# INFN-E-MAFLUNE,INFN-E-MAFI,INFN-E-ADS, UE-FREYA,UE-CHANDA,UE-SCINTILLA

## INFN-Energia

M. Osipenko[1], M. Ripani[1], G. Ricco[1], B. Caiffi[3]
M.Battaglieri[1], R. De Vita[1], E. Fanchini[1], F. Panza[1]
G.Lomonaco[3], D.Chersola[3]
In Collaboration with:
M. Pillon[4], D. Trucchi[2], G. Firpo[5], S. Minutoli[1], S. Cerchi[1],
G. Gariano[1], F. Gatti[3], and D. Corsini[3].

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[5]Ansaldo Nucleare

Genoa, Italy

# INFN-E Genova 2015

| Project | Start/End | Person | FTE |
|---|---|---|---|
| INFN-E | | M.Osipenko | 0.2 |
| | | M.Ripani | 0.1 |
| | | G.Ricco[A] | |
| | | B.Caiffi[D] | 1.0 |
| | | F.Panza | 1.0 |
| | | E.Fanchini | 1.0 |
| | | G.Lomonaco[A] | 0.1 |
| | | D.Chersola[A] | 0.1 |
| Total | | | 3.6 |
| UE-FREYA | 16/03/11 | M.Osipenko | 0.1 |
| | 29/02/16 | M.Ripani | 0.1 |
| Total | | | 0.2 |
| UE-CHANDA | 1/12/13 | M.Ripani | 0.2 |
| | 30/11/17 | M.Osipenko | 0.1 |
| | | P.Saracco | 0.1 |
| | | G.Ricco[A] | |
| | | G.Lomonaco[A] | 0.1 |
| | | D.Chersola[A] | 0.1 |
| Total | | | 0.6 |
| UE-ERASET | 1/12/13 | M.Ripani | 0.1 |


# UE-Scintilla

***National Coordinator:*** R. De Vita
***Financial Officer:*** M. Pavan
***EU personnel:*** E. Fanchini, V. Vigo

**Project scope:** *Development of systems for the detection of radioactive sources and nuclear material*
**Type:** *Collaborative project (FP7-SEC-2011-1.5-1)*
**Duration:** *36 months (1/1/2012 - 31/12/2014)*
**Funding:** *3MEuro (total) / 300KEuro (INFN)*

## 2014 Activity:

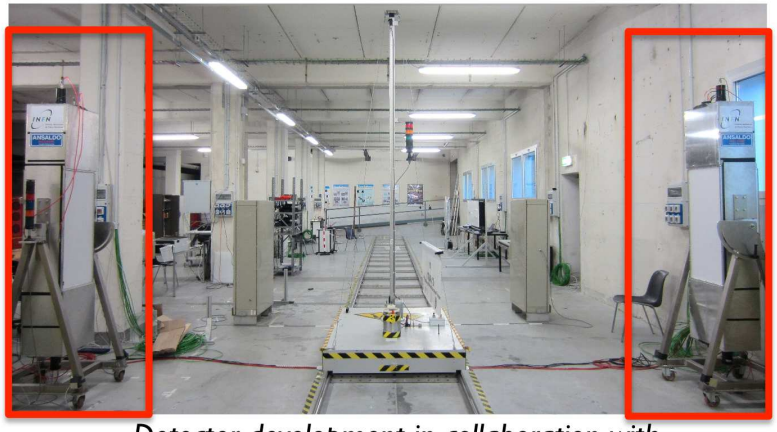
- Second detector pillar constructed, assembled and commissioned in Genova in 2014
- Full RPM system (2 pillars) successfully tested in the Benchmark campaign at JRC-Ispra in November 2014:
  - *Detector performances comply or exceed the RPM international standards for gamma and neutron detection*
  - *Performances comparable or better than commercial systems tested in the same benchmark campaign*
- Project completion 31/12/2014

## Perspective and Exploitation Plan

- Gamma source identification algorithm developed and under test
- International patent application submitted
- Contacts with private companies for possible exploitation established in coordination with Ansaldo Nucleare and INFN-CNTT

## Development of a Radiation Portal Monitor based on Gd-lined plastic scintillator for gamma and neutron detection

- S.M. Carturan et al., EPJ Plus, Vol.129, n.10, (2014)
- A. Alemberti et al., ICATPP proceeding Vol.8, Chapt. 105, pp.659-663 (2014)
- E. Fanchini, Proceeding submitted for the 3He alternatives for international safeguards workshop (2014)
- E. Fanchini, Proceeding submitted to IEE TNS for the ANIMMA 2015 conference (2015)



