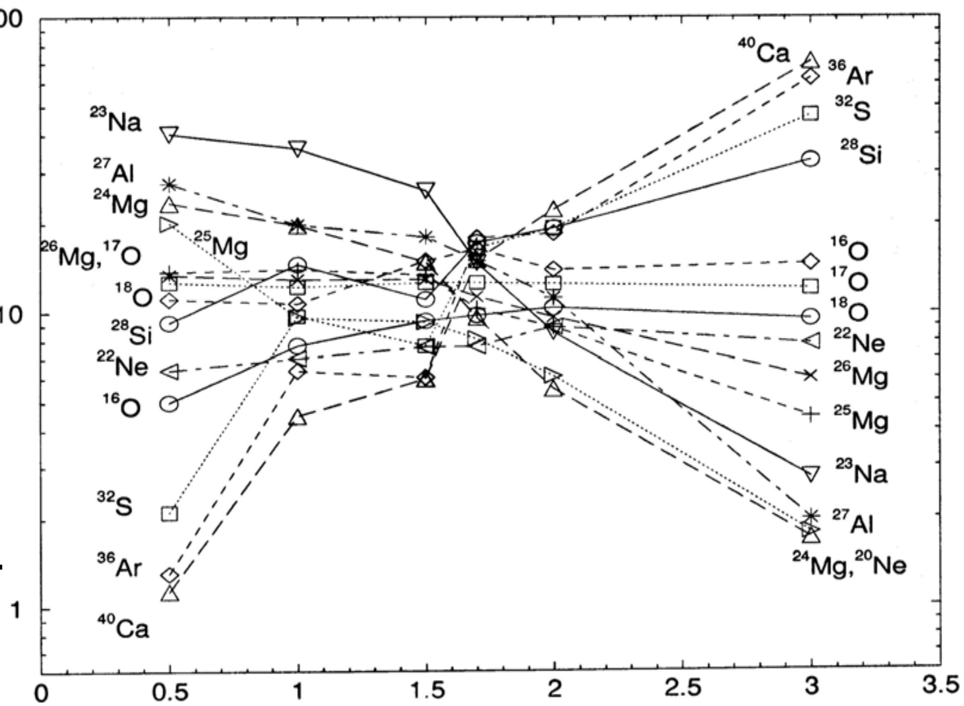
new measurements of $^{12}C(\alpha, \gamma)^{16}O$

R. Plag, M. Heil, F.K.

- revival of D&B approach
- results: total (α, γ) cross section, E1/E2 separation,
  cascade transitions

