POLITECNICO DI MILANO





Neutron Dosimetry and Spectrometry in Complex Radiation Fields using CR-39 detectors

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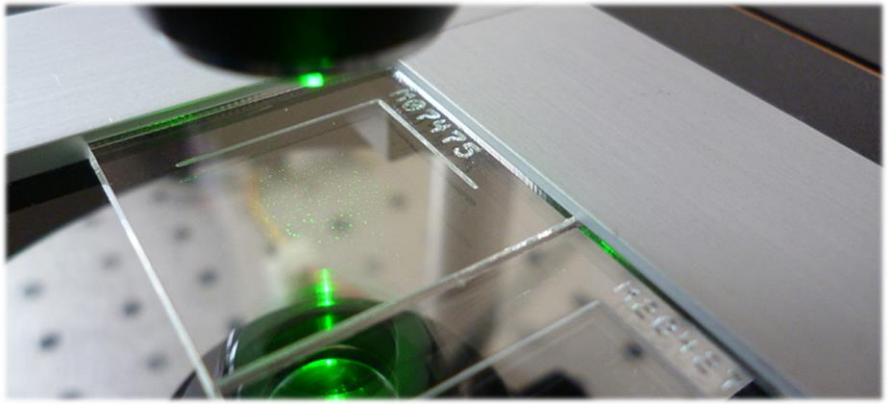
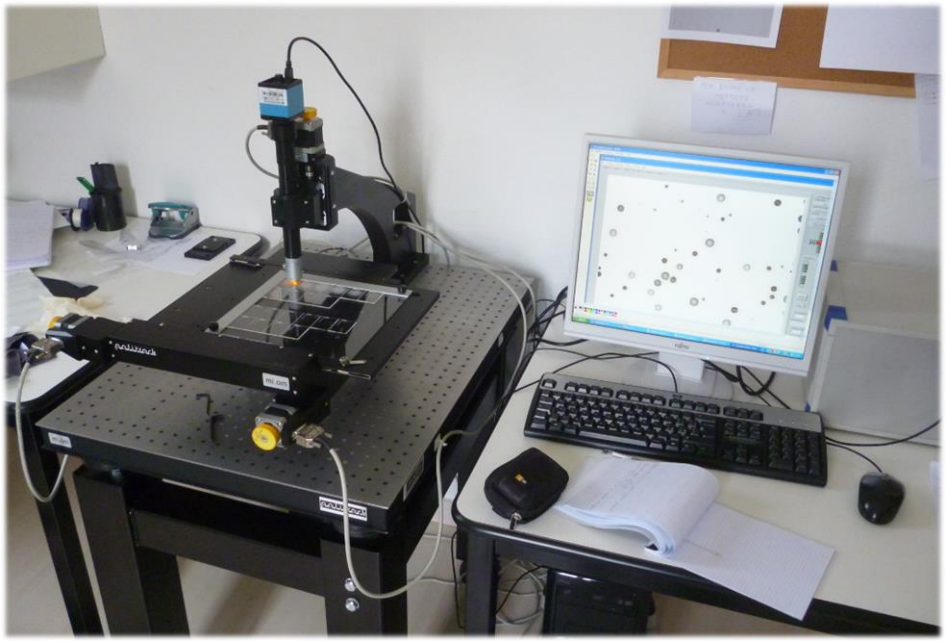
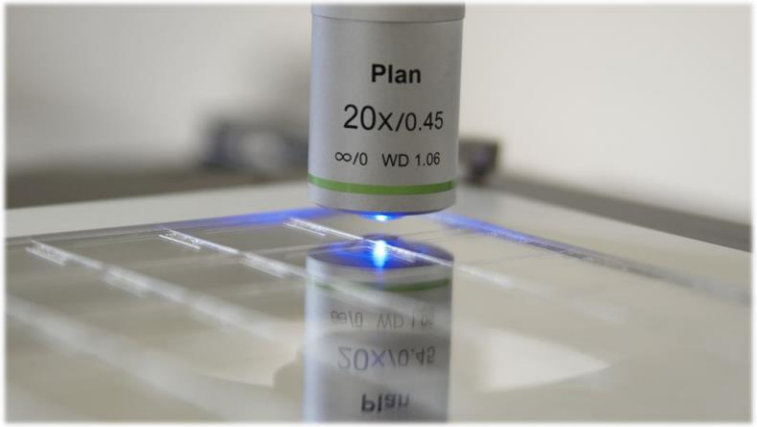