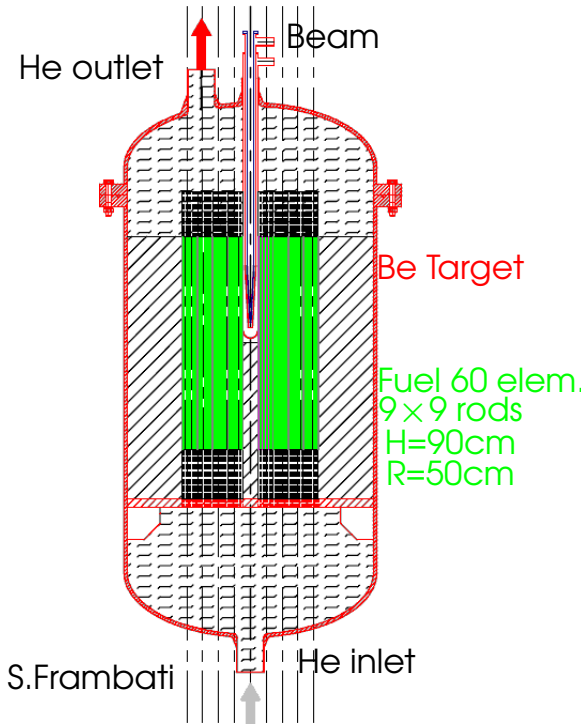
*Detector development in collaboration with Ansaldo Nucleare*

*GRAZIE a tutti i Servizi per il supporto durante tutte le fasi del progetto*

# UE-CHANDA and INFN-E-ADS

- WP12 Task 12.4: "New infrastructure for studies of transmutation and fast system concepts", (INFN, Ansaldo Nucleare).
- Scope: optimization of a subcritical system to perform integral measurements on transmutation processes.
- Methodology: burn-up simulations based on Monte Carlo codes (MCNP/MCB) applied to different fuels and test rods (F.Panza).
- The low power ADS, proposed for LNL, represents an attractive intermediate step to fill the gap between existing and future facilities (Myrrha,EFIT).

G.Ricco et al.,EPJ Plus 129: 64 (2014)



# UE-FREYA (INFN,ENEA,Ansaldo)

Fast reactor neutron spectrum produces less wastes. In development phase spectrum has to be measured. ADS, like UE-FREYA FP7 Project (SCK-CEN, Mol, Belgium), requires measurements of transients ($\mu$s scale).

1. WP1: ADS on-line reactivity monitoring methodologies,
   - in PNS, Source Jerk, Beam Trip methods a fast neutron spectrometer allows to sort neutron transients in groups.
2. WP2: Subcritical configurations for design and licensing of MYRRHA/FASTEF.
   - direct measurement of neutron spectrum improves knowledge of burn-out.

# Diamond Detectors

Comparison with Fission Chamber:

