“SiC detectors for EXTREME LIGHT INFRASTRUCTURE (ELI)-Physics”

Gaetano LANZALONE

Workshop : From Silicon to SiC detectors
7-8 apr 2016
LNS-INFN Catania

ELI

- Nuclear Physics studies @ ELI-NP (Bucharest)
- Nuclear Physics applications @ ELI-Beamlines (Prague)

Nuclear reactions studies in Laser – Plasma

Nuclear Physics studies @ ELI-NP (Bucharest)

Nuclear reactions in Laser – Plasma

Nuclear reactions: ENTRANCE CHANNEL

>Electron screening

>No-g.s. reactions
(an important role can be also played by excited states [Bahcall and Fowler])

>Multi-Reactiones (n>2 : 3-4-… alphas !)

THE ASTROPHYSICAL JOURNAL, 161: 119–134, July 1970

NUCLEAR PARTITION FUNCTIONS FOR STELLAR REACTION RATES*

NETA A. BAHCALL
California Institute of Technology, Pasadena, and Tel-Aviv University, Tel-Aviv, Israel

AND

WILLIAM A. FOWLER
California Institute of Technology, Pasadena
Received 1969 December 11

ABSTRACT

Nuclear partition functions are calculated as a function of temperature for nuclei with mass numbers $A \leq 40$. These functions are important for determining reaction rates when contributions from nuclear excited states are included. Simple approximate expressions for the partition functions are also derived.

The Hoyle state .

ON NUCLEAR REACTIONS OCCURRING IN VERY HOT STARS. I. THE SYNTHESIS OF ELEMENTS FROM CARBON TO NICKEL

F. HOYLE*
MOUNT WILSON AND PALOMAR OBSERVATORIES
CARNEGIE INSTITUTION OF WASHINGTON
CALIFORNIA INSTITUTE OF TECHNOLOGY

Received December 22, 1953

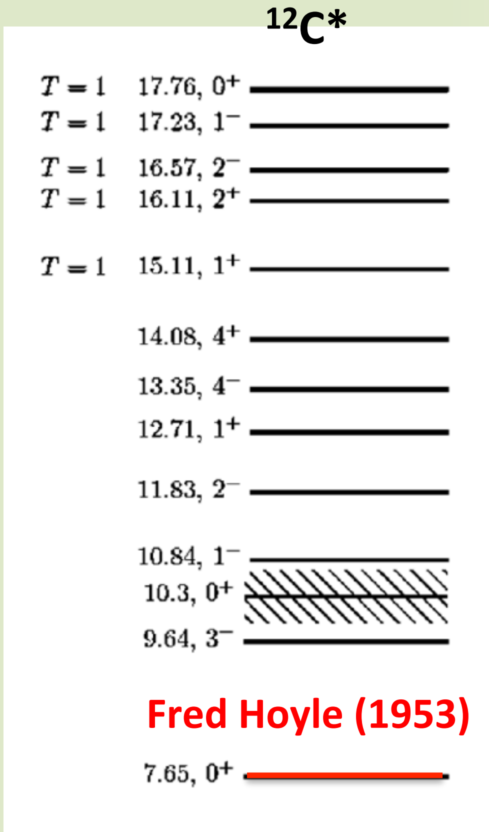
ABSTRACT

The present paper aims to show that the abundances of the chemical elements over the portion of the periodic table from carbon to nickel are consistent with the view that the elements originate at the high temperatures that probably occur in the interiors of certain types of star. The argument takes its most definite form in the discussion of the synthesis of elements below sodium, where it seems that the abundances are in fairly close accord with the known properties of the various nuclei. For sodium and heavier elements sufficiently precise nuclear data are not available, and hence the argument becomes more qualitative than quantitative. Nevertheless, the general nature of the agreement between calculation and observation for these latter nuclei makes the discussion of them worth presenting.

The early parts of the paper are concerned with the relation to cosmogony of the theory of the origin of the elements.

