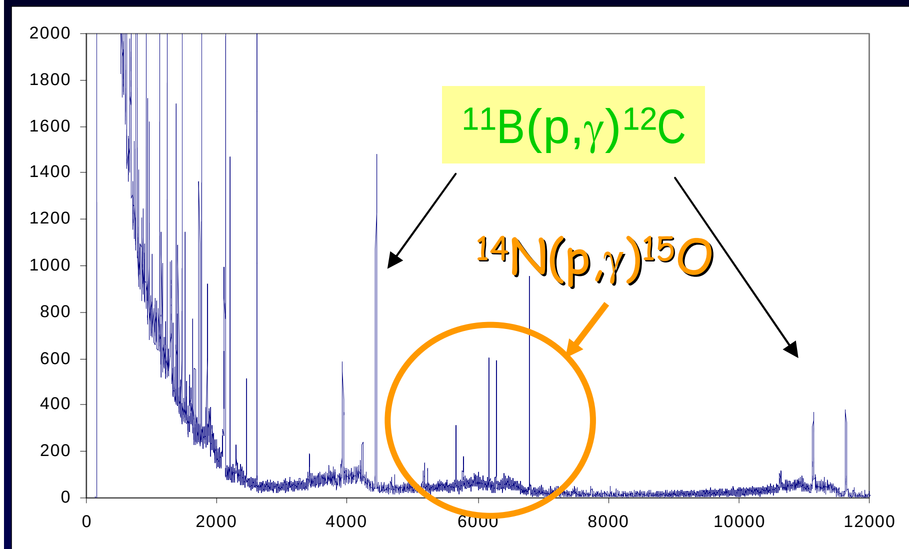


Bck in targets

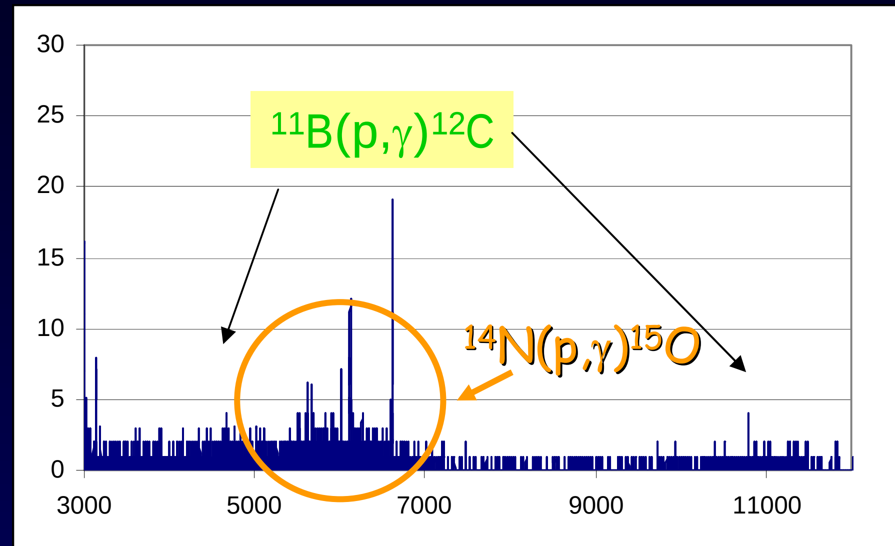
E_{beam}= 200 keV

14N(p,γ)15O

E_{beam}= 140 keV



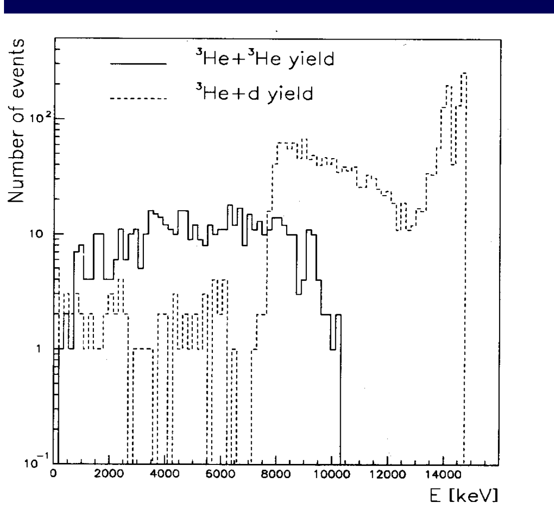
E_γ(keV)