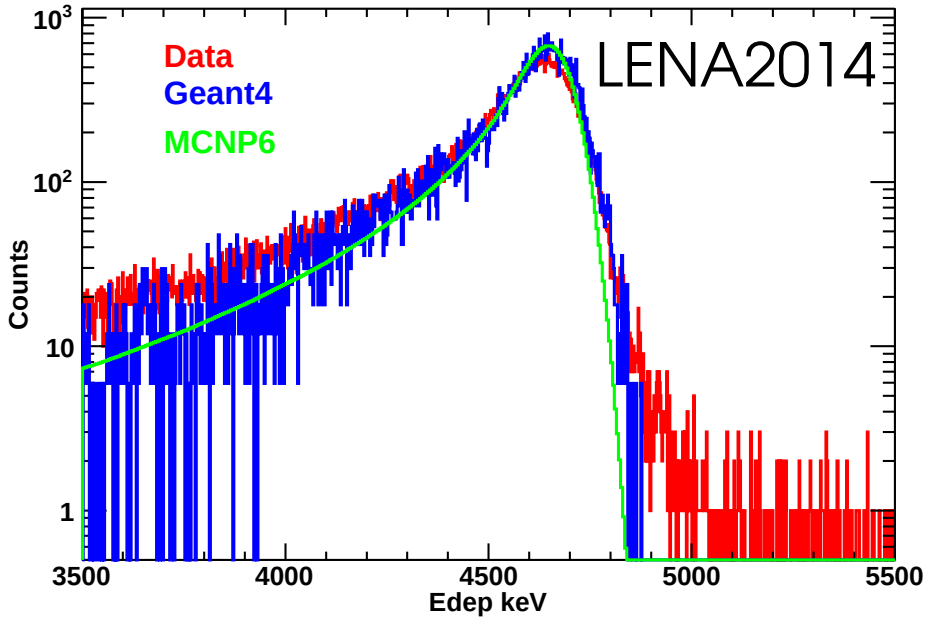
| | Fission Chamber | Diamond Detector |
|---|---|---|
| Charge Mobility | 0.3-0.4 $cm^2/V/s$ | 2000 $cm^2/V/s$ |
| Charge Collection time | 5-7 $\mu s$ | 2-10 ns |
| Counting Rate | 20 kHz | 10 MHz |
| Size | $4 \times 10$ $mm^2$ | $2 \times 2$ $mm^2$ |
| Converter | U,Np,Pu,Th | H, Li, B |
| Efficiency at 0.5 MeV | 1.1 barn ($^{235}U$) | 0.4 barn ($^{6}Li$) |
| Amount | $2 \times 10^{18}$ - $10^{21}$ a | $5 \times 10^{16}$ - $10^{18}$ a |
| Signal Size | 200 fC | 60 fC ($^{6}Li$) |
| Spectroscopy | unfolding | direct ($^{6}Li$) |
| Energy Range | entire | <7 MeV ($^{6}Li$) |

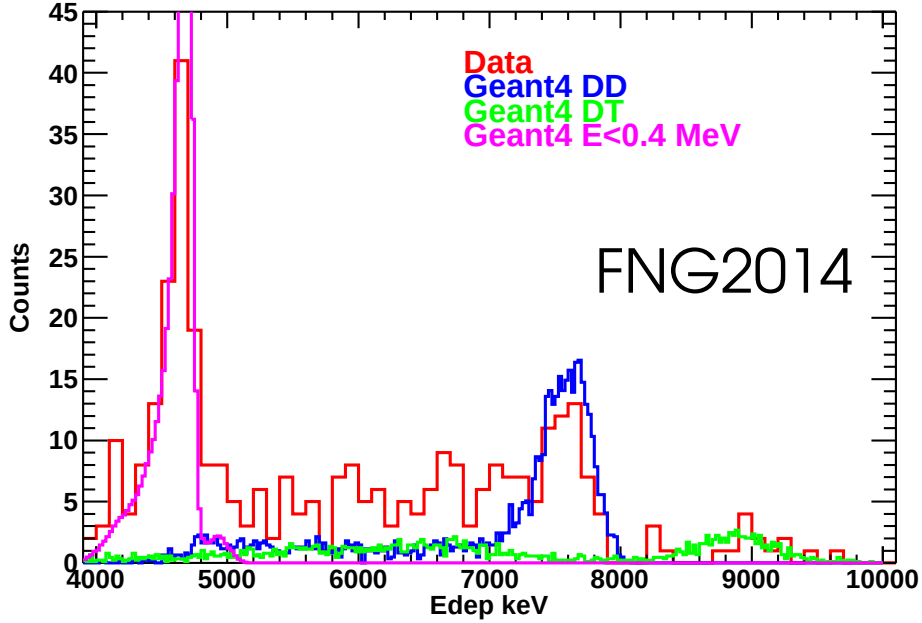
Comparison with Silicon detector:

- factor $\times$4-10 lower radiation damage ($\sigma_{C(n,n')} \times Z_C^2 \rho_C$),
- no intrinsic noise at high temperature ($E_g = 5.5$ eV).