Study of the element:

^{12}C

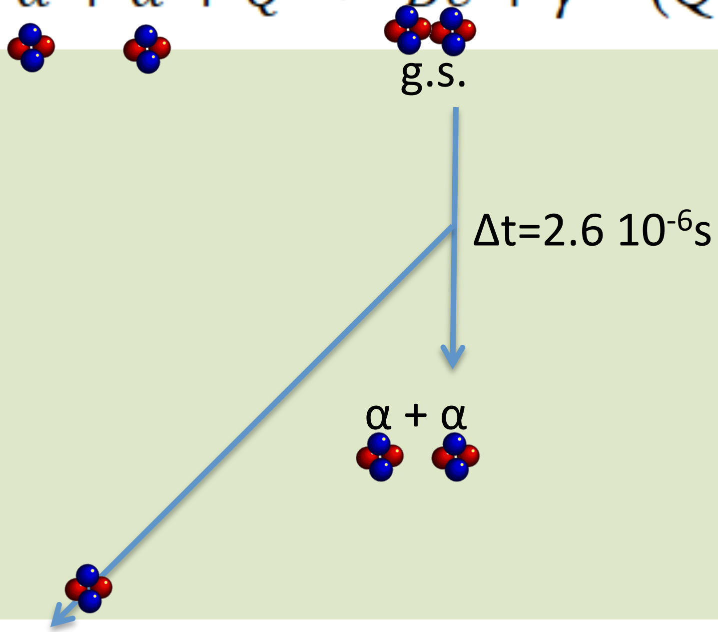


HB (Horizontal Branch)
AGB (Asymptotic Giant Branch)

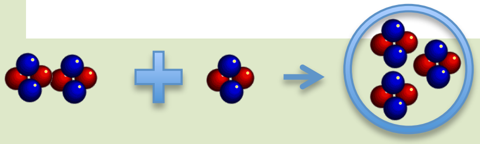
0.1 GK < T < 2GK

Sequential process

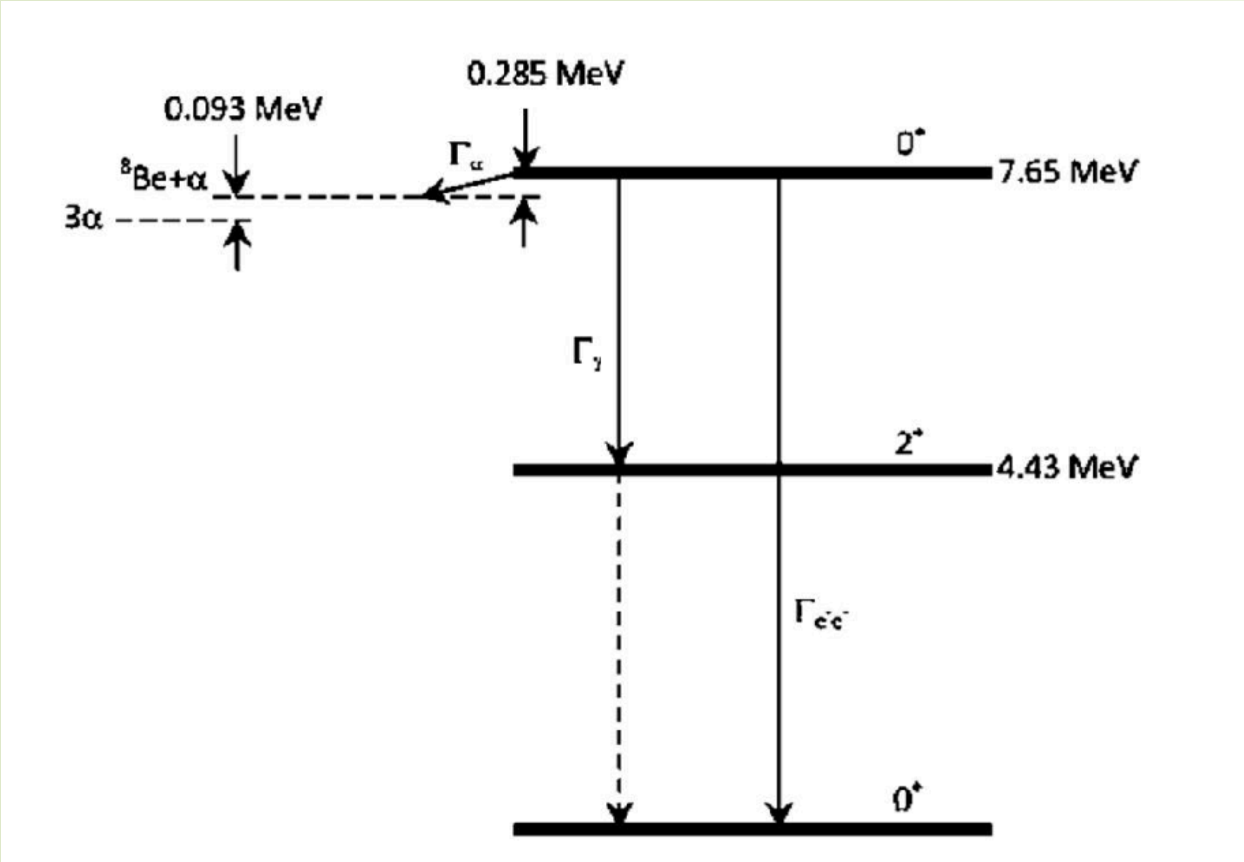
$$\alpha + \alpha + Q \rightarrow {}^{8}Be + \gamma \quad (\text{Q=95 KeV})$$