$^{12}C(\alpha, \gamma)^{16}O$



multiplier for $^{12}C(\alpha,\gamma)^{16}O$ rate

1970 Jaszczak et al. — pulsed α beam, Na
1974 Dyer & Barnes

2005 Plag et al. — 4π BaF_2 array

1987 Redder et al. — intense α beam, G
1996 Ouellet et al.
2001 Kunz et al.
2005 Hammer et al.
2006 Assunção et al.

1982 Kettner et al . — ^{12}C beam, gas targ
1988 Kremer et al.
1999 Roters et al.
2001 Gialanella et al.

2001 Rogalla et al. — recoil separators
2003 Ikeda et al.
2006 Schürmann et al.
2006 Matei et al.

typical α beam experiments

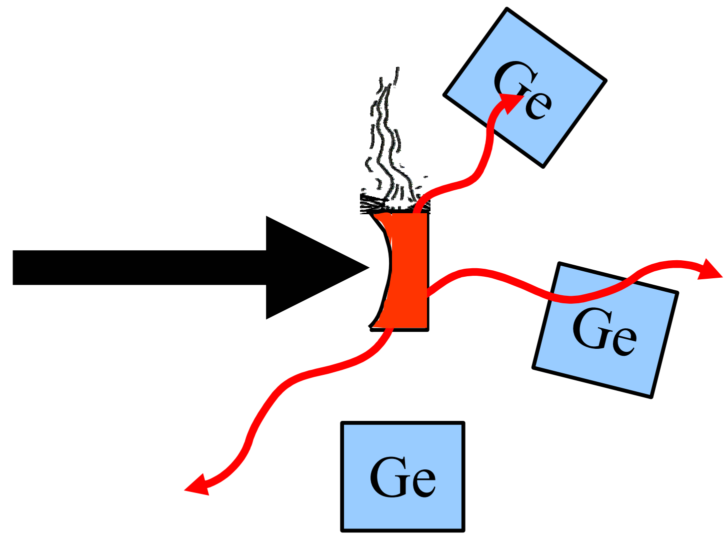
e detectors

ut

excellent energy resolution

low efficiency $\Rightarrow$ intense α-beams

= sample and background problems



ulsed α beam

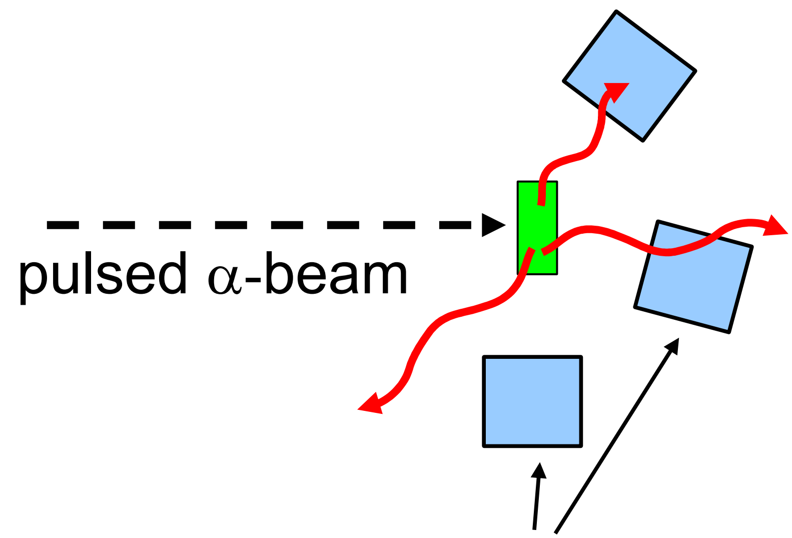
ut

no sample problems,

background discrimination via TOF