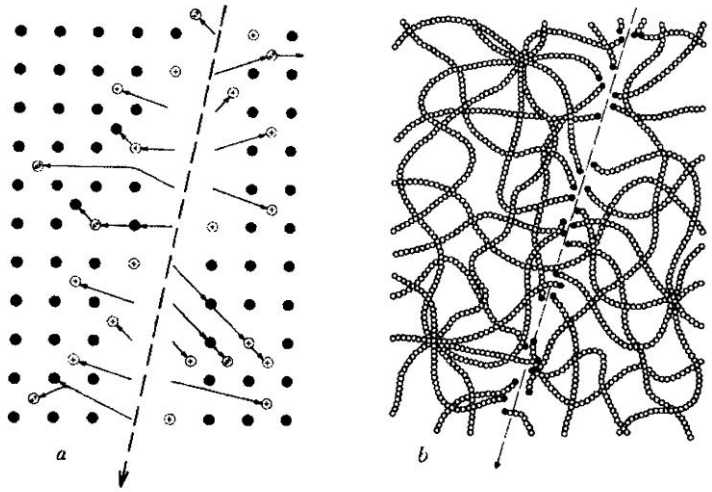
CR-39® detector from RTP

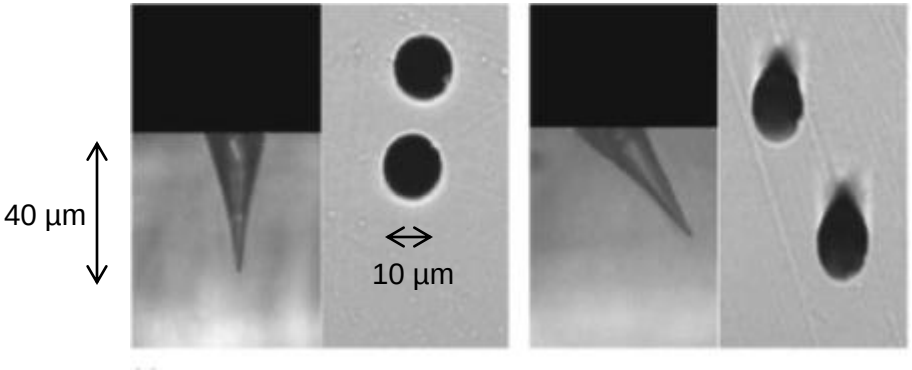


Politrack® instrument



Neutron dosimetry with CR-39 detectors





B. Dorschel et al. / Radiation Measurements 37 (2003) 563 – 571

Physics of track detectors

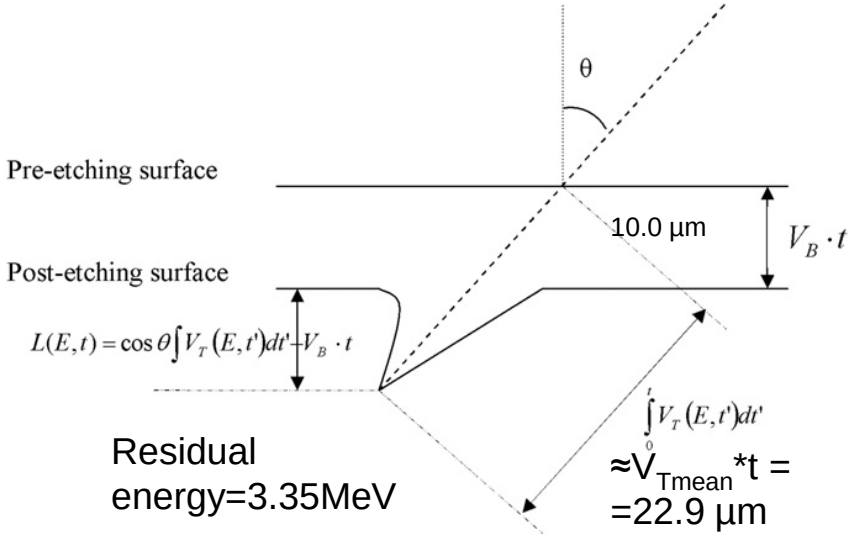
When an ionizing charged particle passes through a dielectric material the transfer of energy to electrons results in a trail of damaged molecules along the particle's track.

Radiation Detection and Measurements, G. Knoll

The tracks can be enlarged to be made visible, by etching in NaOH at 98°C for 90 minutes. The opening of the track is then of about 5-20 µm depending on the type and energy of the hadrons.

What is LET_{nc} measured in CR-39?

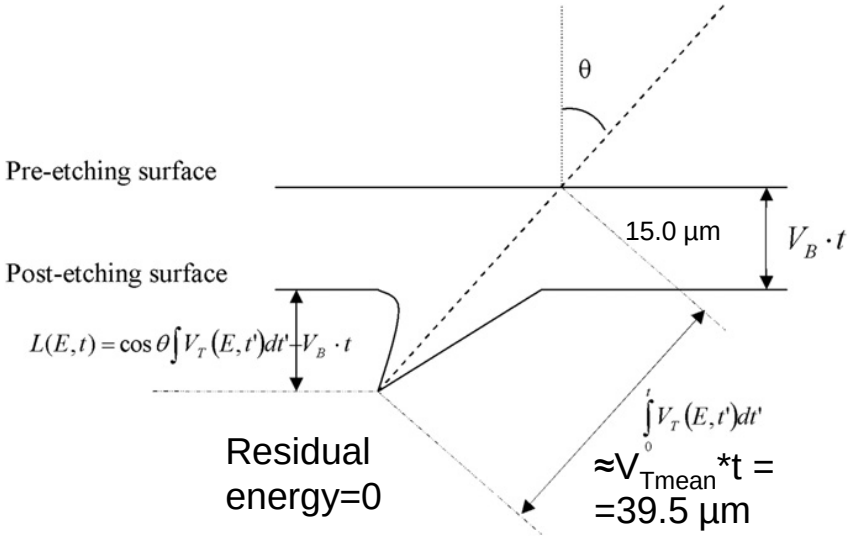
Etching time 60 min
Alpha energy 6.1 MeV (Cf-252)



Residual energy=3.35MeV

≈V_{Tmean}*t = =22.9 µm

Etching time 90 min
Alpha energy 6.1 MeV (Cf-252)



Residual energy=0

≈V_{Tmean}*t = =39.5 µm

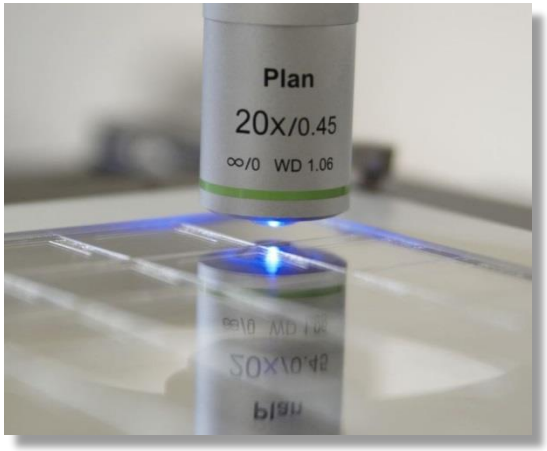
$$LET_{nc} = \frac{E_i - E_r}{x} = \frac{6100 - 3350}{22.9} = 120 \left[keV/\mu m \right]$$

$$LET_{nc} = \frac{E_i - E_r}{x} = \frac{6100 - 0}{39.5} = 154 \left[keV/\mu m \right]$$

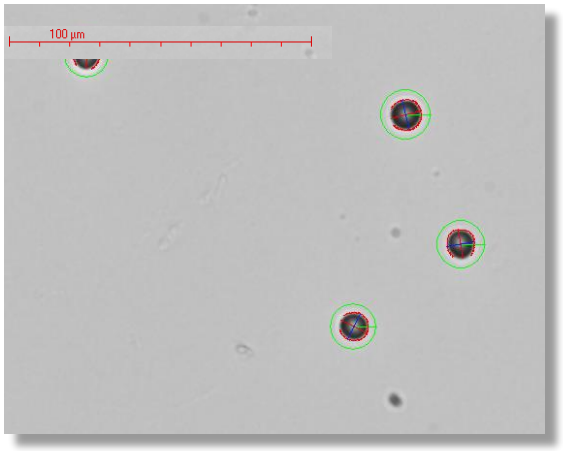
LET_{nc} is the calculated from the V ratio (V_t/Vb)

CR-39 detector analysis with POLITRACK™

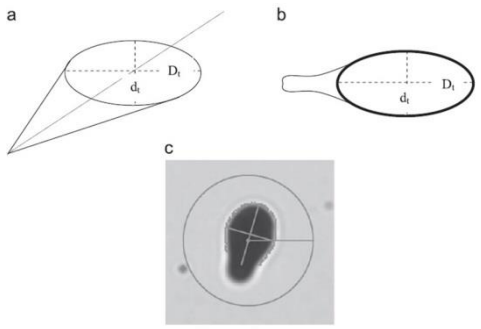
- Automatic counting and geometrical analysis of the tracks by POLITRACK (a)
- Track filtering (account for dust particles or surface defects) (b)
- V_t and LET_{nc} and impinging angle determination (c)
- LET_{nc} distribution (d)



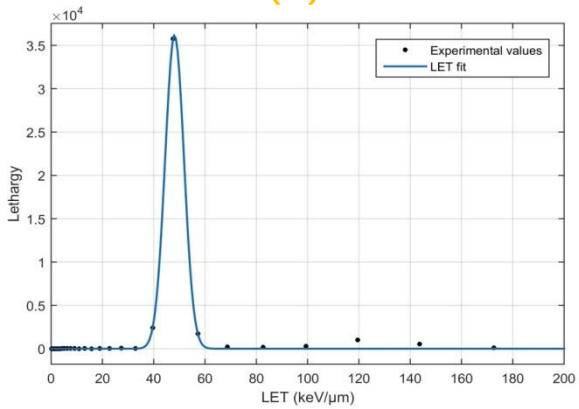
(a)



(b)



(c)