$$^{8}Be + \alpha \rightarrow {}^{12}C + \gamma + Q \quad (\text{Q=7,4Mev})$$

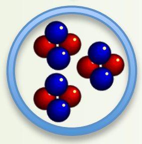


… other sequential processes : 16O, 20Ne, etc.



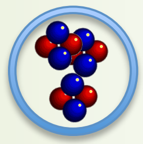
^{12}C $_{gs}$

R_H/R_{gs}=1.5



3α

Bose-Einstein



α+Be

Exit Channel (A)

Direct (short interaction time)

PRL **108,** 202501 (2012) PHYSICAL REVIEW LETTERS week ending 18 MAY 2012

Improved Limit on Direct α Decay of the Hoyle State

O. S. Kirsebom,[1,*] M. Alcorta,[2,†] M. J. G. Borge,[2] M. Cubero,[2] C. Aa. Diget,[3] L. M. Fraile,[4] B. R. Fulton,[3] H. O. U. Fynbo,[1] D. Galaviz,[2,‡] B. Jonson,[5] M. Madurga,[2,§] T. Nilsson,[5] G. Nyman,[5] K. Riisager,[1] O. Tengblad,[2] and M. Turrión[2,||]

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The current evaluation of the triple-α reaction rate assumes that the α decay of the 7.65 MeV, 0^+ state in ^{12}C, commonly known as the Hoyle state, proceeds sequentially via the ground state of ^{8}Be. This assumption is challenged by the recent identification of two direct α-decay branches with a combined branching ratio of 17(5)%. If correct, this would imply a corresponding reduction in the triple-α reaction rate with important astrophysical consequences. We have used the ^{11}B(^{3}He, *d*) reaction to populate the Hoyle state and measured the decay to three α particles in complete kinematics. We find no evidence for direct α-decay branches, and hence our data do not support a revision of the triple-α reaction rate. We obtain an upper limit of 5×10^{-3} on the direct α decay of the Hoyle state at 95% C.L., which is 1 order of magnitude better than a previous upper limit.

Exit Channel (A')

Multifragmentation (long interaction time)

Evidence for α-particle condensation in nuclei from the Hoyle state deexcitation

Ad.R. Raduta [a,b,*], B. Borderie [a], E. Geraci [c,d,e], N. Le Neindre [a,f], P. Napolitani [a], M.F. Rivet [a], R. Alba [g], F. Amorini [g], G. Cardella [c], M. Chatterjee [h], E. De Filippo [c], D. Guinet [i], P. Lautesse [i], E. La Guidara [c,j], G. Lanzalone [g,k], G. Lanzano [c,1], I. Lombardo [g,d], O. Lopez [f], C. Maiolino [g], A. Pagano [c], S. Pirrone [c], G. Politi [c,d], F. Porto [g,d], F. Rizzo [g,d], P. Russotto [g,d], J.P. Wieleczko [l]

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ABSTRACT

The fragmentation of quasi-projectiles from the nuclear reaction $^{40}Ca + ^{12}C$ at 25 MeV/nucleon was used to produce excited states candidates to α-particle condensation. Complete kinematic characterization of individual decay events, made possible by a high-granularity 4π charged particle multi-detector, reveals that $7.5 \pm 4.0\%$ of the particle decays of the Hoyle state correspond to direct decays in three equal-energy α-particles.

branching ratio

$$\frac{\Gamma_{3\alpha}}{\Gamma_{\alpha}} < 0{,}04$$

1994 Freer et al. [«Phys. Rev. C» 49(4), R1751 (1994)]
O. S. Kirsebom et al., «Phys. Rev. Lett.» 108, 202501 (2012)

$$R \propto \frac{\Gamma_{\alpha_0}\Gamma_{rad}}{\Gamma} T^{-3/2} e^{(-\frac{Q}{kT})}$$

$$\frac{\Gamma_{3\alpha}}{\Gamma_{\alpha}} < 0{,}17$$

2011, Raduta et al. [«Phys. Lett. B» 705, 65 (2011).]