high efficiency γ-detectors required

$\Rightarrow$ **limited energy resolution**

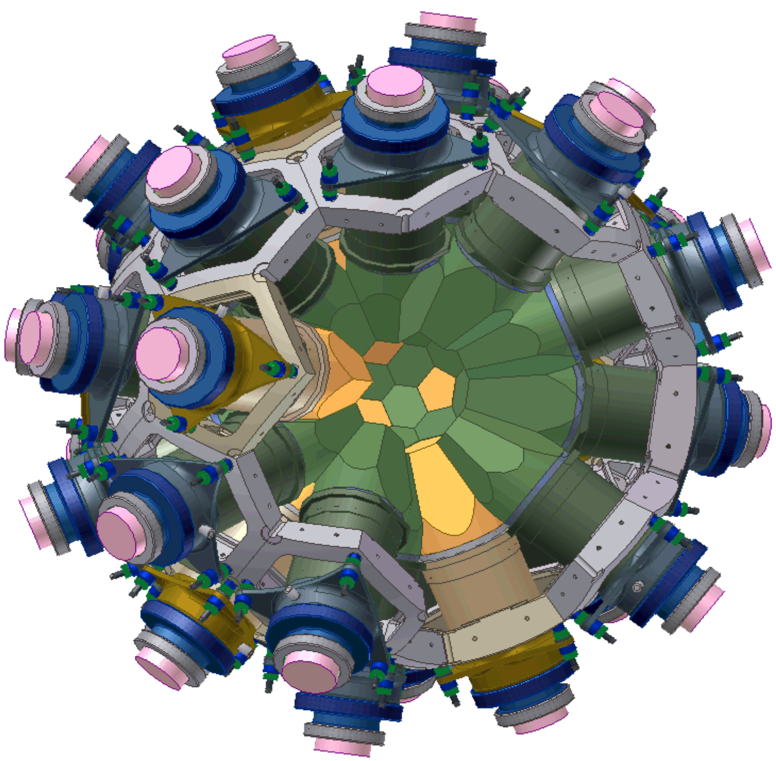


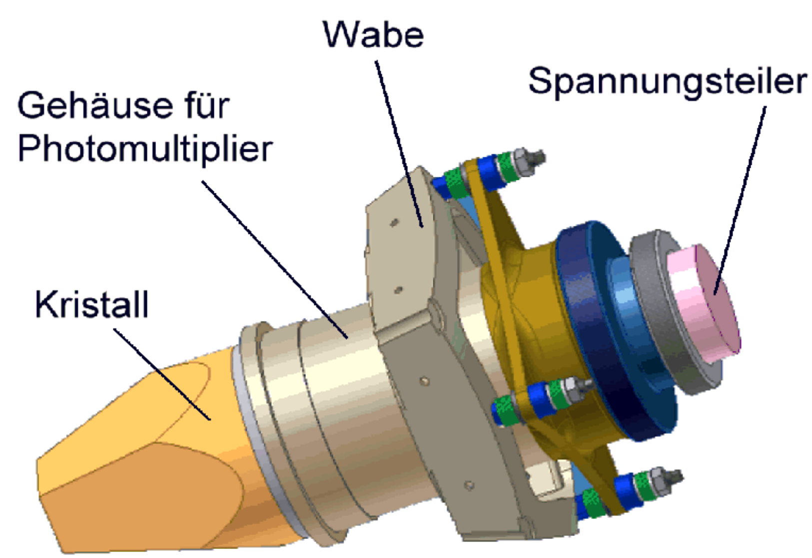
efficient γ detection

crucial

revived D&B approach @ FZK

- optimized efficiency
  - ⇒ 4π solid angle
  - ⇒ 100% intrinsic efficiency
  - ⇒ 42 fold geometry
- data acquisition with ADC system
  - ⇒ reliable off-line analyses
- detailed GEANT simulations
  - ⇒ accurate background determination





^{12}C samples

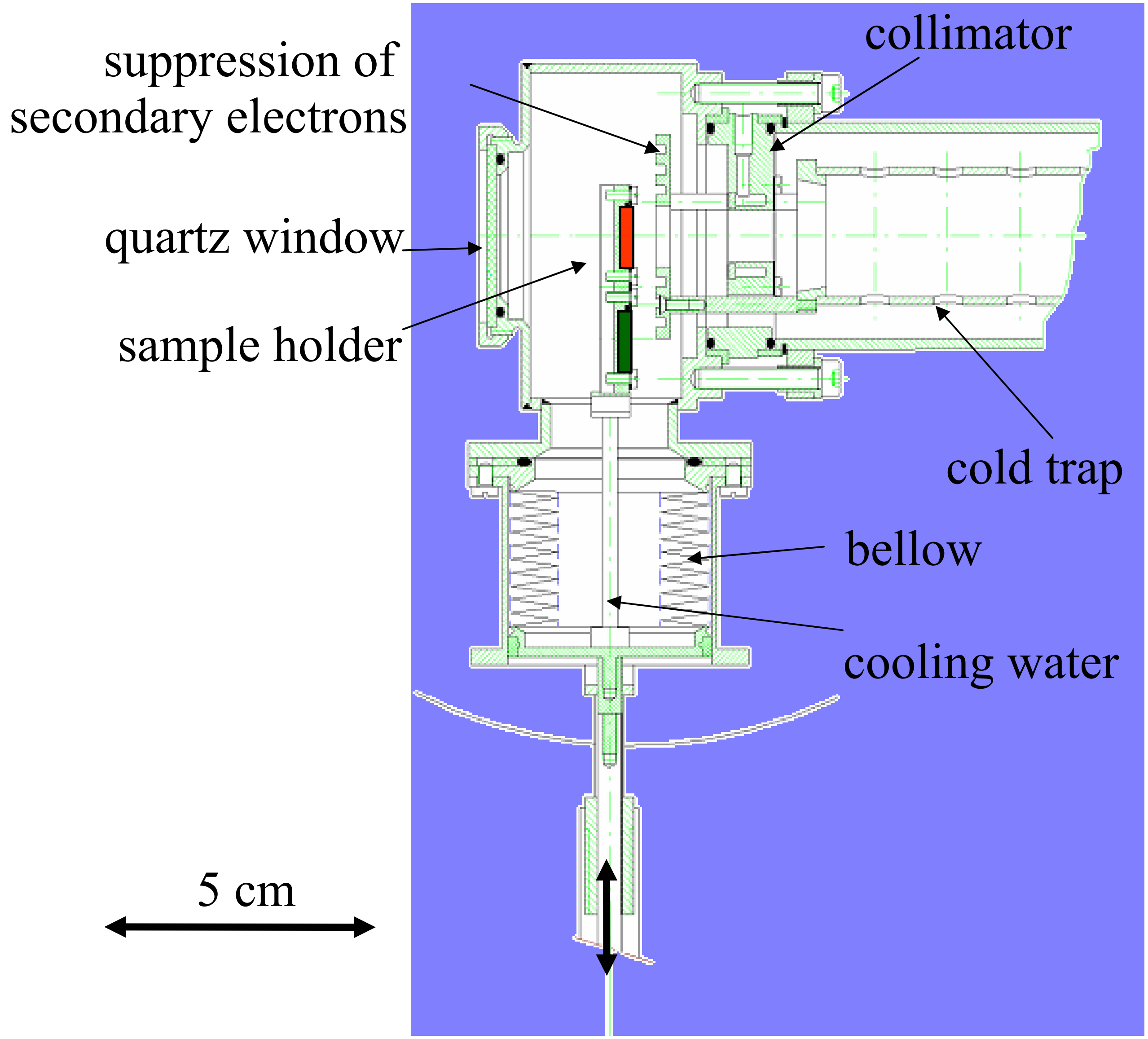
- produced at mass separator SIDONIE@CSNSM, Orsay, F
- implanted with only 200 eV
- mass separation $^{12}C/^{13}C \geq 9 \times 10^5$
- thickness 30-120 µg/cm^2, $\Delta E_\alpha \approx 50$ keV
- backings: - copper with 5 µm „pure“ gold
  - ultra pure copper (99,9999%)