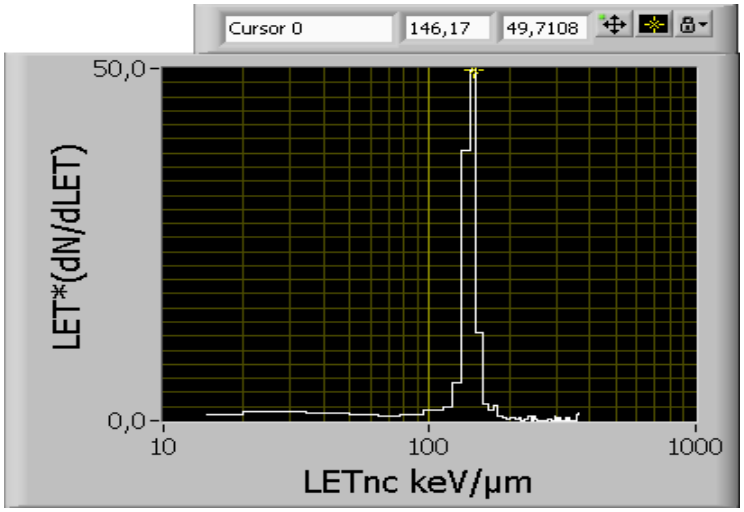


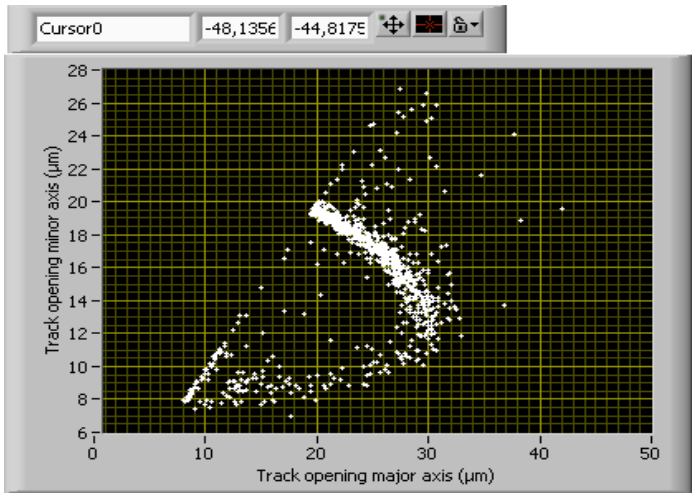
(d)

- <u>Dose Calculation</u> => $$H = \frac{1}{\rho . A} \cdot 1.602 \cdot 10^{-6} \cdot \sum_{i=1}^{n} \frac{\overline{LET}_i}{\cos \vartheta_i} \cdot Q\left(\overline{LET}_i\right)$$

Calibration of CR-39 dosimeters

Determination of V ratio through the fission fragment technique.

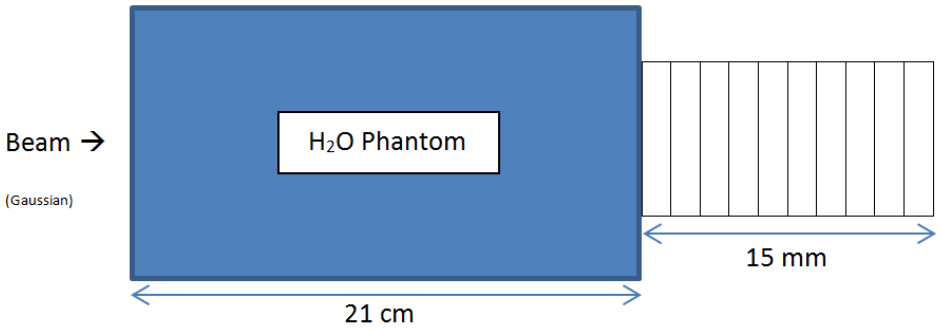


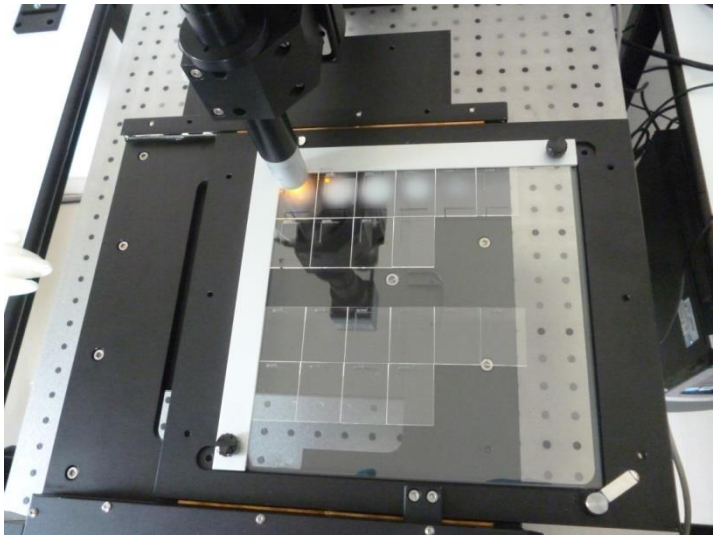


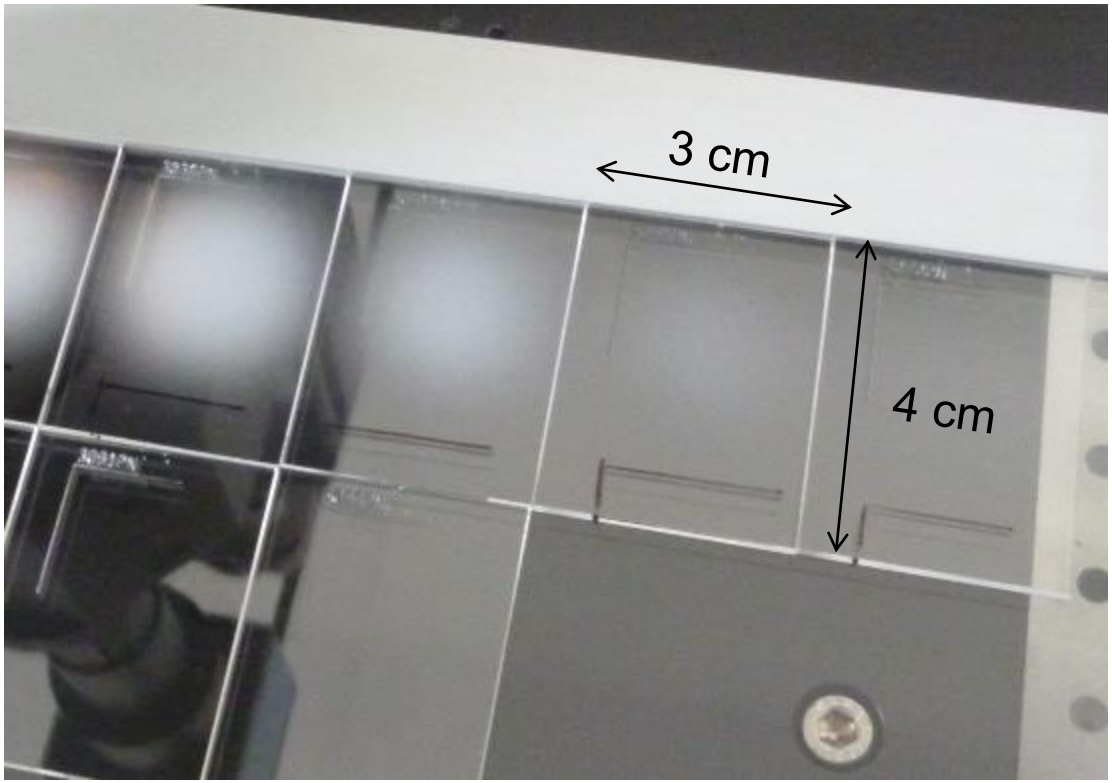
LET spectrum of alpha particles measured in the Detector 3060 irradiated with an electroplated Cf source. The LET peak for a V_b of 10 µm/h is at 146 keV/µm.