E_γ(keV)

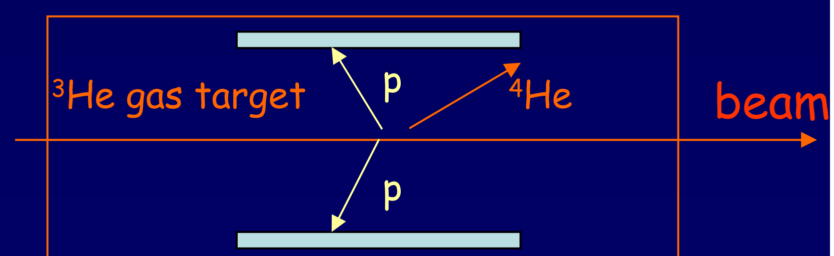
Bck in the beam

$^3He(^3He,2p)^4He$



d contamination was present in the beam (HD)
$\Rightarrow$ *$^3He(d,p)^4He$.*

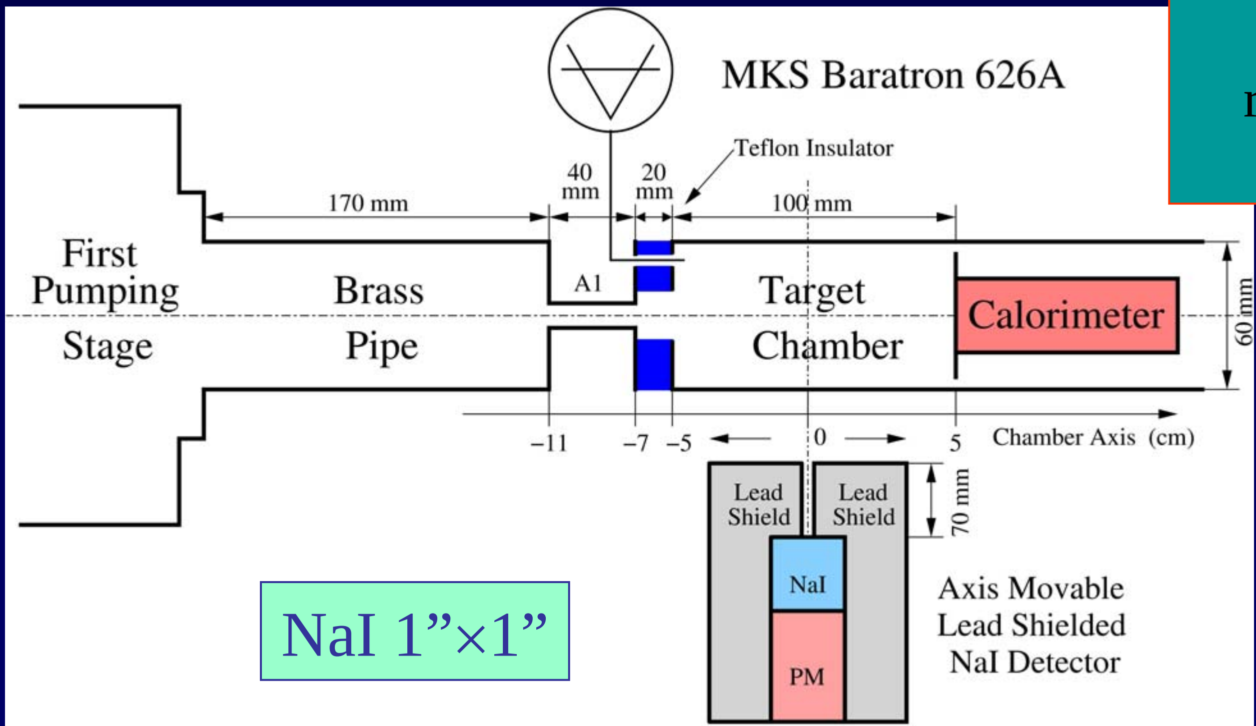
Si detectors



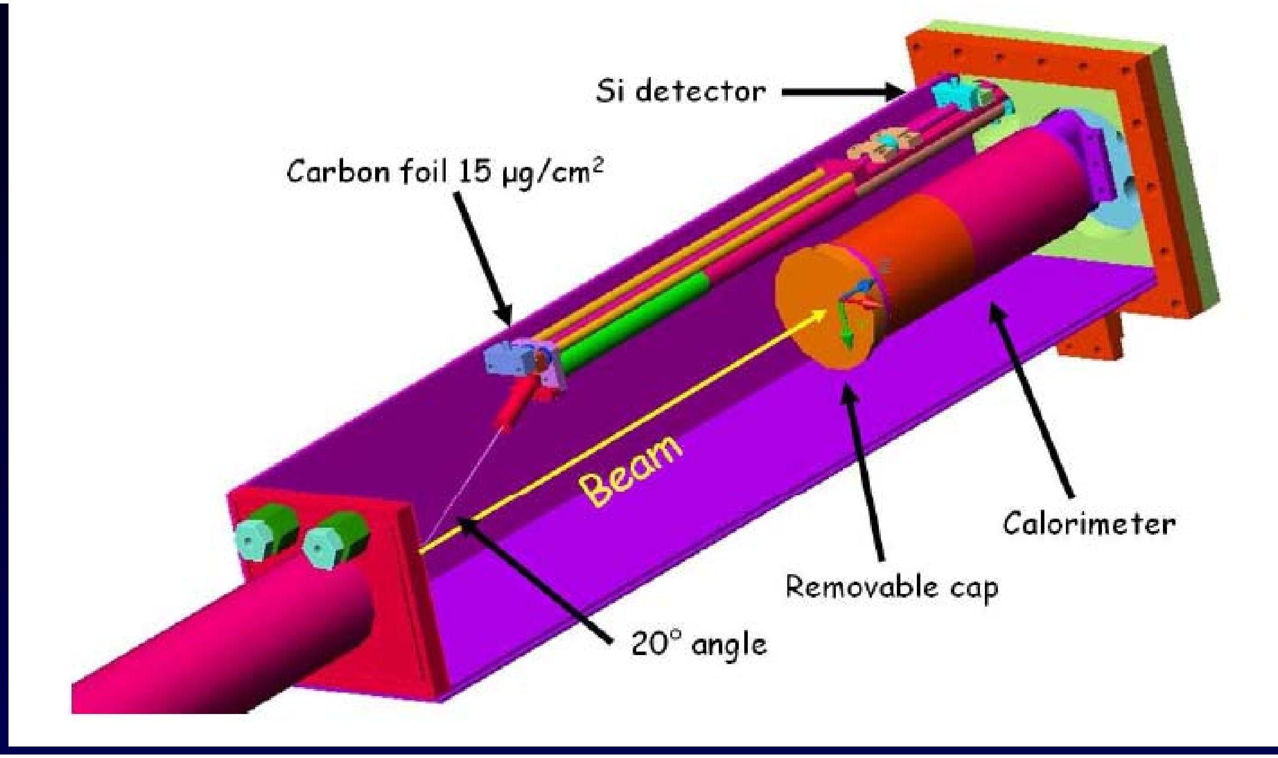
High current in gas target→beam heating