sample changer

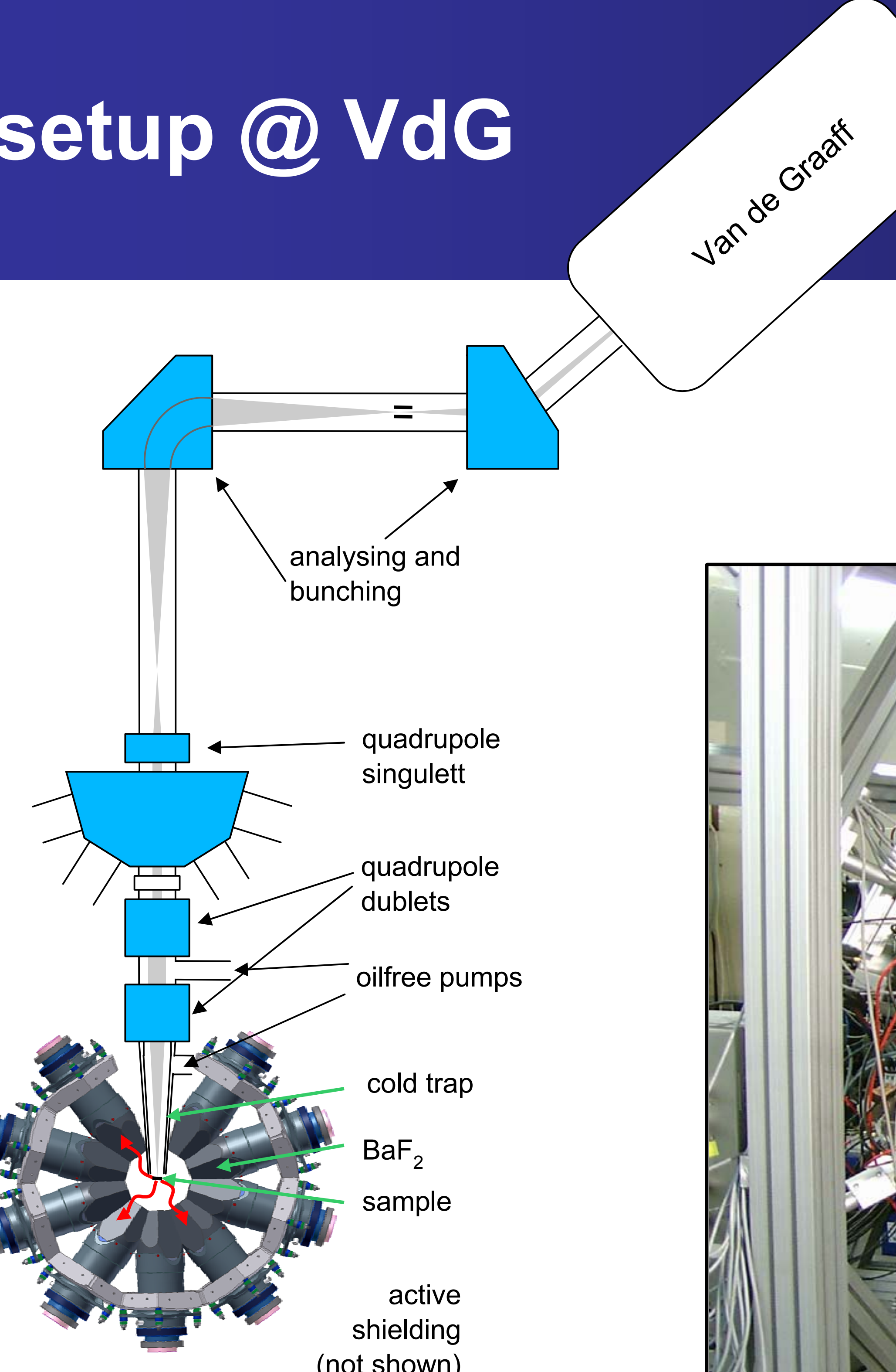
yclic measurement

C vs **blank**

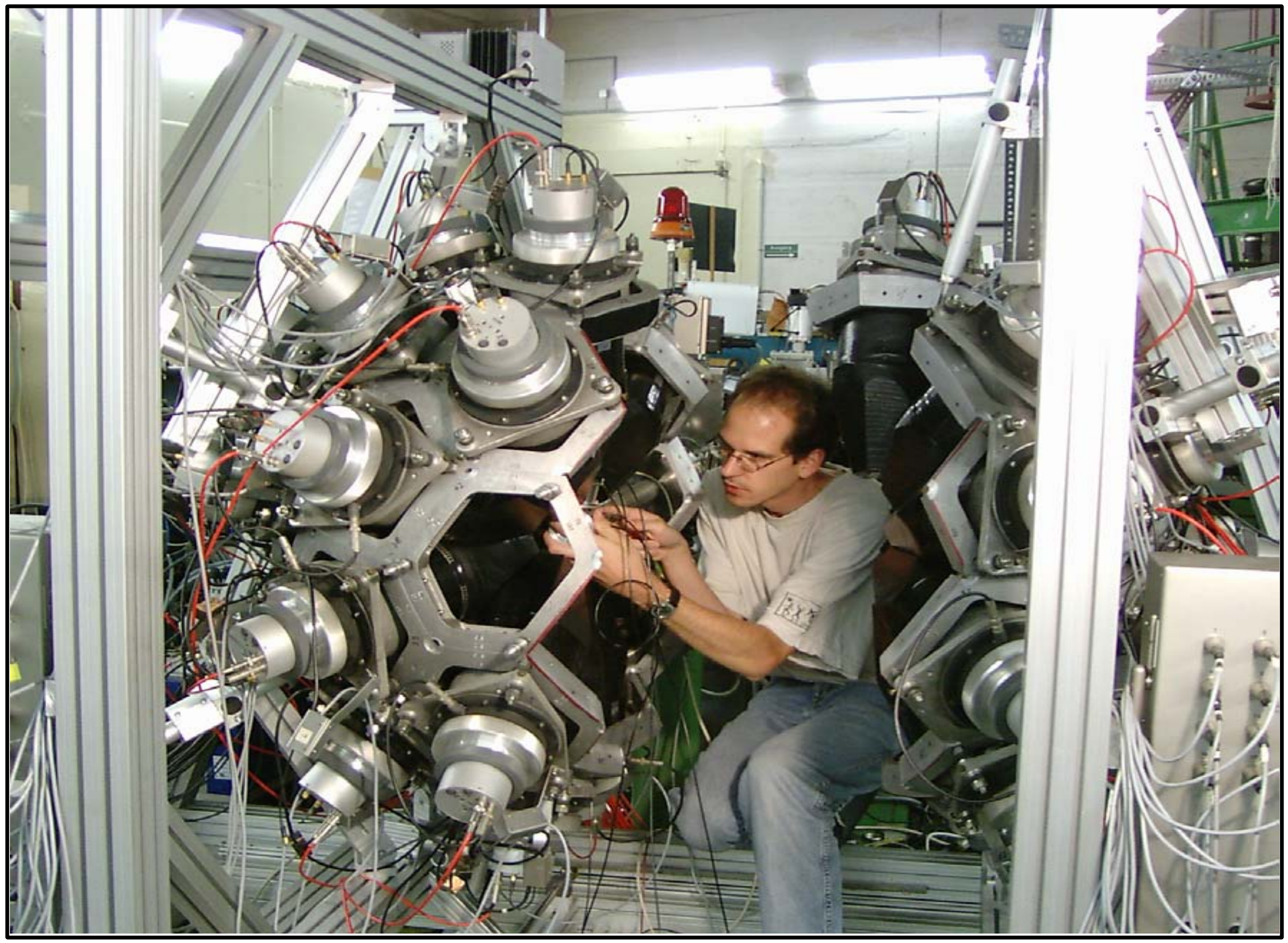
very 15 min



setup @ VdG



α-beam	- average intensity:	6 μA
	- repetition rate:	1 MHz
	- pulse width:	2 ns

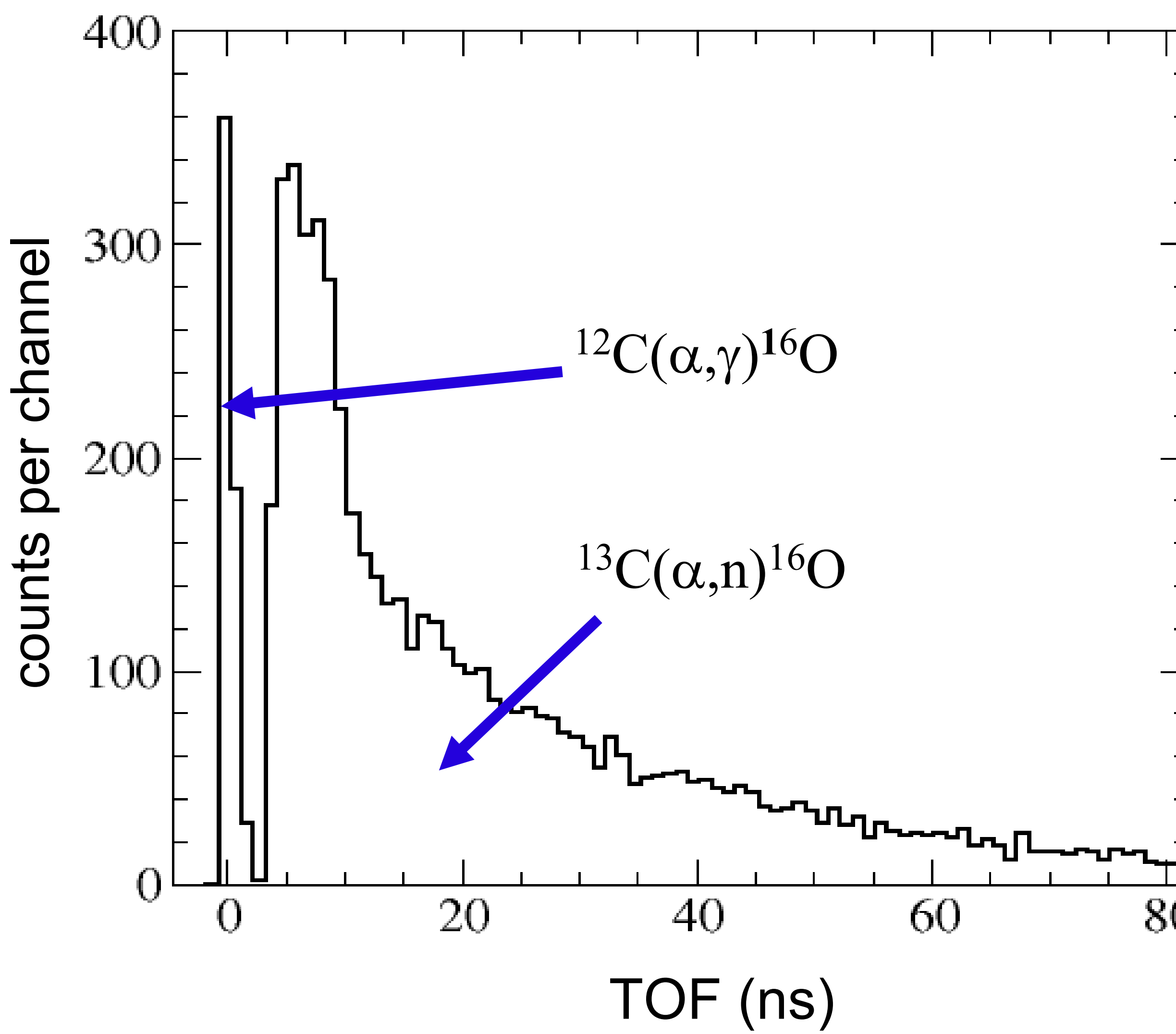