Exit channel

Nuclear lifetime
(PRL 1995 by Attallah et al.)

VOLUME 75, NUMBER 9 PHYSICAL REVIEW LETTERS 28 AUGUST 1995

Charge State Blocking of *K*-Shell Internal Conversion in ^{125}Te

F. Attallah,[1] M. Aiche,[1] J. F. Chemin,[1] J. N. Scheurer,[1] W. E. Meyerhof,[2] J. P. Grandin,[3] P. Aguer,[4] G. Bogaert,[4] J. Kiener,[4] A. Lefebvre,[4] J. P. Thibaud,[4] and C. Grunberg[5]

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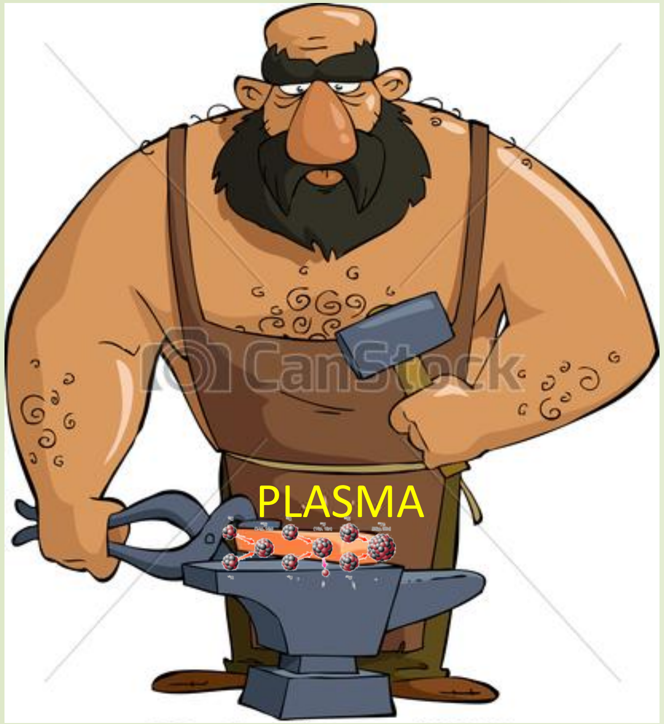
(Received 18 January 1995)

We have studied the atomic charge state dependence of the nuclear lifetime of the 35.5-keV first excited state of ^{125}Te. For the 47^+ and 48^+ ions, 300% and 640% increases, respectively, of the half-life were found with respect to the neutral-atom value (1.49 ns). These unusually large effects are due to the energetic blocking of *K*-shell internal conversion as the charge state increases past 47^+.

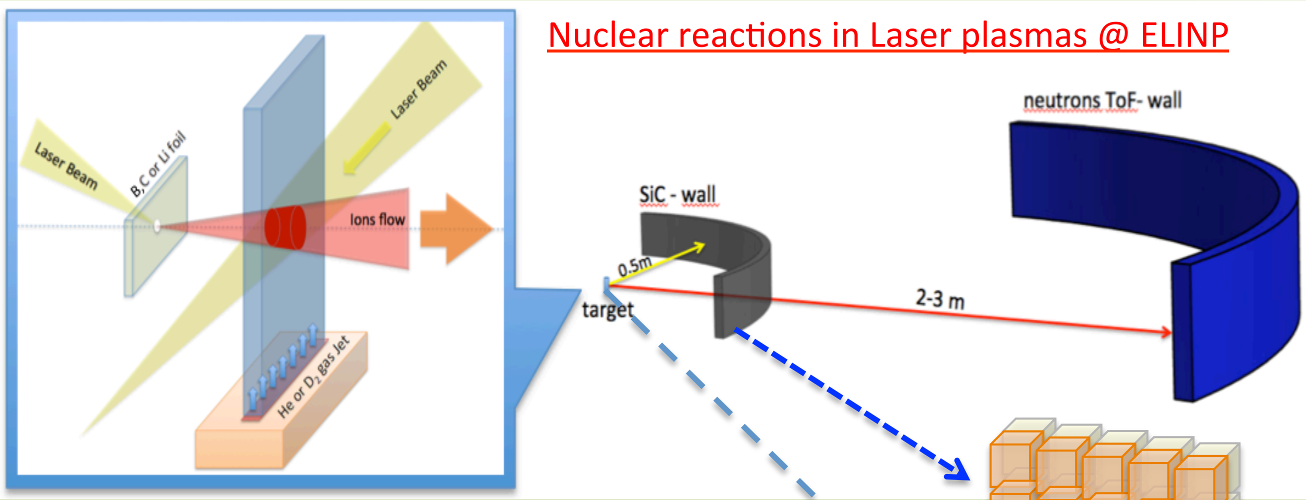
We must create the plasma in a Laboratory …