# Calibration of Prototype

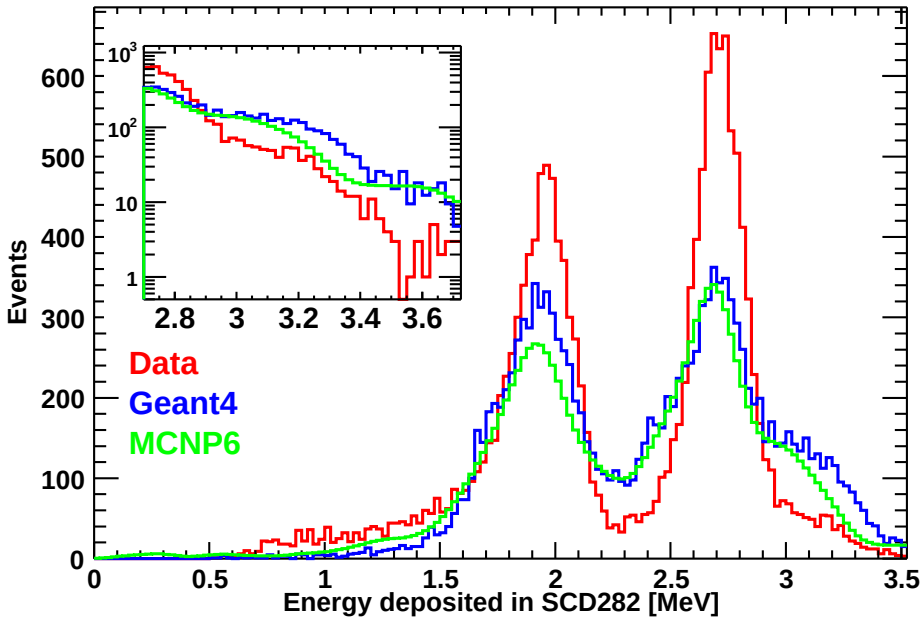
- Experiment at TRIGA of LENA (Pavia) to determine response to thermal (graphite column) neutrons:
  - near fission chamber normalization,
  - absolute amount of $^{6}$Li (40 nm thick $\times$2.2 mm$\times$3 mm).
- Experiment at FNG of ENEA (Frascati) to determine response to fast (DD-fusion, 90°) neutrons:
  - $^{115}$In activation foil normalization,
  - agreement with Geant4 extrapolation for 2.5 MeV neutrons within 11% (stat.) and 20% (sys.).

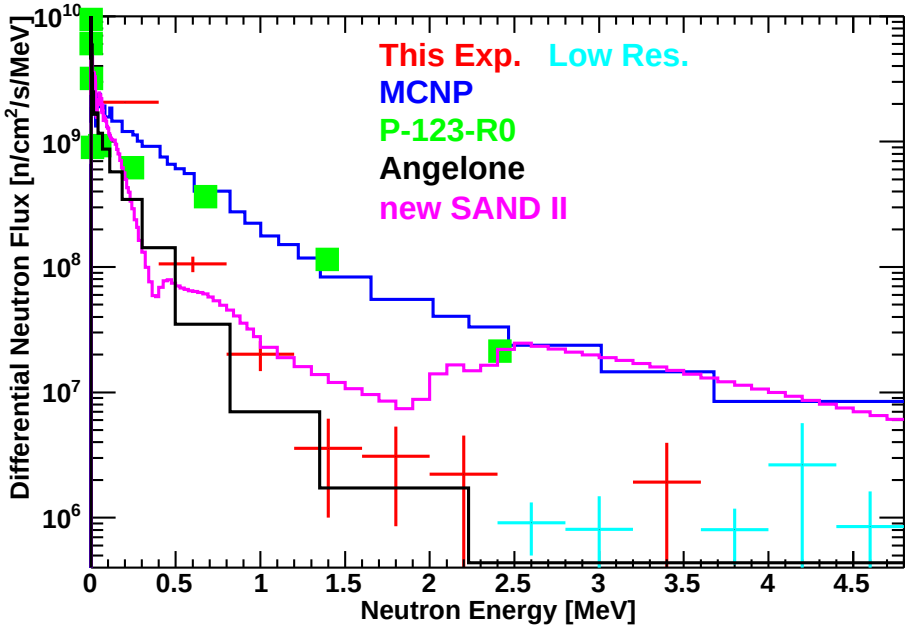


# Neutron Flux in Fast Reactor

- 6m runtime at 5 W reactor power, trigger rate 44 Hz.
- Total measured flux $\sim$ 90% of expected from MCNP simulations, normalized (in different point) to activation foil measurement at 3.5 kW reactor power,
- neutron flux at $E_n > 0.5$ MeV 5-10 times lower,
- extrapolation factor due to position difference $\times 0.82$,
- extrapolation factor due to power difference $\times 0.0014$.