neutron background from $^{13}C(\alpha, n)^{16}O$

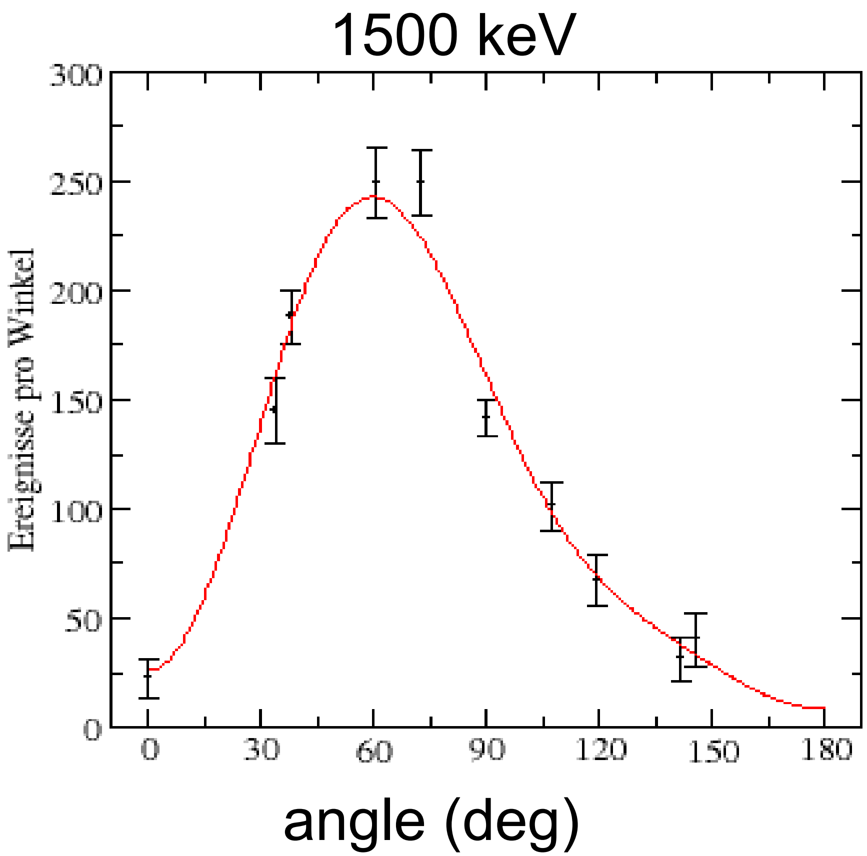
am-induced carbon deposition sample gives rise to background $^{13}C(\alpha,$**n**$)^{16}O$

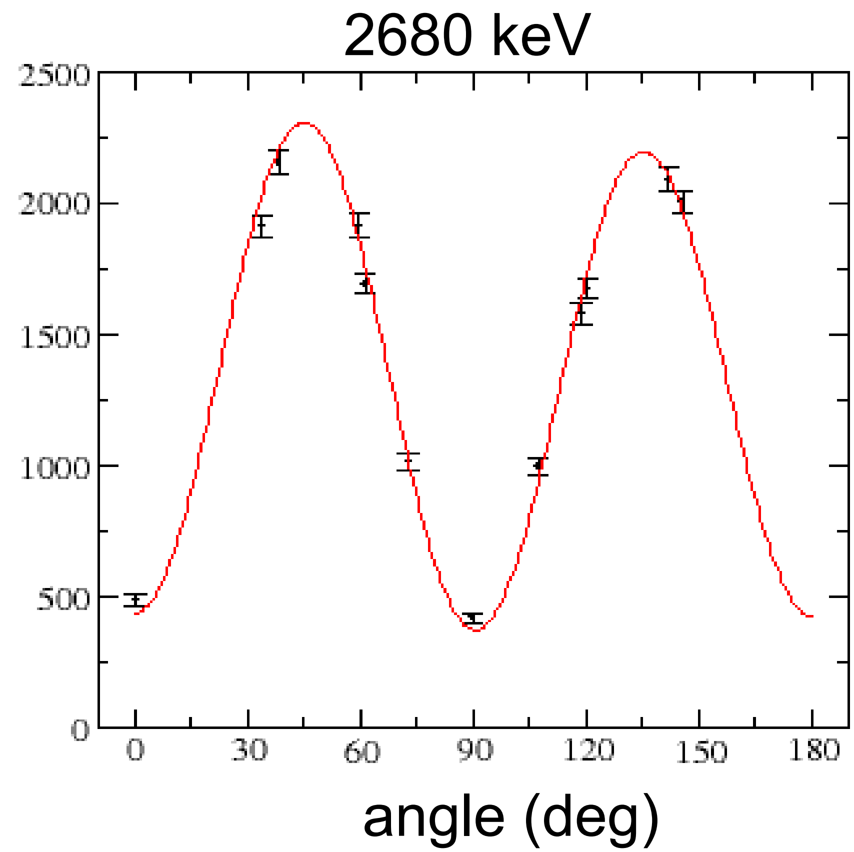
utrons appear delayed compared prompt γ-rays