LET spectrometry and dosimetry for beam diagnostics

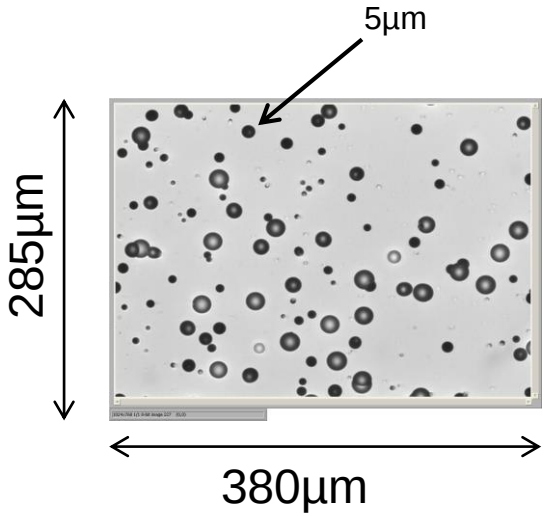
Proton beam
- Gaussian
- 10 mm FWHM
- E = 183.7 MeV

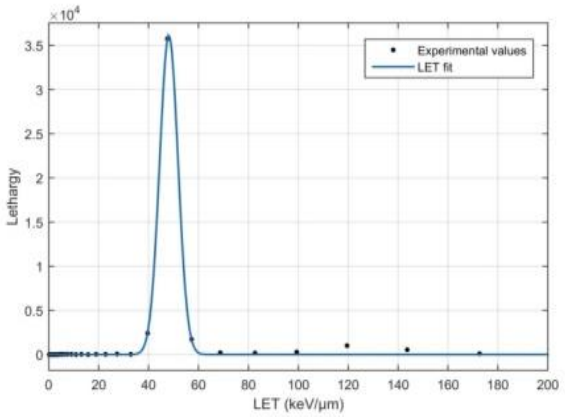




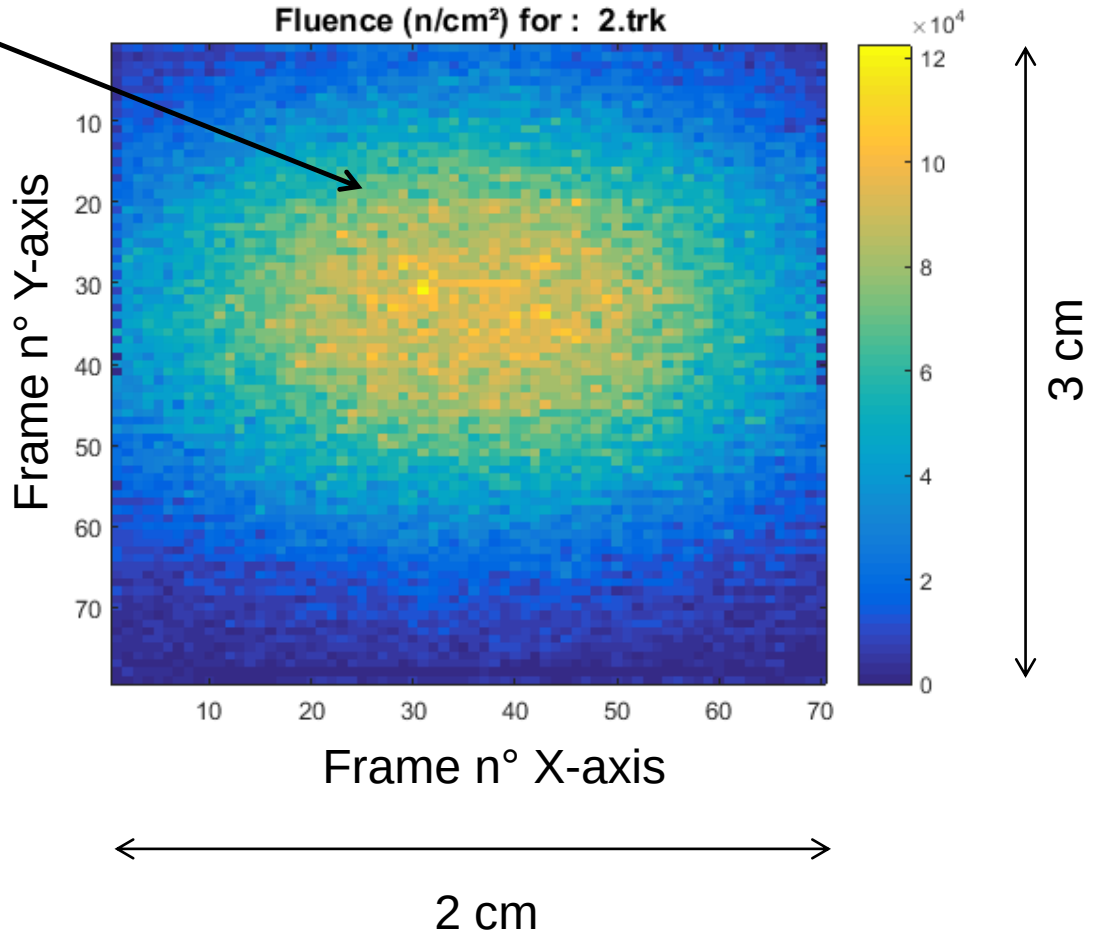


In-beam LET spectrometry and dosimetry in Proton beams



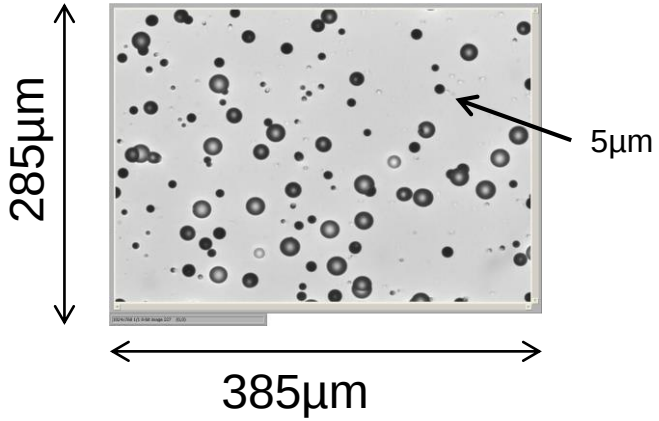


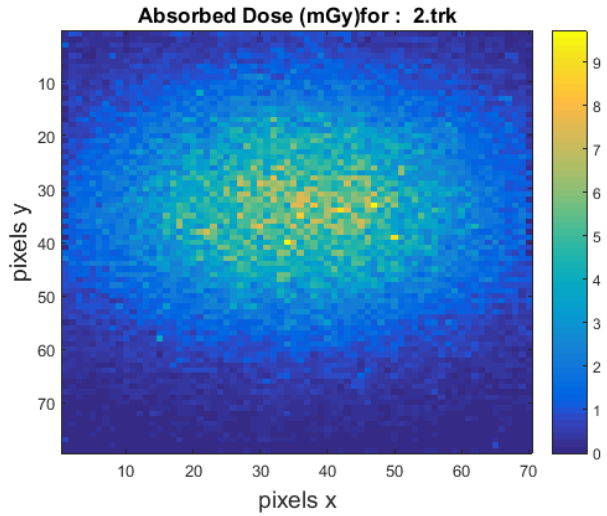
Exposed CR-39 surface reconstruction from captured frames