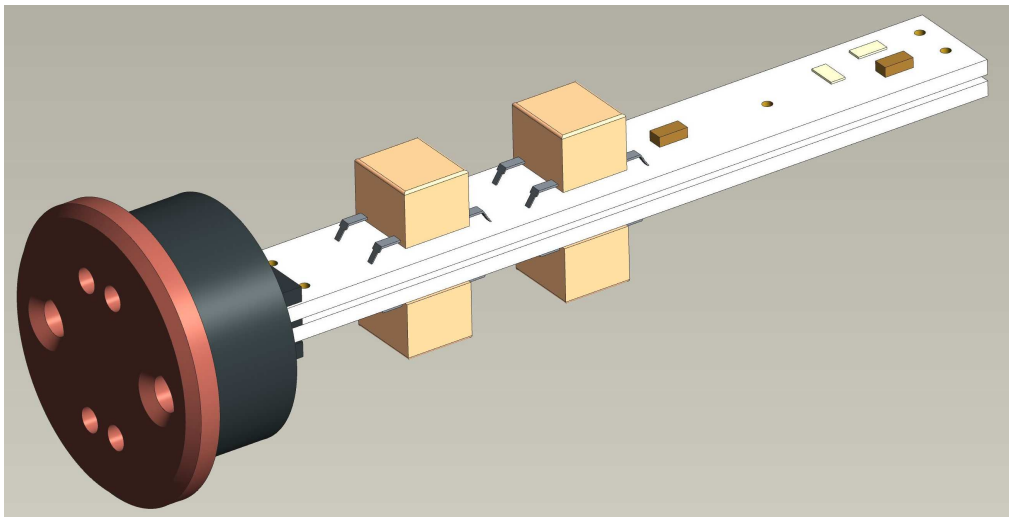


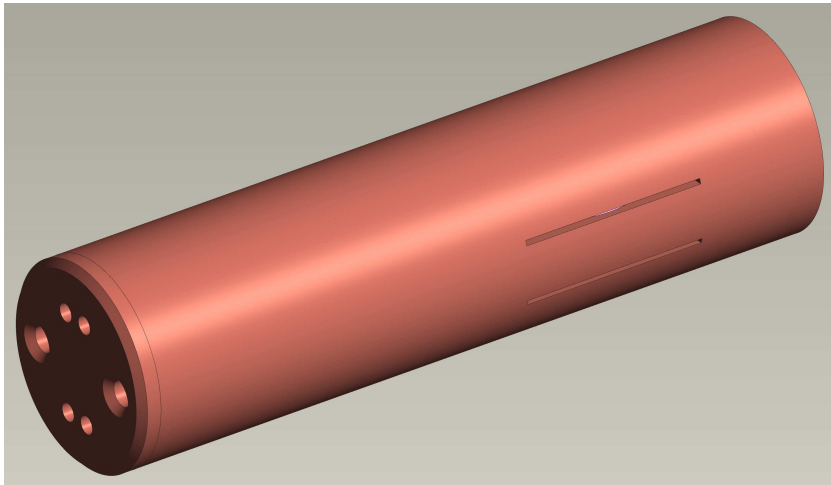
# New Sandwich Assembly

- E6 300 $\mu$m electronic grade single crystal diamonds.
- Contacts by Daniele Trucchi (100 nm Au) - needs reduction of material budget to improve resolution.
- New PCB, shield and housing design - $D \sim 3$ cm (limited by components) needs reduction to $< 1$ cm,
- 10 m long RG174 cables (50 Ohm), separate HV cables (G.Ottonello).