… to study Nuclear Reactions

Extreme Light Infrastructure – Nuclear Physics

Detectors working in plasmas environment



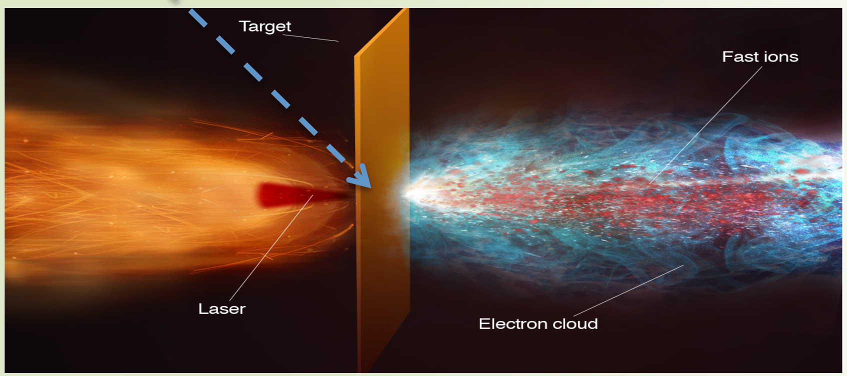
Gas-Jet Target: Thin Mode

(few mms)

minimize "plasma-plasma friction", the energy dissipation of the fast flowing plasma colliding with the gas-jet plasma, in order to work in a more "conventional" nuclear physics experimental scheme (projectiles on a rest target).

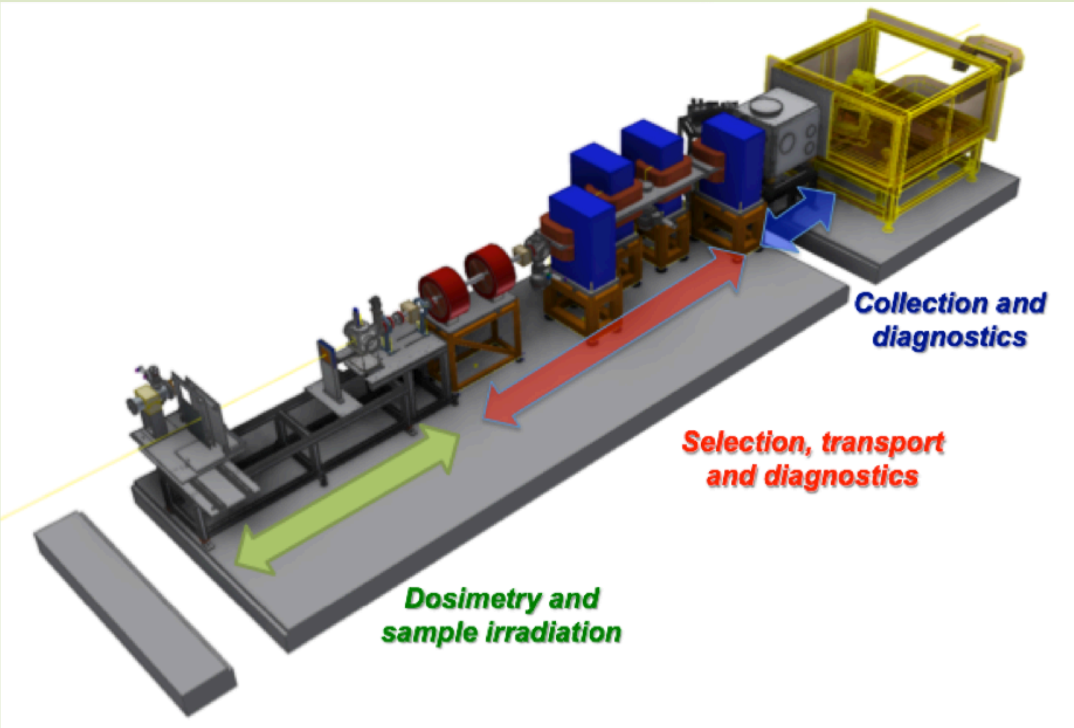
Requirements

- ✓ Radiation Hardness
- ✓ Timing
- ✓ Insensibility to the visible radiation
- ✓ X-ray sensitivity
- ✓ Neutrons sensitivity (ITER, ESS, etc.)