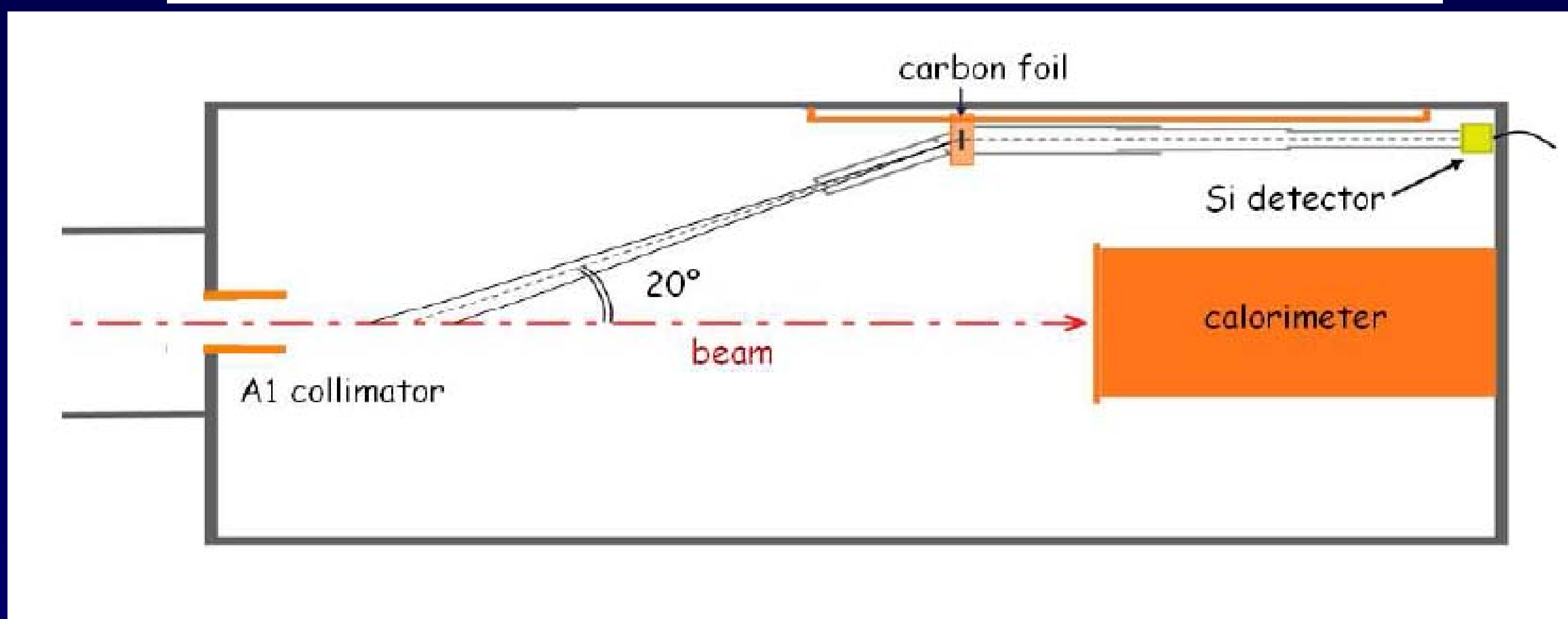
$$h_{beam} = \frac{\rho_{beam}}{\rho} \propto \frac{dW}{dx} = \frac{dE}{d(\rho x)} \rho I_p$$