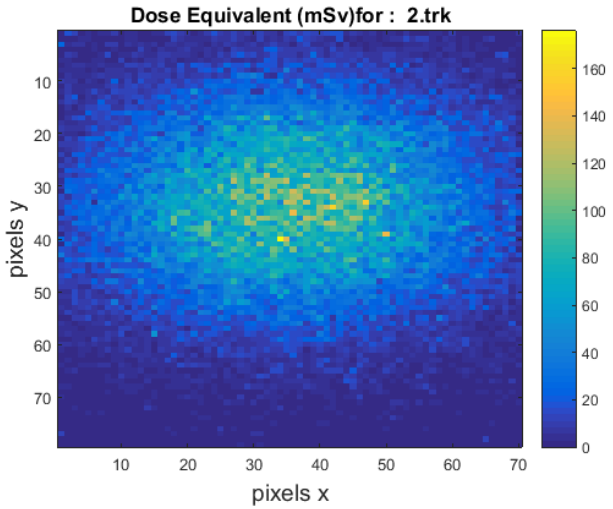
In-beam LET spectrometry and dosimetry in Proton beams

- Spatial resolution: 0.37 µm
- Pixel/Frame size : 285 µm * 385 µm
- Sensitive area : 70 * 79 pixels/frames (2 * 3 cm)





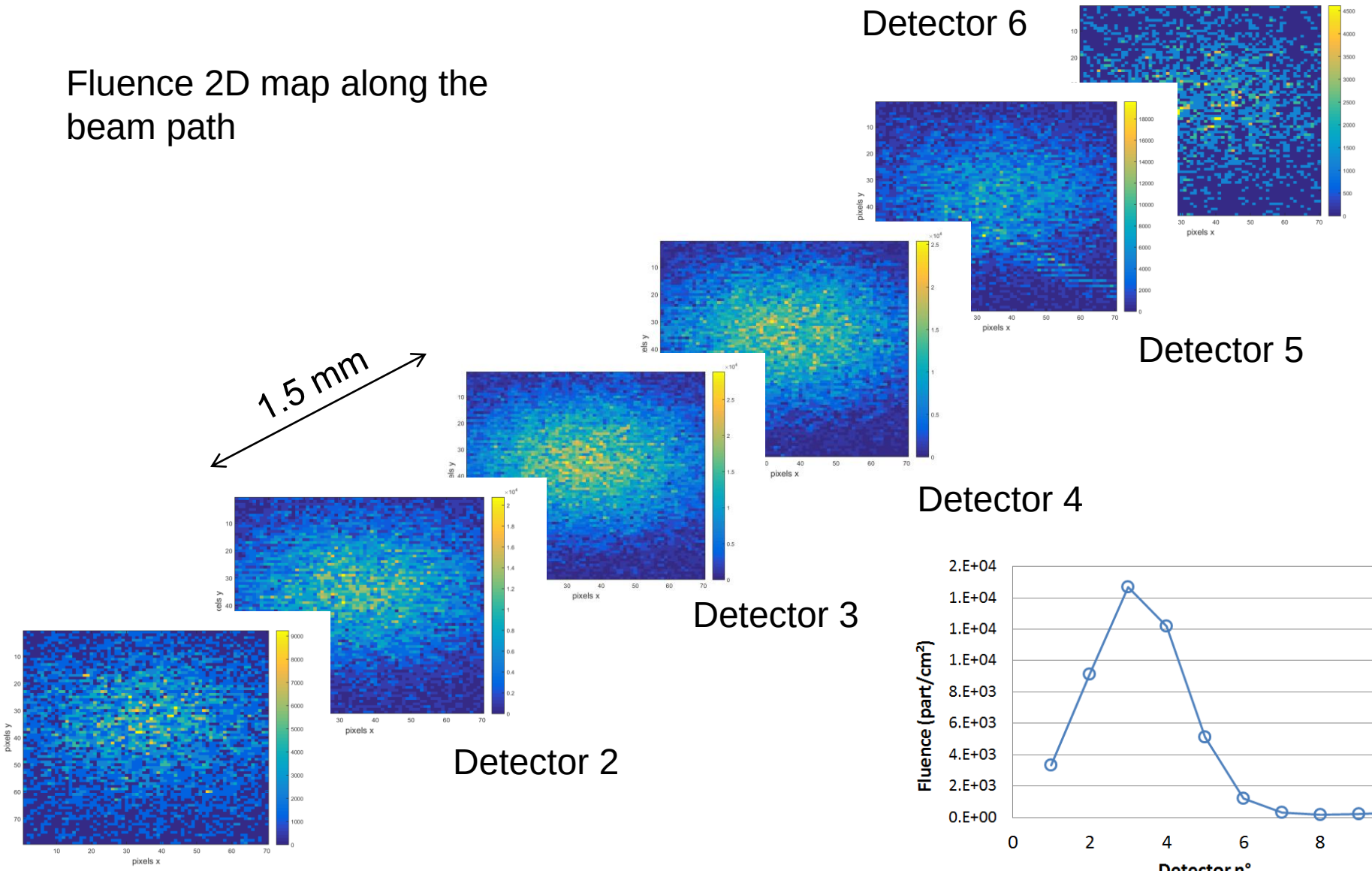
2D distribution of the Absorbed dose (mGy)



2D distribution of the Dose Equivalent (mSv)