ELIMED

ELI-Beamlines MEDical and multidisciplinary applications



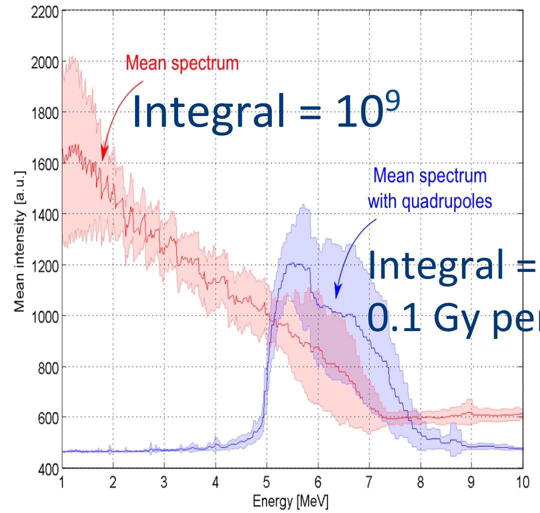


FIGURE 4 – Average proton beam spectrum extracted from the traces recorded by the forward Thomson Parabola, without (in red) and with (in blue) the quadrupole system.

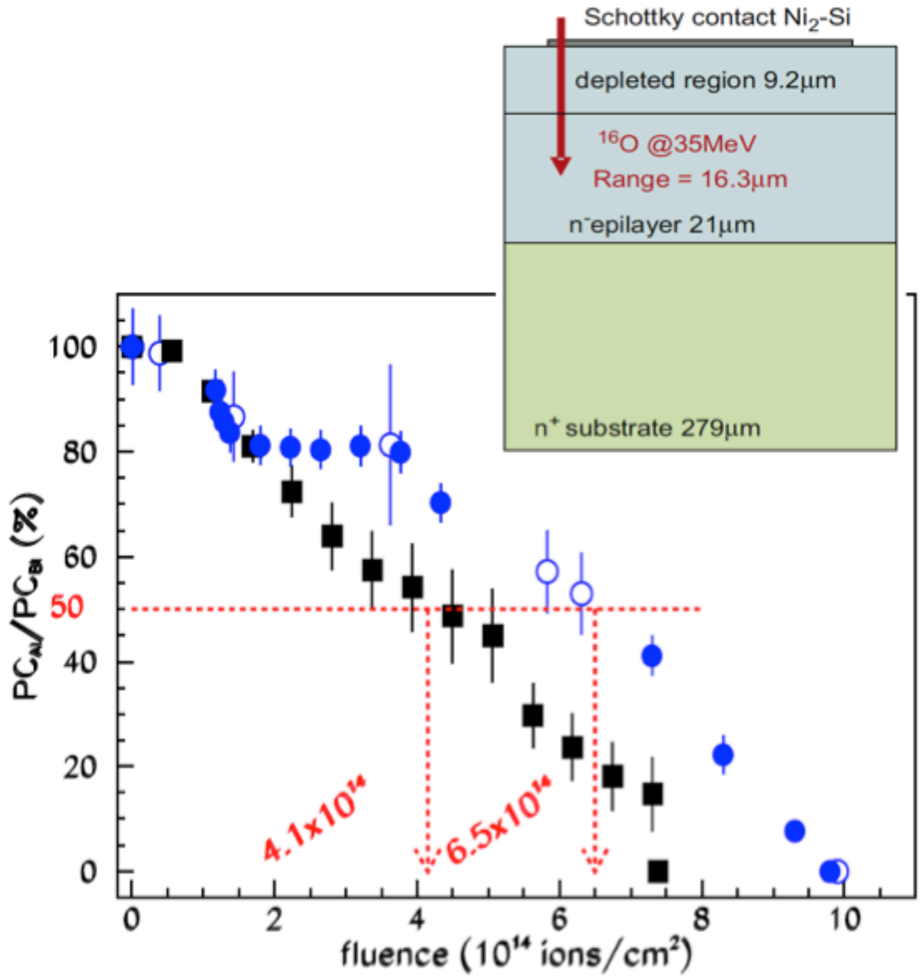
LOA run (Paris, F) is running — PRELIMINARY