$h_{beam} < 10\ \%$ if $dW/dx < 200$ mW/cm

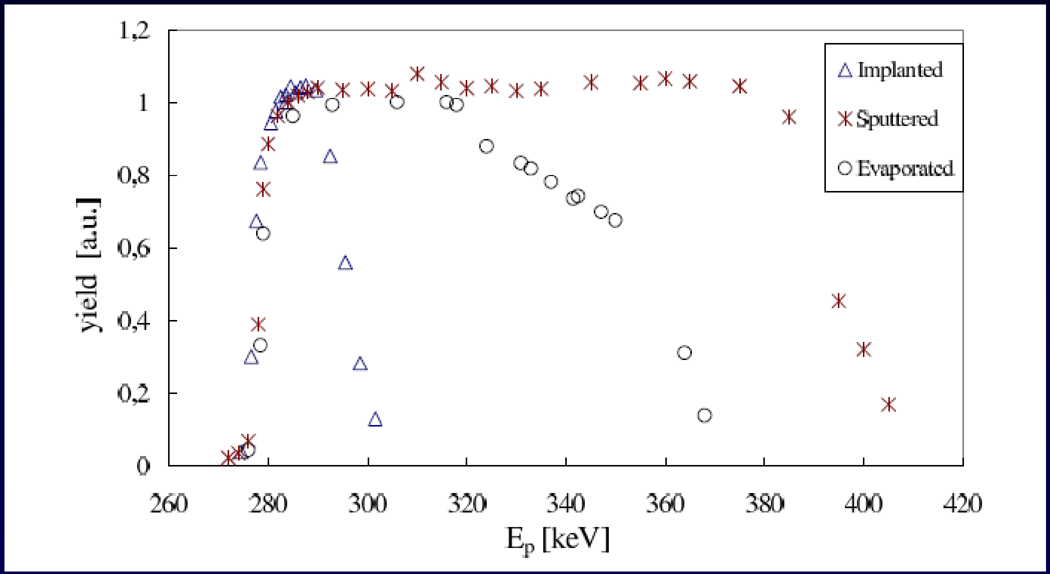


259 keV resonance of 14N+P

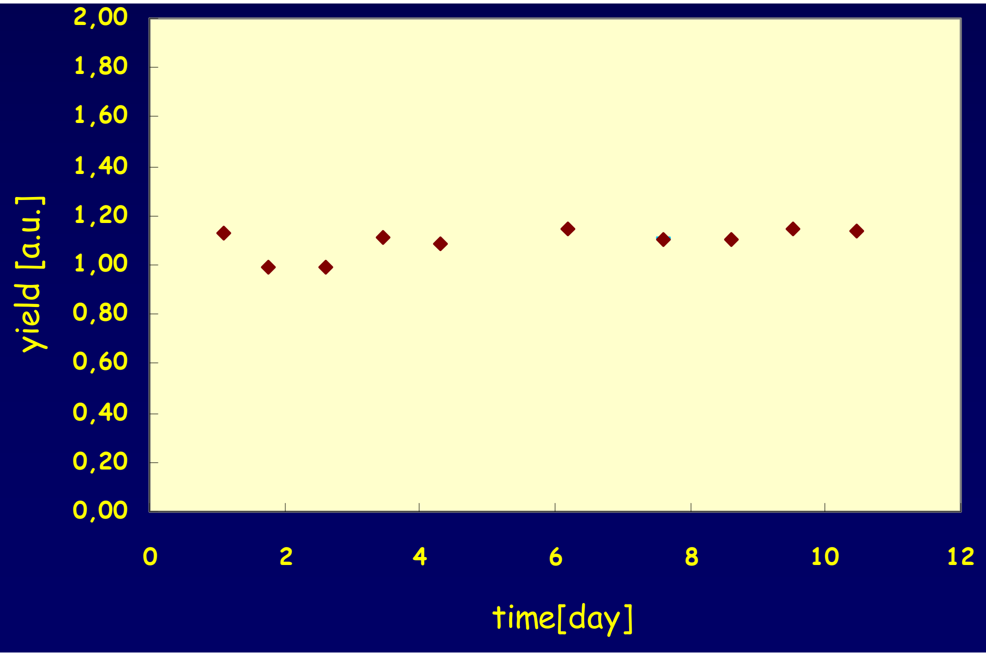

Si detector
Carbon foil 15 μg/cm²
Beam
Calorimeter