n be discriminated by
e of flight and **sum energy**



angular distributions



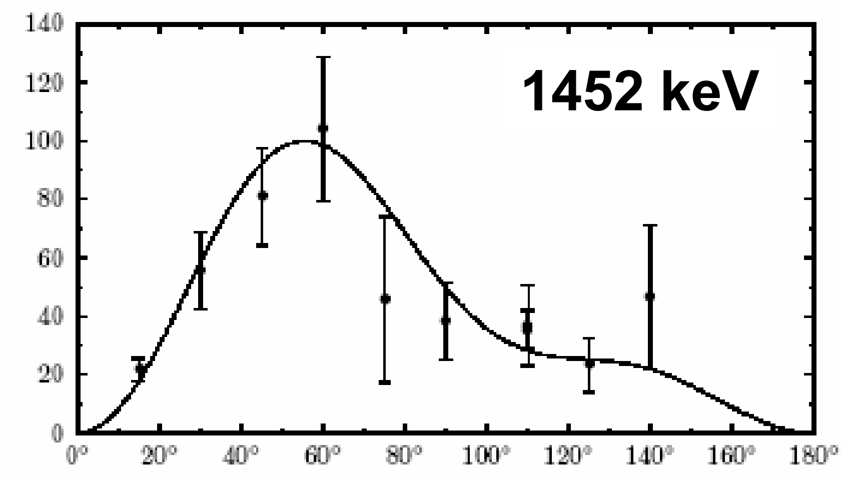


determine E1 and E2 contributions for extrapolation to Gamow window

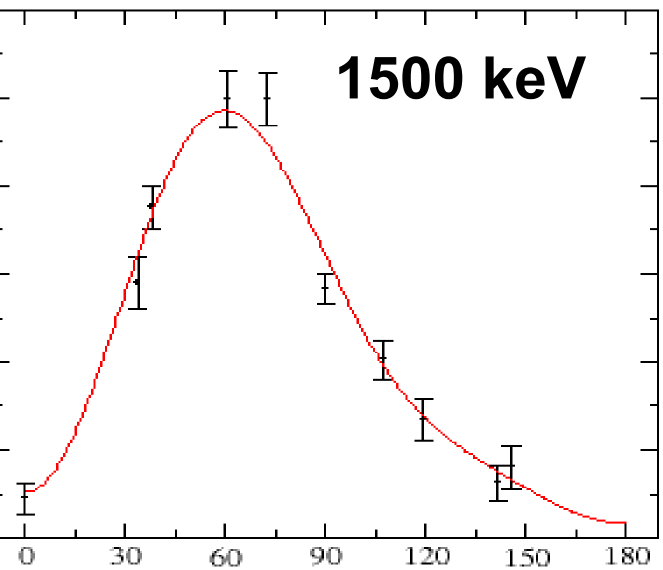
$$W = f\left(P_2\right) + \frac{\sigma_{E2}}{\sigma_{E1}} f\left(P_{2,} P_4\right) + \frac{6}{5}\sqrt{\frac{5\sigma_{E2}}{\sigma_{E1}}}\cos\varphi f\left(P_{1,} P_3\right)$$

angular distributions

Fey et al. 2006

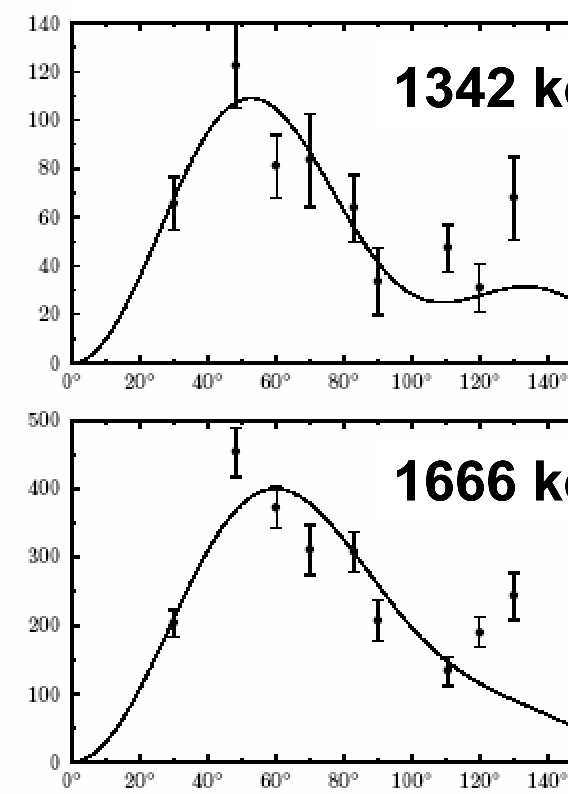


this work



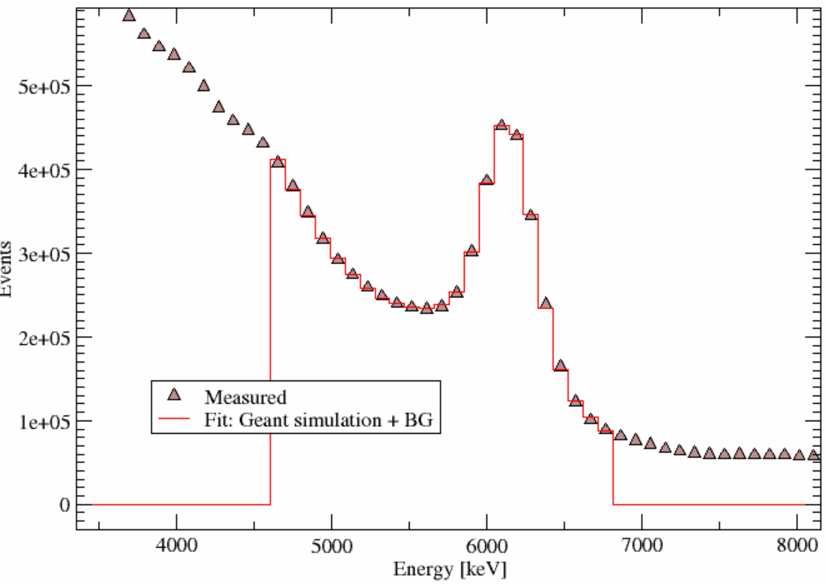
angle (deg)