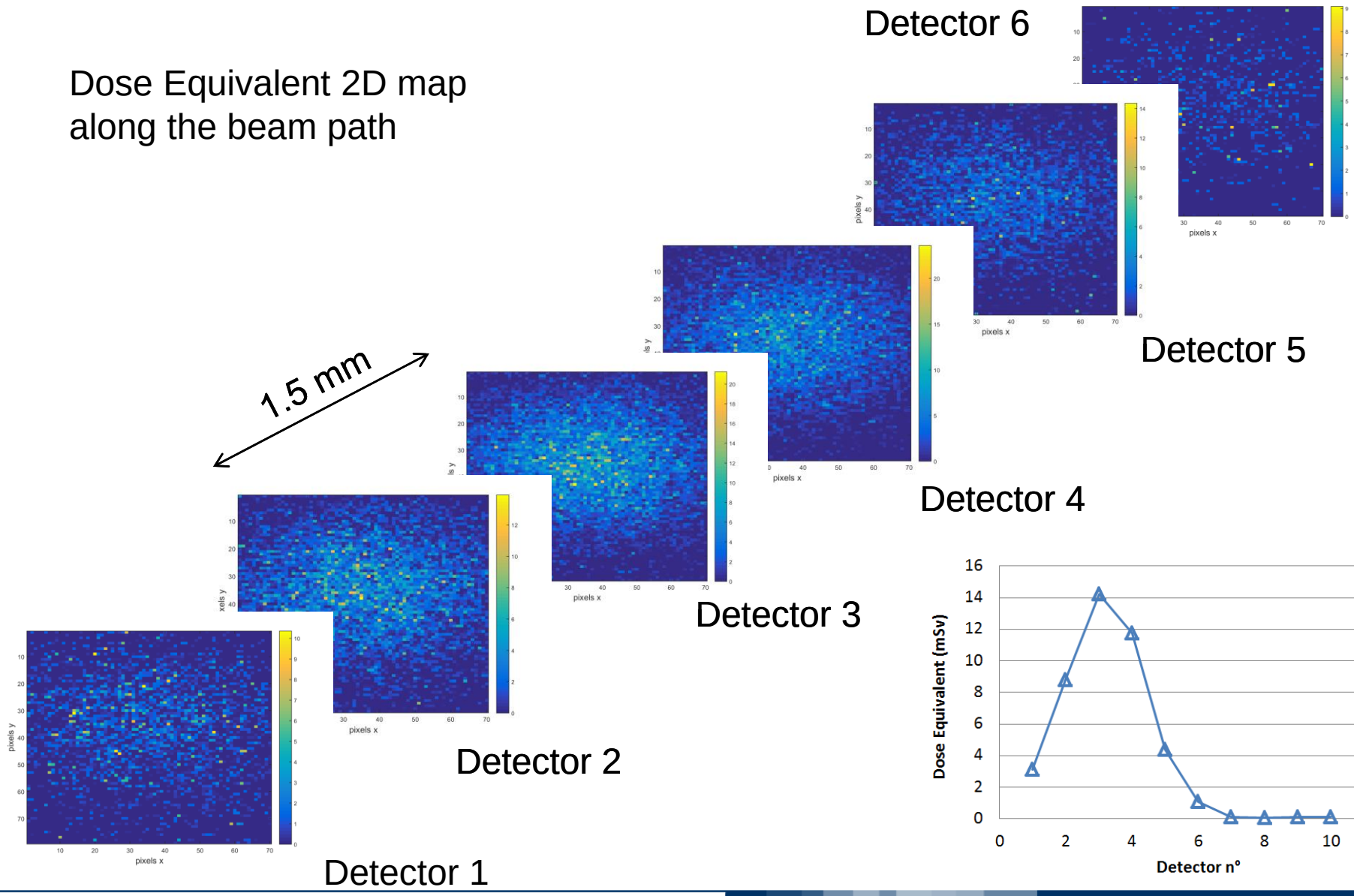
In-beam LET spectrometry and dosimetry in Proton beam

Fluence 2D map along the beam path

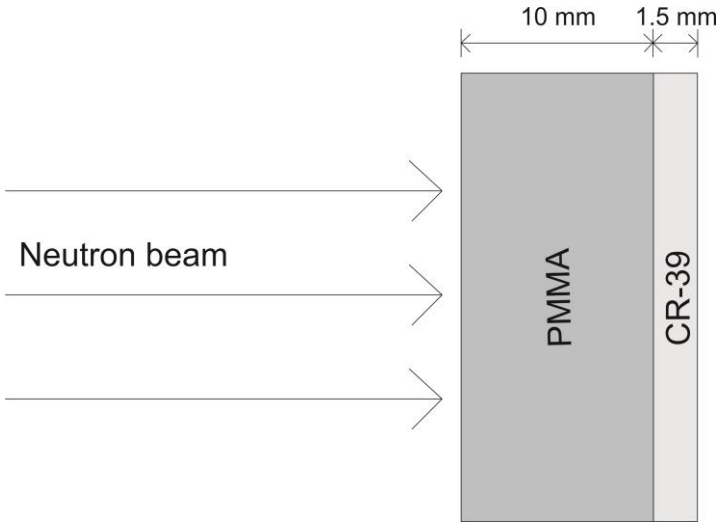


In-beam LET spectrometry and dosimetry in Proton beam

Dose Equivalent 2D map
along the beam path



Neutron dosimetry with CR-39 detectors



In the PMMA radiator, the type of secondary particles produced is strongly dependent on the neutron beam energy (E_n):

E_n < 10 MeV : (n,p) reactions

E_n > 10 MeV : (n,p) reactions
+ (n,α) reactions
+ (n,d) reactions
+ (n,t) reactions

http://www.oecd-nea.org/janis/

Fragmentation of O and C atoms occur due to inelastic scattering and spallation reactions when E_n > 10 MeV

Neutron dosimetry with CR-39 detectors

Neutron Cross section on C and H

Chemical composition:

PMMA: $(C_5O_2H_8)_n$

CR-39: $(C_6O_8H)_n$

C compensates for reduction in neutron cross section on H at $E_n > 10MeV$

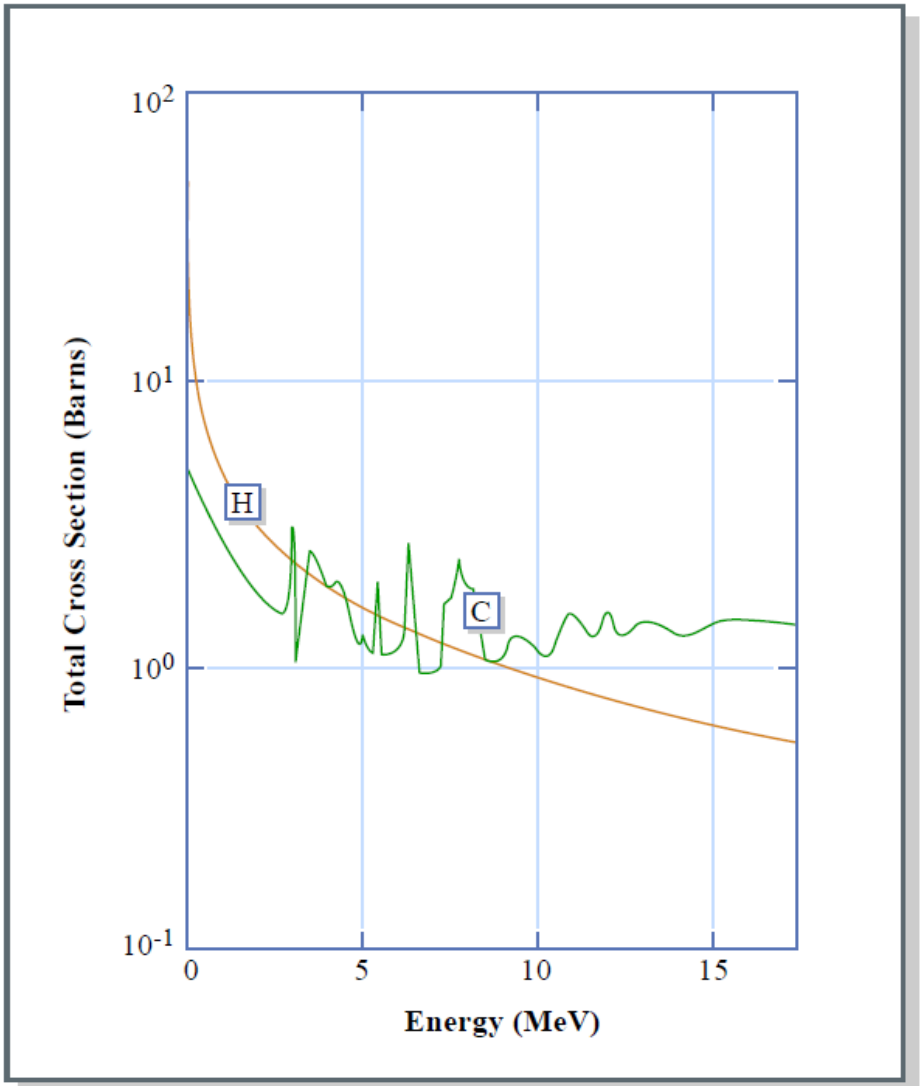
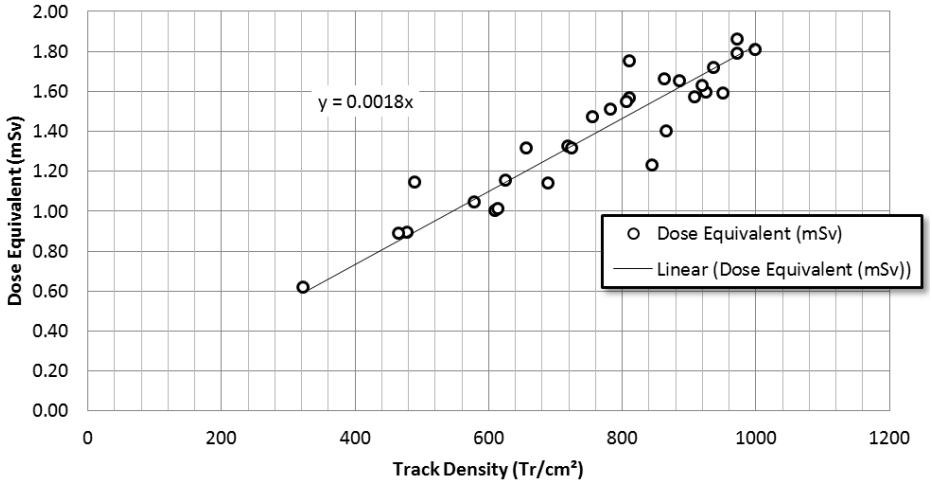