Removable cap
20° angle


carbon foil
Si detector
20°
calorimeter
beam
A1 collimator

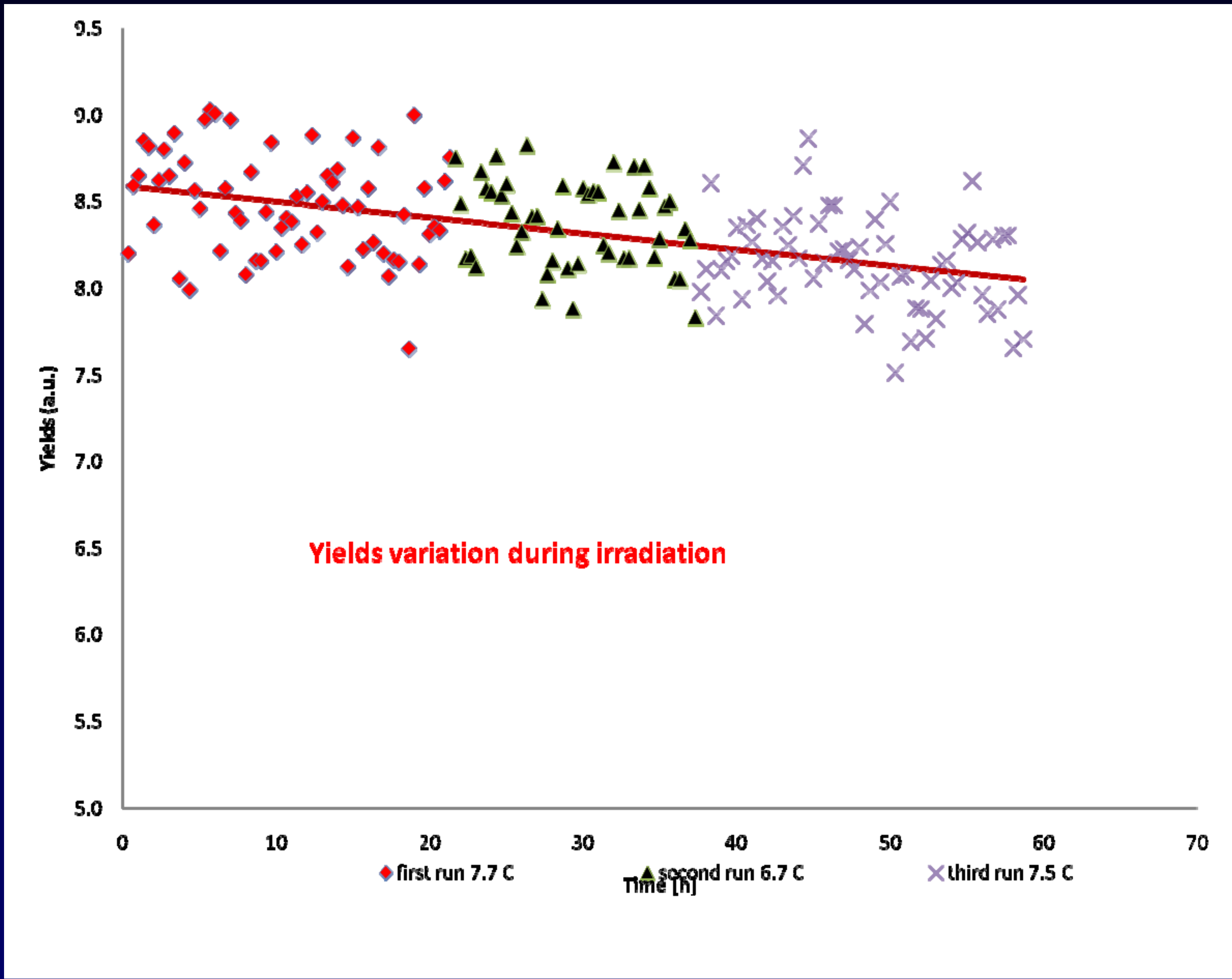
High current on solid target→target stability



Target stability!!