PCB design by S. Cerchi

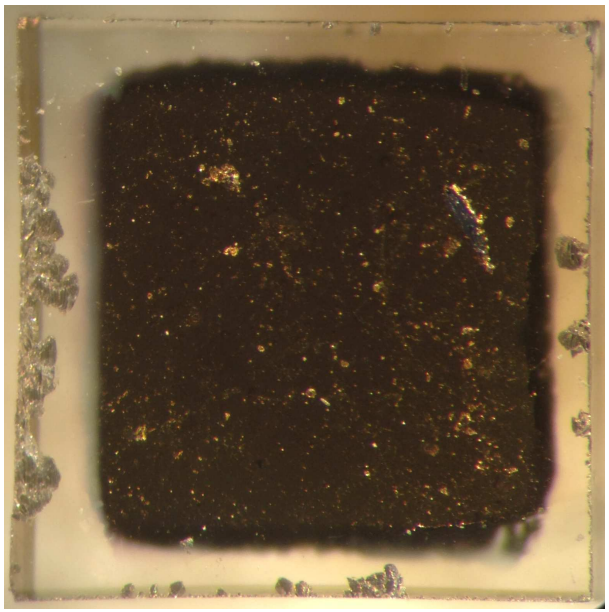


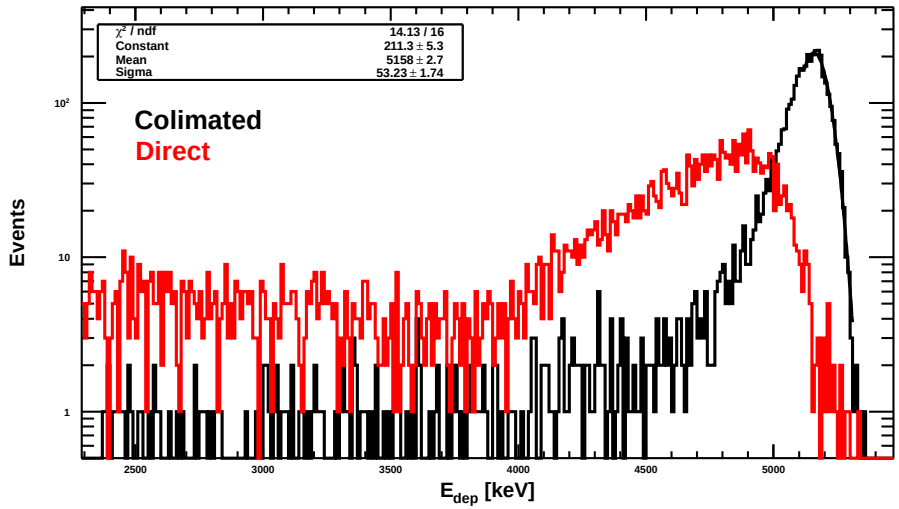
housing design by V. Vigo



# New Contacts

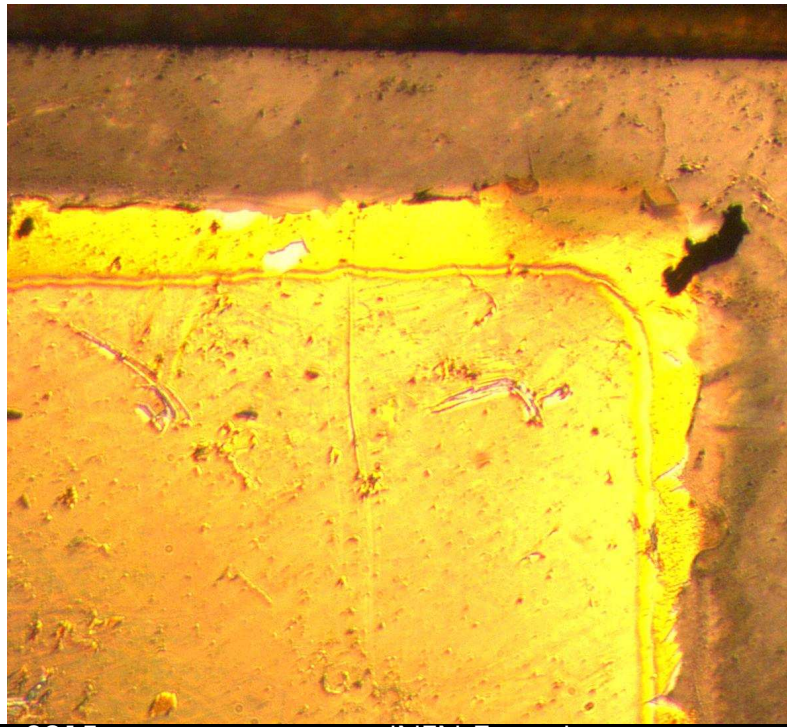
- first $2 \times 2$ mm$^2$ 500 $\mu$m diamond with contacts by D. Trucchi glued to PCB,
- test with $^{241}$Am $\alpha$-source showed that detector is working, but has large dead area,
- resolution of 50-60 keV was observed, while resolution due to electronics noise using 3 m cable was 23 keV.