Figure by MIT OCW.

Neutron Dosimetry in High Energy Neutron beams



Ring cyclotron facility at the Research Center for Nuclear Physics (RNCP), Osaka University

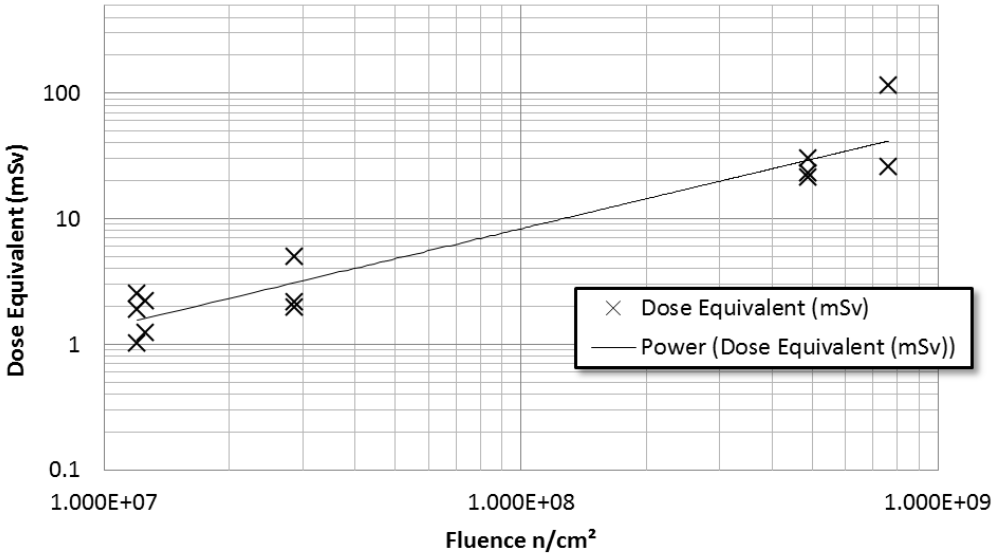
100 MeV and 300 MeV neutron beams produced from $^{7}Li(p,n)^{7}Be$ reactions on 10 mm Lithium target

Thanks to Chris Cassel

Los Alamos Neutron Science Centre (LANSCE) facility, in New Mexico, USA

Large spectrum from fast to relativistic neutron (30 keV up to 750 MeV)

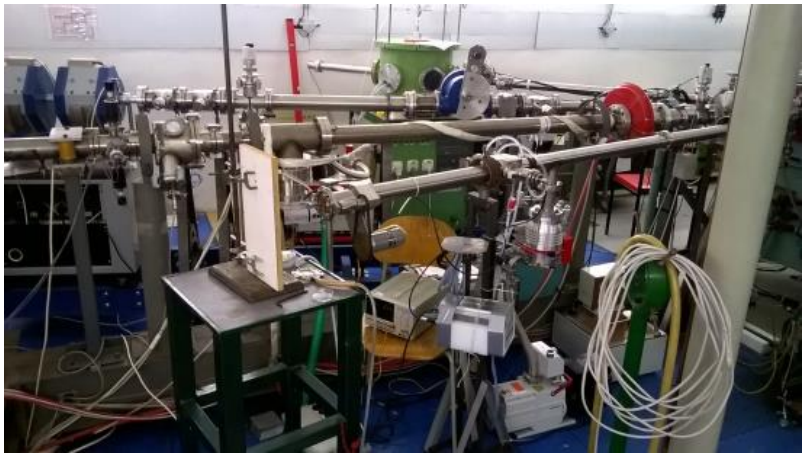
Thanks to Ben. Bergmann



Neutron Dosimetry

Mono-energetic Neutron beams @ VdG, CTU, Prague:

- $T(p,n)^3He$ -> 0.7 MeV
- $D(d,n)^3He$ -> 4.1, 4.7 MeV
- $T(d,n)^4He$ -> 15.0, 15.8, 16.7 MeV,
- AmBe neutron source – spectrum < 11 MeV
- Ambient dosimeters exposed next to liquid scintillators



Résumé: ARDENT 2013-2015

Table 1. Evolution of tasks scheduled for the PhD research work in the frame of the ARDENT WP3.

Month n° →	4	8	12	16	20	24	28	32	36
Tasks	**1st trim. 2013**	**2nd trim. 2013**	**3rd trim. 2013**	**1st trim. 2014**	**2nd trim. 2014**	**3rd trim. 2014**	**1st trim. 2015**	**2nd trim. 2015**	**3rd trim. 2015**
Training activities	X	X	X	X	X	X	X	X	
Dose measurement		X	X	X	X			X	
LET spectrometry			X	X	X	X		X	
Monte Carlo simulations			X	X	X	X	X	X	
Intercomparison					X	X	X	X	
Convertor Optimistion					X	X	X		
Final Prototypes							X	X	X
Business plan							X	X	X
Thesis writing							X	X	X

List of publications

1. Caresana, M., et al., 2013. Personal and Environmental Dosimetry with a Dosimeter Based on CR-39 SSNTD in Quasi-monoenergetic Neutron Field http://dx.doi.org/10.1093/rpd/nct320. Published online December 8, 2013.