	Conventional beams	Laser-driven beams
Maximum energy	250 MeV 400 AMeV	😃 (250 😟 ?)
Current	order of nA	😃
Monochromaticity	ΔE/E ≤10^{-2}	Broad beam: optical solutions, target solutions?, both? 😟
Stability, reproducibility, control, dosimetry	Less that 3%	😱
Radiobiology	Almost known	😟

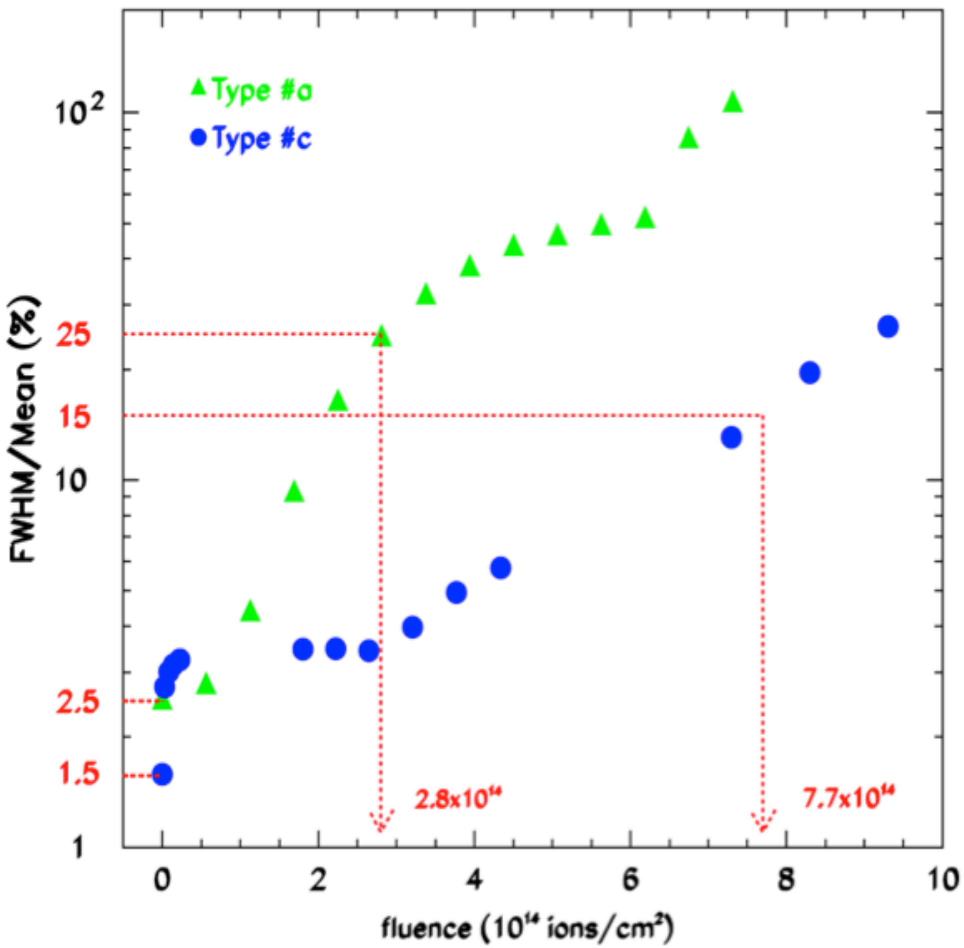
GAP Cirrone, pablo.cirrone@lns.infn.it

R.H. Experimental data

^{16}O @ 35 MeV



Ratio of peak centroid of ^{16}O energy spectrum after (PC_{AI}) and before irradiation (PC_{BI})