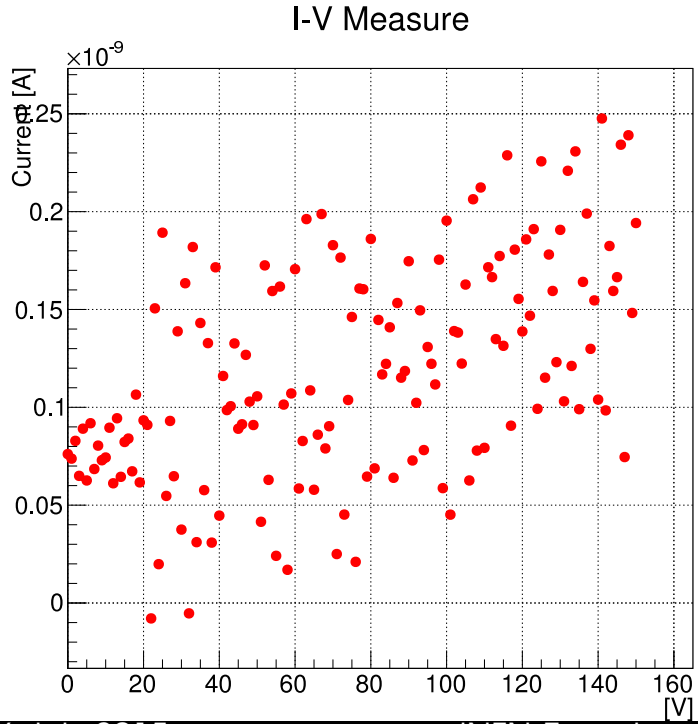
# LiF deposition

- 200 nm of LiF were deposited by D. Corsini,
- test was made on gold plated Si wafer to calibrate deposited LiF thickness, measured by Prof. M. Canepa on helixometer,
- Al mask was used to protect 0.2 mm wide frame for contact wirebonding,
- LiF thickness was measured by profilometer.



# Detector Bonding

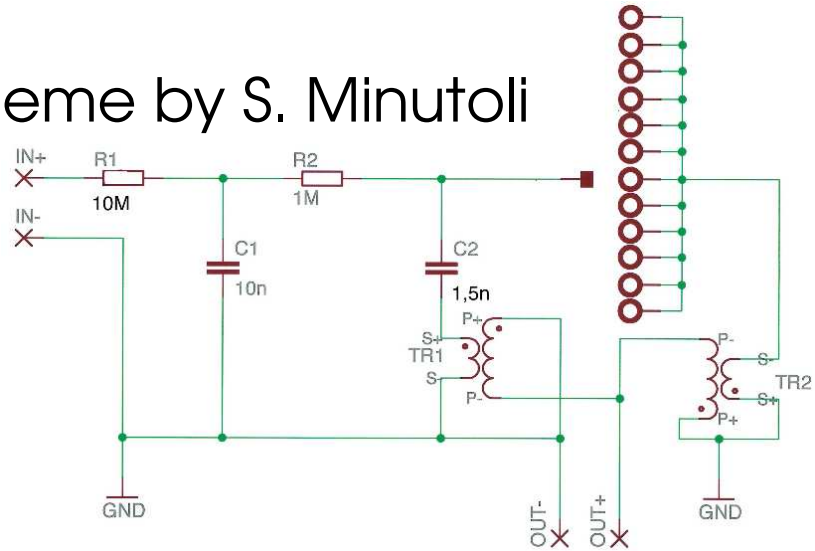
- bonding was performed by G. Gariano,
- diamond detector was glued with its bottom contact to PCB pad by e-Solder 3025 conductive glue,
- 50 $\mu$m W gold plated wire was soldered to PCB and glued to the top contact,
- I vs. V characteristic was measured to check resistivity with Keithly 2410.



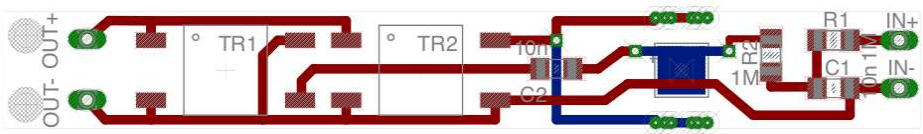
# New Readout

- signals from both sides of each diamond are collected, and preamplified $\times 4$,
- overall signal strength improvement $\times 8$,
- old detectors with fast electronics (R.Cardarelli amplifier) had resolution of 100 keV,
- expected resolution of new detector 30 keV.