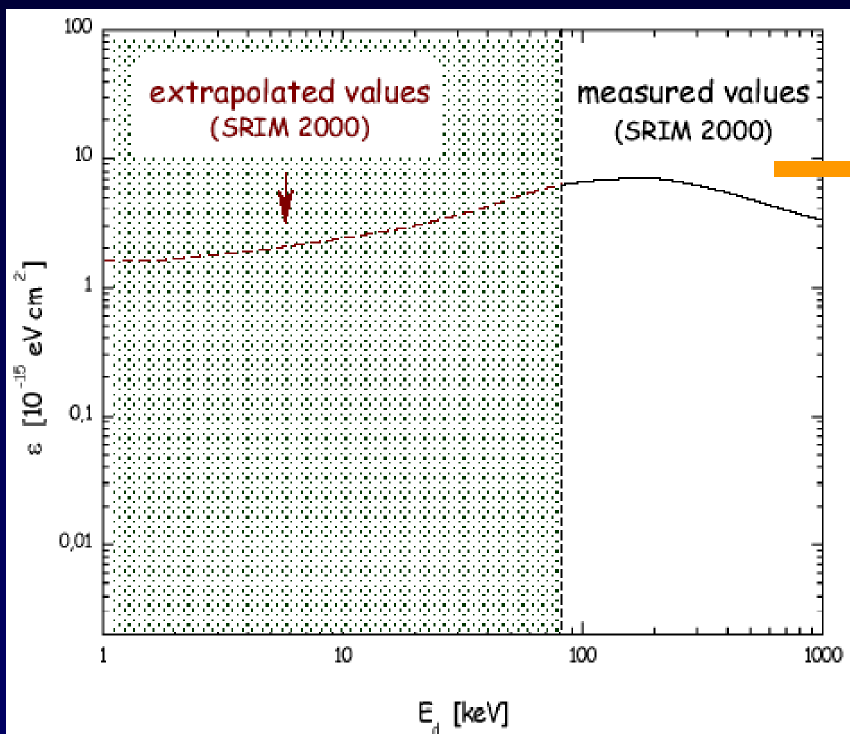
25Mg targets for 25Mg+p experiment

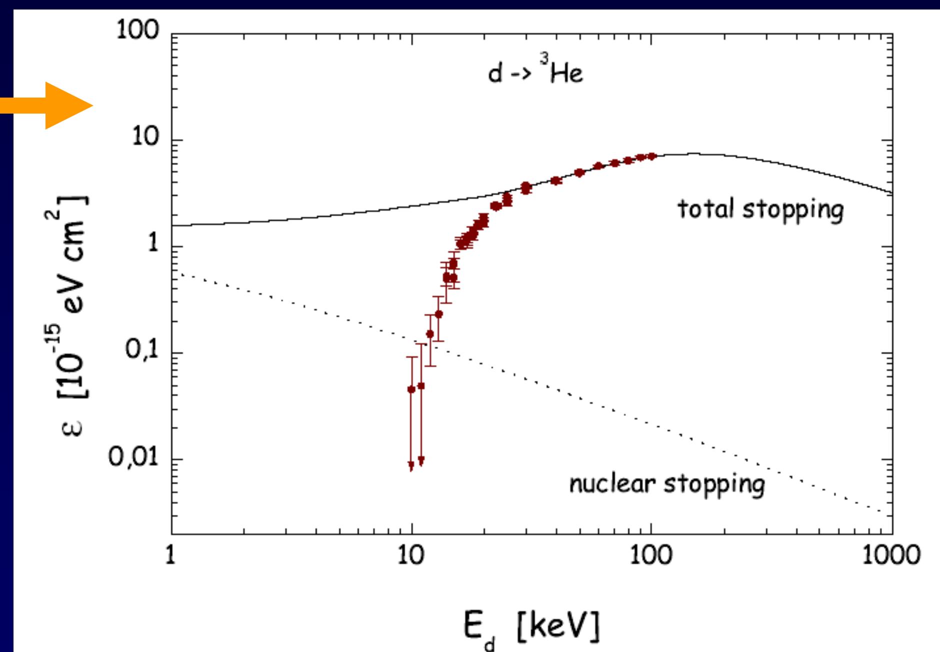


Stopping power at low energies is often obtained from extrapolations from high energy data.