Assunção et al. 2006

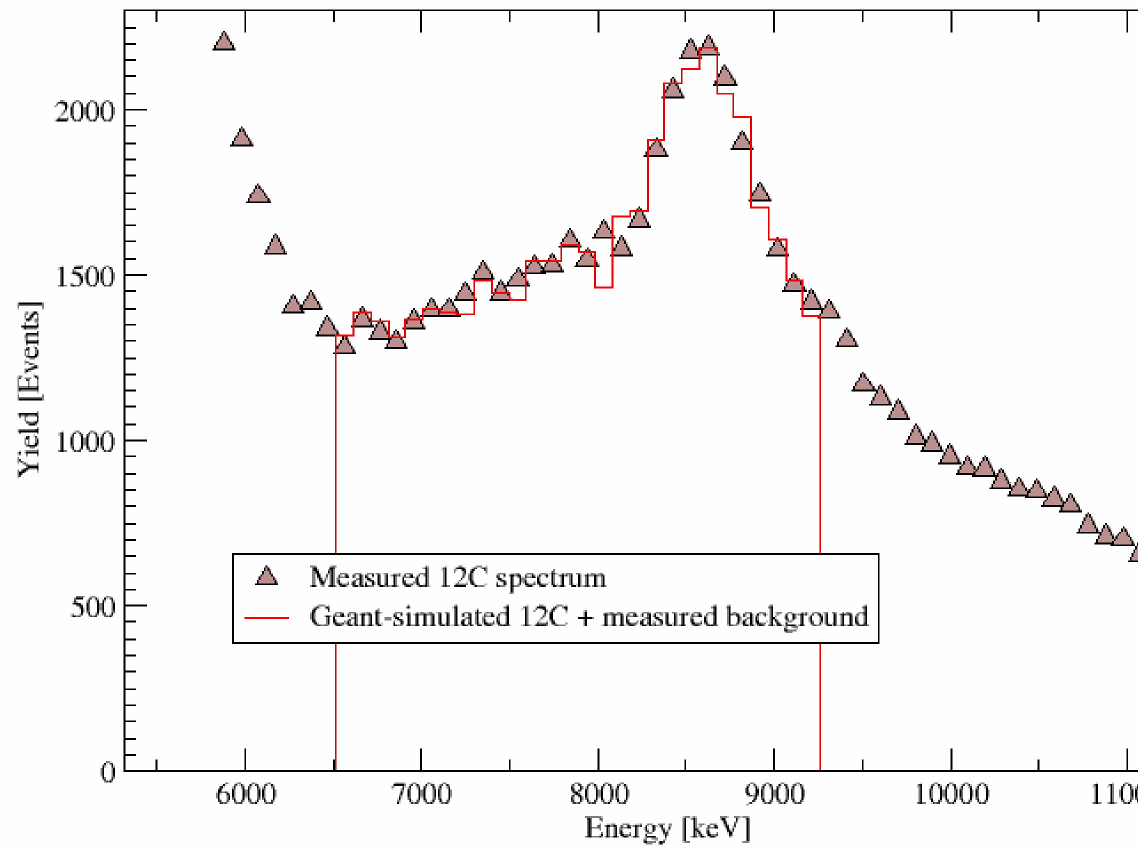


γ spectra

calibration with Pu/C source



$^{12}C(\alpha, \gamma)^{16}O$



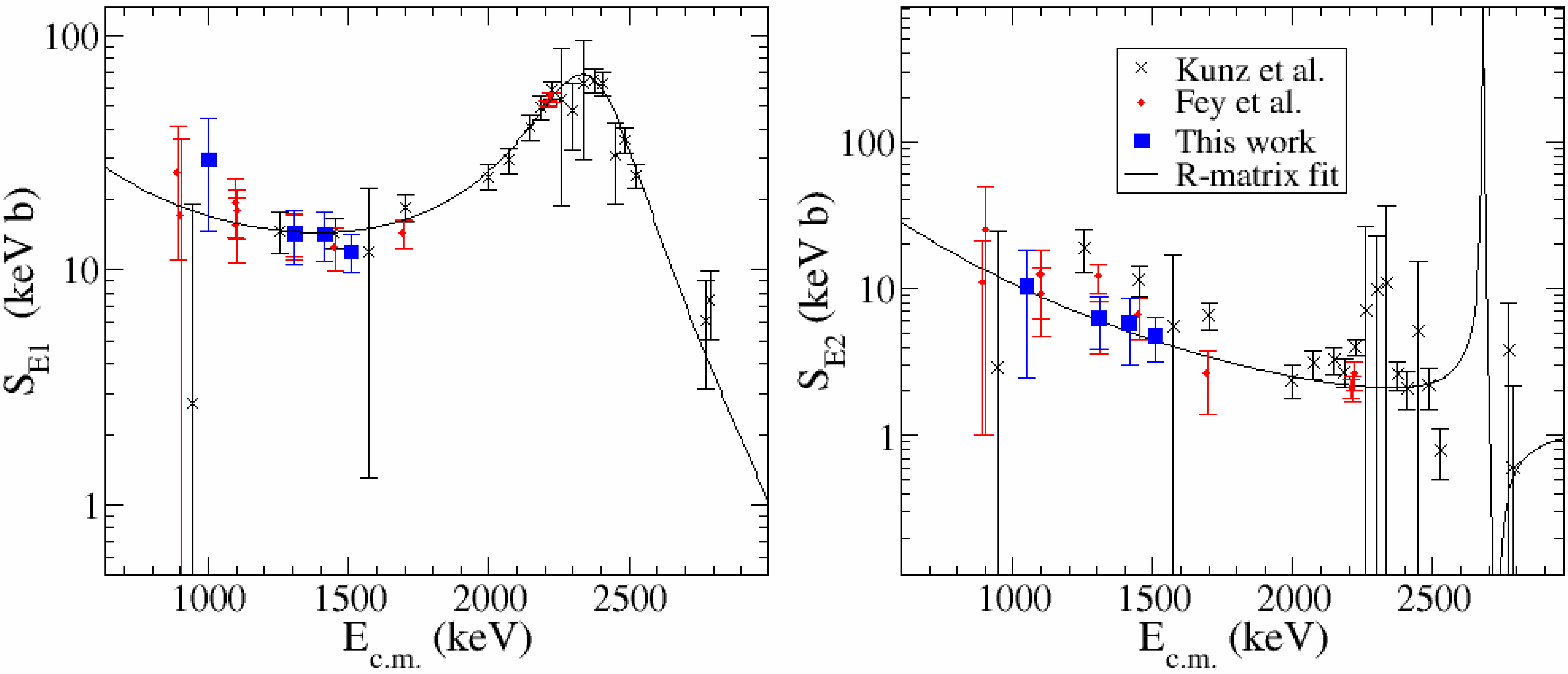
cascade transitions

NACRE: 7-10% „and therefore negligible….“

E_{cm} (keV)	S_{E1} (keVb)	S_{E2} (keVb)	S_{casc} (keVb)
1002	29±15	10±8	16±9
1308	14± 4	6± 2	10± 3
1416	14± 3	6± 3	7± 2
1510	12± 2	5± 2	7± 2

present systematic uncertainties ±10%, independent of other exps.

S factors



present S factors compared to best measurement with Ge detectors

after ~10 yr of optimization

S factors @ 300 keV

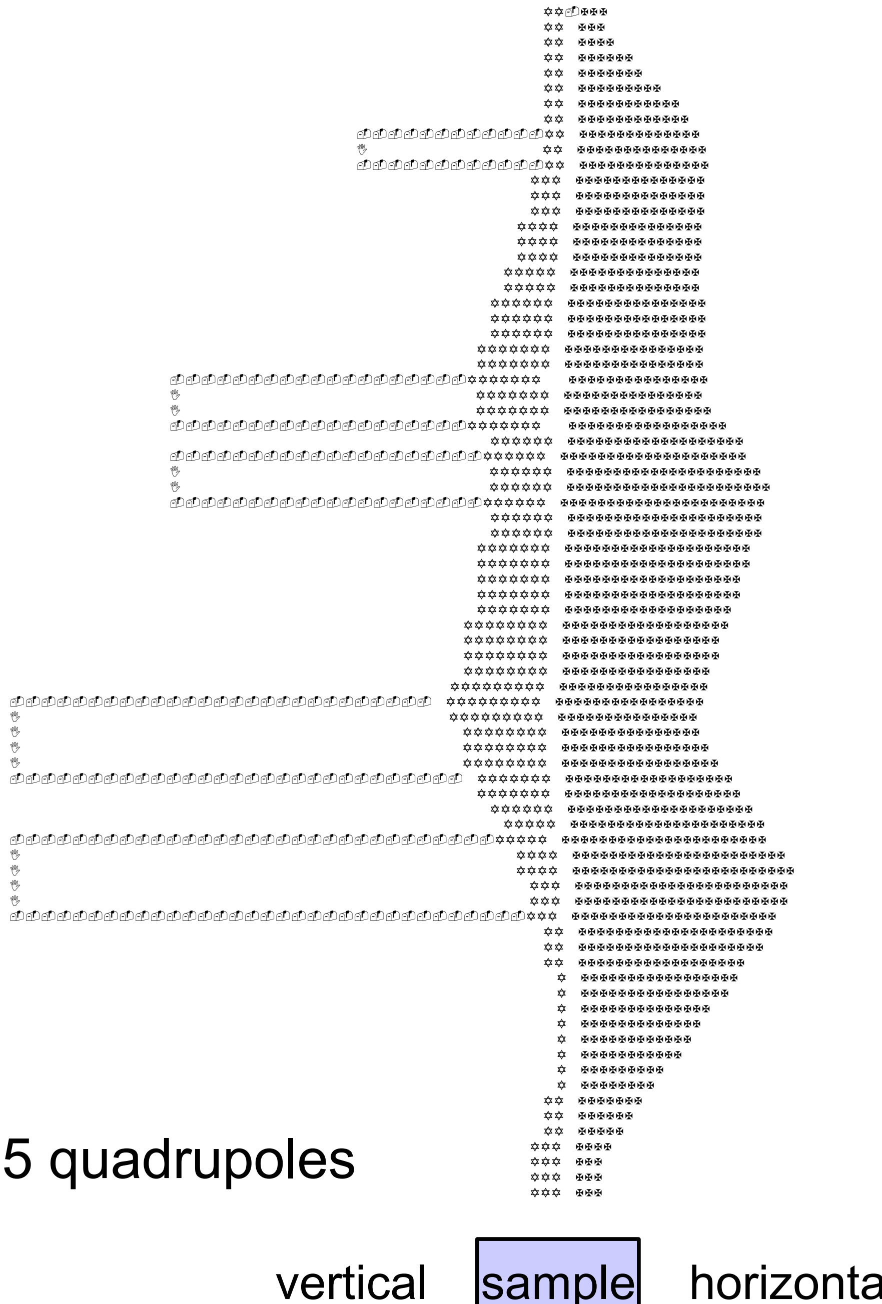
	S_{E1} (keVb)	S_{E2} (keVb)
Fey et al.	77±17	81±22
NACRE	79±21	120±60
FZK	**75±27**	**81±21**

Woosley: . . . the **acceptable** experimental error bar on the total $^{12}C(\alpha;\gamma)^{16}O$ rate needed to be **10% or less** for the laboratory physicists to declare a victory ….

remaining problems

- **beam optics**
  substantial losses between accelerator and sample → increase of background

- **vacuum**
  „bad“ vacuum in parts of beam line
  → ^{13}C build-up



focusing of strongly divergent α-beam with 5 quadrupoles

summary

- $^{12}C(\alpha,\gamma)^{16}O$ cross section measured between 1.0 and 1.5 MeV including angular distributions and cascade transitions

- first use of 4π BaF_2 detector yields uncertainties comparable to the results obtained with the long optimized Ge setup

- significant improvements with comparably simple modifications
  - better accuracy
  - accessible energy range down to 750 keV

from nbarns to Charlie Barnes

HAPPY BIRTHDAY
AND
VERY BEST WISHES!!!!

Hermann Beer
Sara Bisterzo
Laurent Coquard
Cesar Domingo
Michael Heil
Justyna Marganiec
Marita Mosconi
Ralf Plag
Fritz Voss
Stephan Walter
Klaus Wisshak