scheme by S. Minutoli




PCB by S. Cerchi



# Results MAFI/MAFLUNE


- B. Caiffi, "Neutron Shielding Assessment and Diagnostic in Tokamaks", PhD thesis Genoa University (2015),
- B. Caiffi et.al, "Characterization of scCVD diamond detectors with sources", NIM A754, 24 (2014),
- B. Caiffi et.el, "Analysis of the Response of CVD Diamond Detectors for UV and sX-Ray Plasma Diagnostics Installed at JET", Physics Procedia 62, 79 (2015),
- B. Caiffi et.al, "Proton recoil telescope based on diamond detectors for measurement of fusion neutrons", TNS (2015), arXiv:1505.06316,
- B. Caiffi et.al, "Dose Rate Analysis for TBM Port #16 after Shutdown", ITER_D_QZUA22 v1.0.
- B. Caiffi et.al, "Neutron shielding study of the DEMO upper vertical port", Eurofusion Deliverable PMI-5.3-04,
- M. Osipenko et.al, "Single Crystal Diamonds for Neutrons", EPJ.Plus 129, 268 (2014),
- M. Osipenko et.al, "Test of a prototype neutron spectrometer based on diamond detectors in a fast reactor", TNS (2015), arXiv:1505.06314,
- M. Osipenko et.al, "Neutron spectrometer for fast nuclear reactors", NIM (2015), arXiv:1505.06654,
- M. Osipenko et.al, "Comparison of Fast Amplifiers for Diamond Detectors", INFN-13-17-GE, airXiv:1310.1000 (2013),
- A. De Franco, "Misure di Flusso in Reattore ADS Veloce", MD thesis Genoa University (2012).

# Results ADS/FREYA/CHANDA


- G.Mila et al., "Pulsed neutron and source jerk experiments for reactivity assessments in deep subcritical configuration", PHYSOR 2014,
- P. Saracco et al., "A preliminary study of an improved area method, adapted to short time transients in subcritical systems.", PHYSOR 2014,
- S.Dulla et al., "Reflector effects on the kinetic response in subcritical systems", ANS MC2015,
- G.Ricco et al., "An intrinsically safe facility for forefront research and training on nuclear technologies", EPJ Plus, 129: 64 (2014),
- M.Osipenko et al., "Measurement of neutron yield by 62 MeV proton beam on a thick beryllium target", NIM A723, 8 (2013),
- R.Alba et al., "Measurement of neutron yield by 62 MeV proton beam on a thick Beryllium target", J.Phys.Conf.Ser. 420, 012162 (2013),
- M.Osipenko et al., "Comprehensive measurement of neutron yield produced by 62 MeV protons on Beryllium target", IEEE Advancements in Nuclear Instrumentation Measurement Methods and their Applications, 1293, 1 (2013),
- M.Schillaci et al., "Complete determination of neutron yield from 62 MeV protons on $^{9}$Be for the design of a low-power ADS", EPJ Web of Conferences 66, 10015 (2014),
- C.Viberti, "Progetto di massima di un reattore di ricerca sotto-critico veloce sostenuto da un acceleratore di protoni da 70 MeV", MD thesis Genoa University (2010).
- A.Celentano, "Produzione di neutroni da bersaglio spesso", MD thesis Genoa University (2010).

# INFN-E Genova 2016

| Project | Start/End | Person | FTE |
|---|---|---|---|
| INFN-E | | M.Osipenko | 0.2 |
| | | M.Ripani | 0.2 |
| | | G.Ricco[A] | |
| | | F.Panza | 1.0 |
| | | G.Lomonaco[A] | 0.2 |
| | | D.Chersola[A] | 0.2 |
| Total | | | 1.8 |
| UE-FREYA | 16/03/11 | M.Osipenko | 0.05 |
| | 29/02/16 | M.Ripani | 0.05 |
| Total | | | 0.1 |
| UE-CHANDA | 1/12/13 | M.Ripani | 0.2 |
| | 30/11/17 | M.Osipenko | 0.1 |
| | | P.Saracco | 0.1 |
| | | G.Ricco[A] | |
| Total | | | 0.4 |

# Richieste Servizi

| Servizio | Richieste (m.u.) | Obiettivi |
|---|---|---|
| Elettronica | 2+2(S.Minutoli) +2(G.Ottonello) | sviluppo PCB det., amp. readout montaggio, cavi |
| Progettazione | 2 | maschere evap., involucro det. |
| Officina | 2 | maschere evap., involucro det. |
| Calcolo | 2 | calc. parallelo (Intel PHI) |