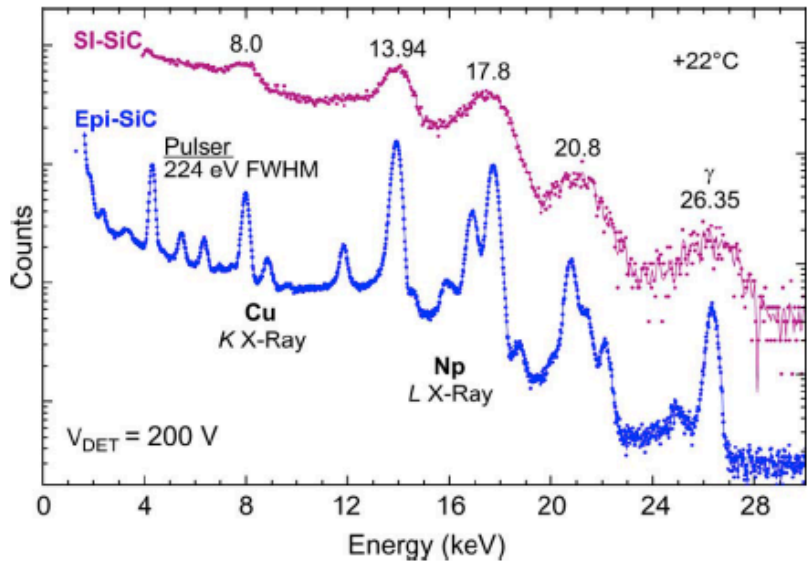
Relative Energy resolution

G. Raciti et al. Nuclear Physics A 834 (2010) 784

M. De Napoli et al. NIMA 600 (2009) 618

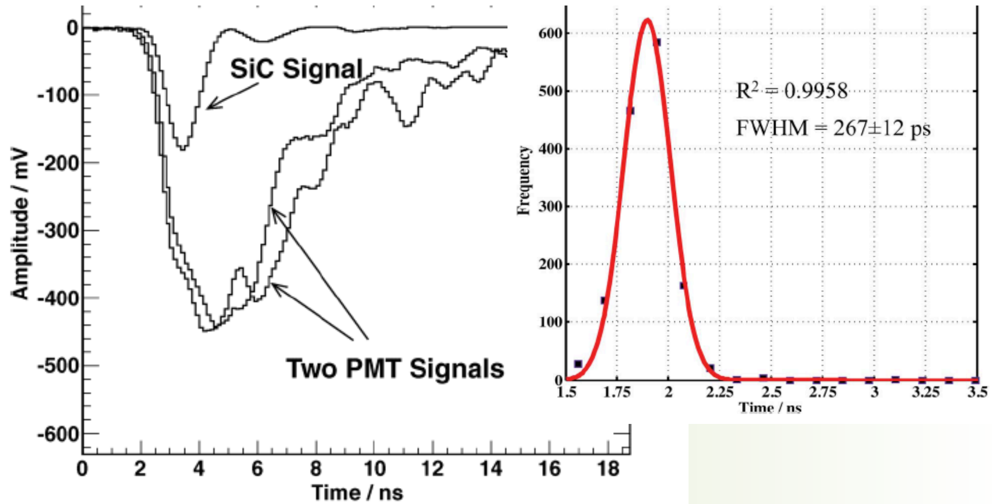
SiC performance

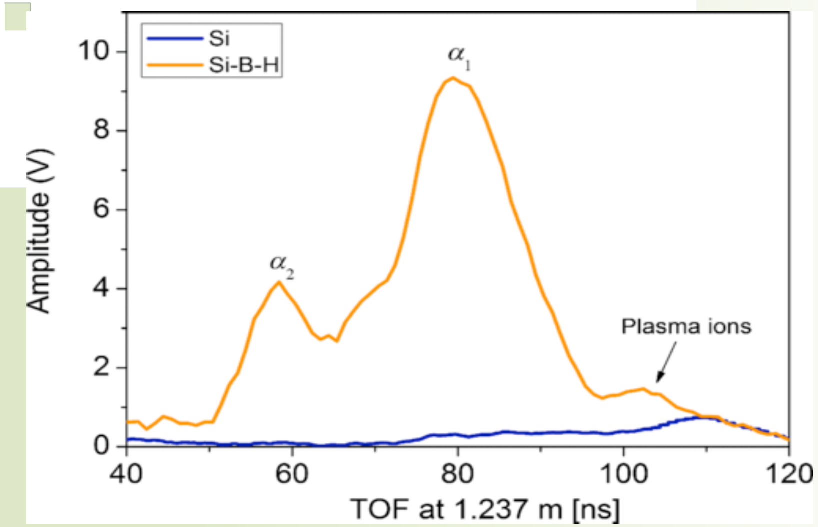
- ✓ Low leakage current ➔ high energy resolution ➔ X-rays detection
- ✓ Timing ➔ sub-nanoseconds ➔ ToF application
- ✓ Insensible to visible light ➔ neutrons and charged particles detection in plasmas



G. Bertuccio et al. IEEE Trans. Nucl. Scie. 60, NO. 2, APRIL 2013

Xiaodong Zhang IEEE Trans. Nucl. Scie. VOL. 60, NO. 3, JUNE 2013





A. Picciotto et al. Phys. Rev. X 4, 031030 (2014)

TOF distribution measured by the SiC detector for the Si-H-B (orange curve) and Si (blue curve) targets

THANKS,

For your attention !