BUT, sometimes extrapolation fails!

$^3He(d,p)^4He$

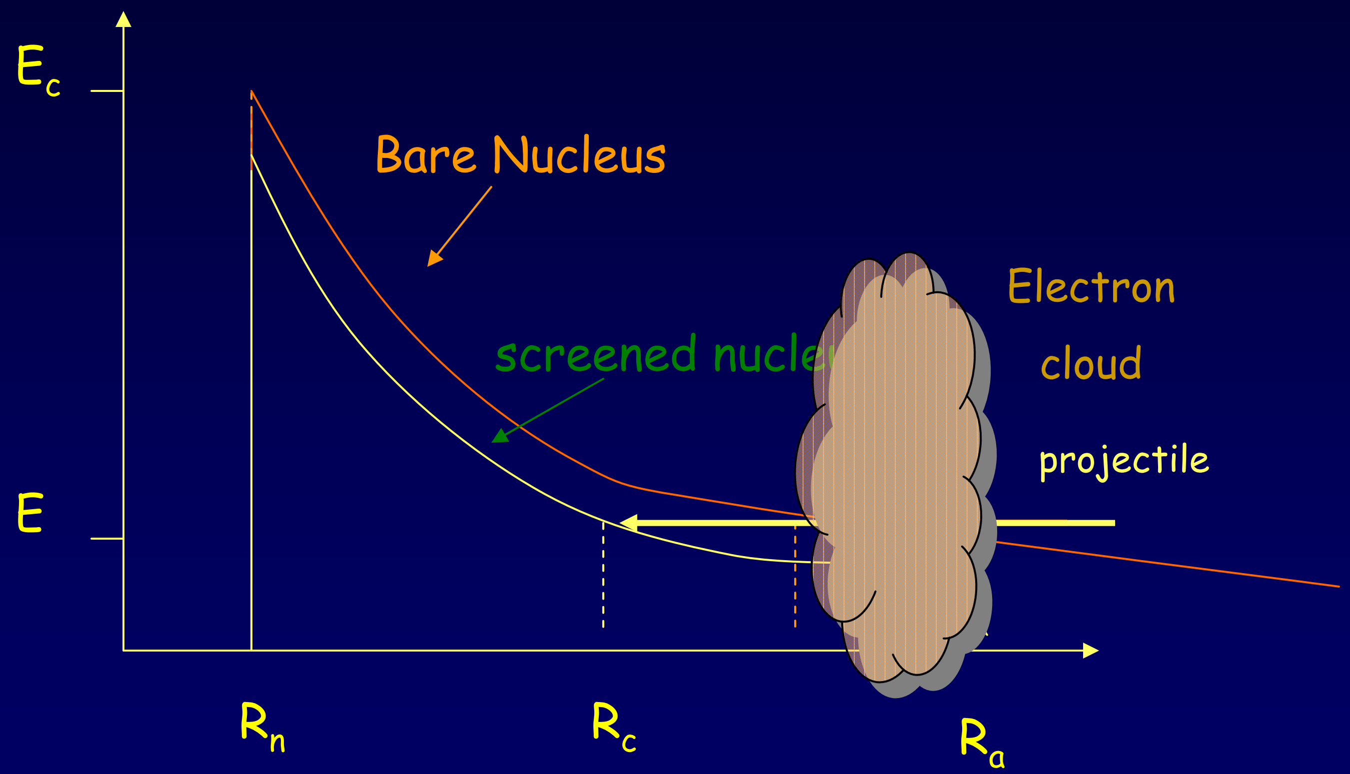




A. Formicola et al. Eur. Phys. J. A 8, 443 (2000)

The screening effect

In the laboratory at $E<E_c$, the cross section is enhanced by the screening effect of the electrons bounded to the target nucleus



14N+p

Ground state results

data from 390 keV to 135 keV