2. Trompier, F., et al., 2013. Comparison of the response of padc neutron dosimeters in high energy neutron fields. Radiat. Prot. Dosim. First published online: December, 1 2013

3. Caresana, M., et al, 2014. Dose measurements with CR-39 detectors at the CERF reference facility at CERN, Radiation Measurements, ISSN 1350-4487, http://dx.doi.org/10.1016/j.radmeas.2014.04.010.

4. Caresana, M., Ferrarini, M., Parravicini, A., Sashala Naik, A., "Calibration of a passive rem counter with monoenergetic neutrons", Radiation Measurements(2014), doi: 10.1016/j.radmeas.2014.07.019.

List of conferences & Training (2015)

Done:

- MMND Conference – Oct 2014, Port Douglas, Australia
- B&A secondment in the CERN's KT group with Dr. Zoe Lawson, Jan-Feb 2015
- Experimental activities at INFN Catania & CTU Prague, Feb-April 2015

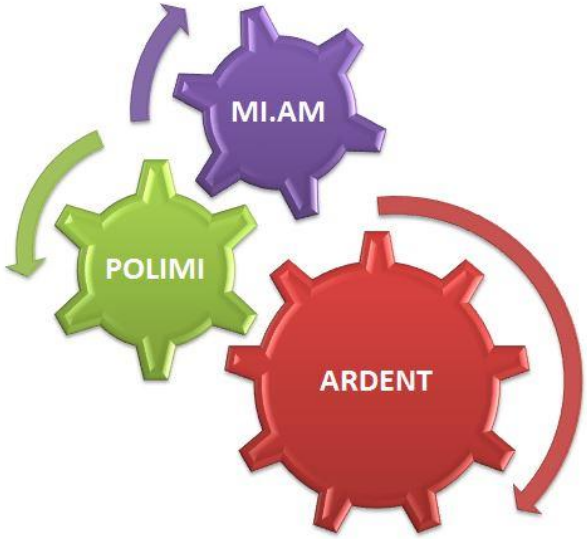
Upcoming:

- UC Berkeley & Lawrence Berkeley National Lab, June 2015
- IEEE San Diego, October 2015
  - Abstract submitted on LET spectrometry applications

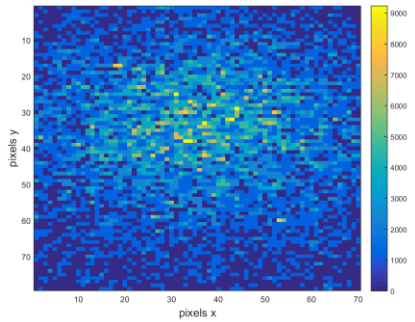
Collaborations during ARDENT

- Collaborations within ARDENT
  - Politecnico di Milano – Politrack® development
  - CERN - Medipix comparison + B&A training
  - Austrian Institute of Technology (AIT) - Monte Carlo
  - Czech Technical University (CTU) – Timepix comparison

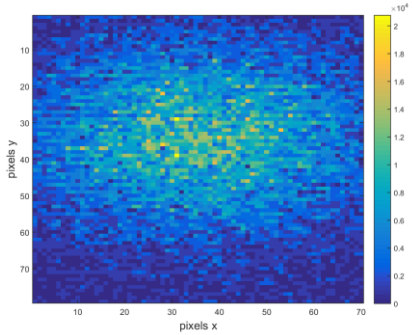
- Collaborations outside ARDENT
  - IRSN France
  - CAM3D Srl
  - UC Berkeley
  - Lawrence Berkeley National Laboratory



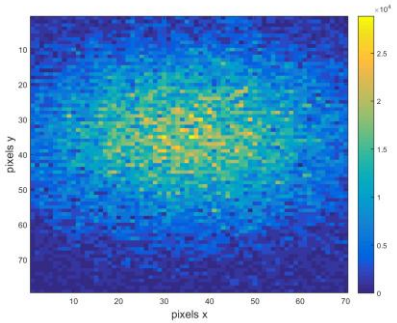
In-beam LET spectrometry and dosimetry @ CNAO - Protons



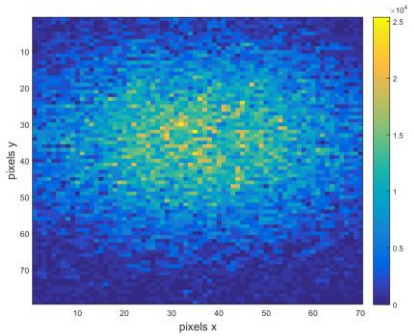
Det 1



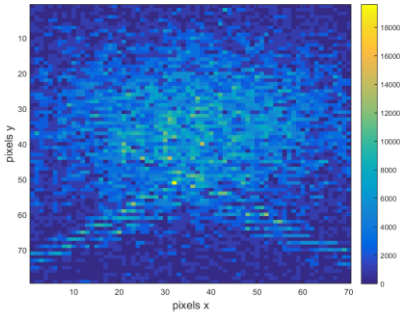
Det 2



Det 3



Det 4



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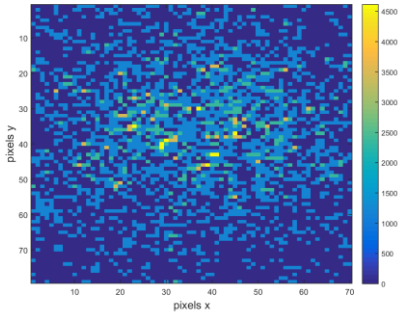
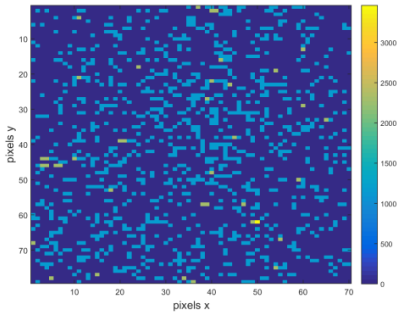
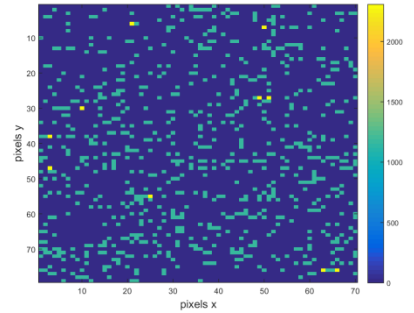


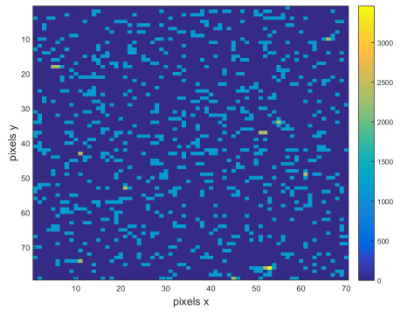
Det 6



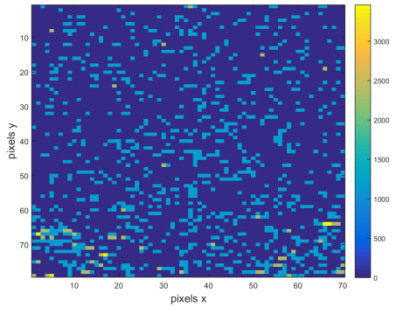
Det 7



Det 8



Det 9



Det 10