µ-Loss for LIPAc

LIPAc: Linear IFMIF Prototype Accelerator

Cryogenic Beam Loss Monitors Workshop

CERN - 18th October 2011

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Overview

IFMIF, LIPAc: a brief introduction

µ-Loss: why, where, how…

Tests:

- Cryogenic
- Neutron beams at room temperature

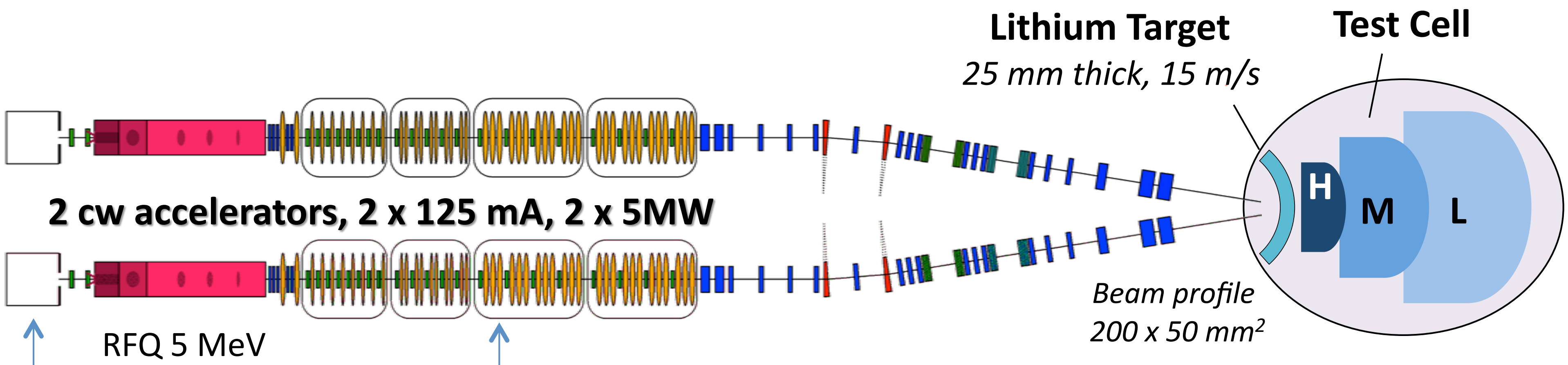
IFMIF

IFMIF* : to test materials submitted to very high neutron fluxes for future Fusion Reactors.

*International Fusion Materials Irradiation Facility

international agreement of the **BA** (JAEA+F4E) = **IFMIF** + IFERC + JT60-SA

High	> 20 dpa/y	0.5 l
Medium	> 1 dpa/y	6 l
Low	1 dpa/y	> 8 l



deuteron source
140 mA, 100 keV

Superconductive Linac 40 MeV
(Half Wave Resonators)

Flux ~ 10^{17} neutrons/s

Typical reactions

$^7Li(d,2n)^7Be$

$^6Li(d,n)^7Be$

$^6Li(n,T)^4He$

Challenging linear accelerator

World records:

- highest power
- highest intensity
- highest space charge
- longest RFQ

⇒ Validation or prototyping phase

LIPAc

1.125 MW ≡ ability for the Beam Dump to evacuate the whole energy of the LHC beams every 11 minutes!

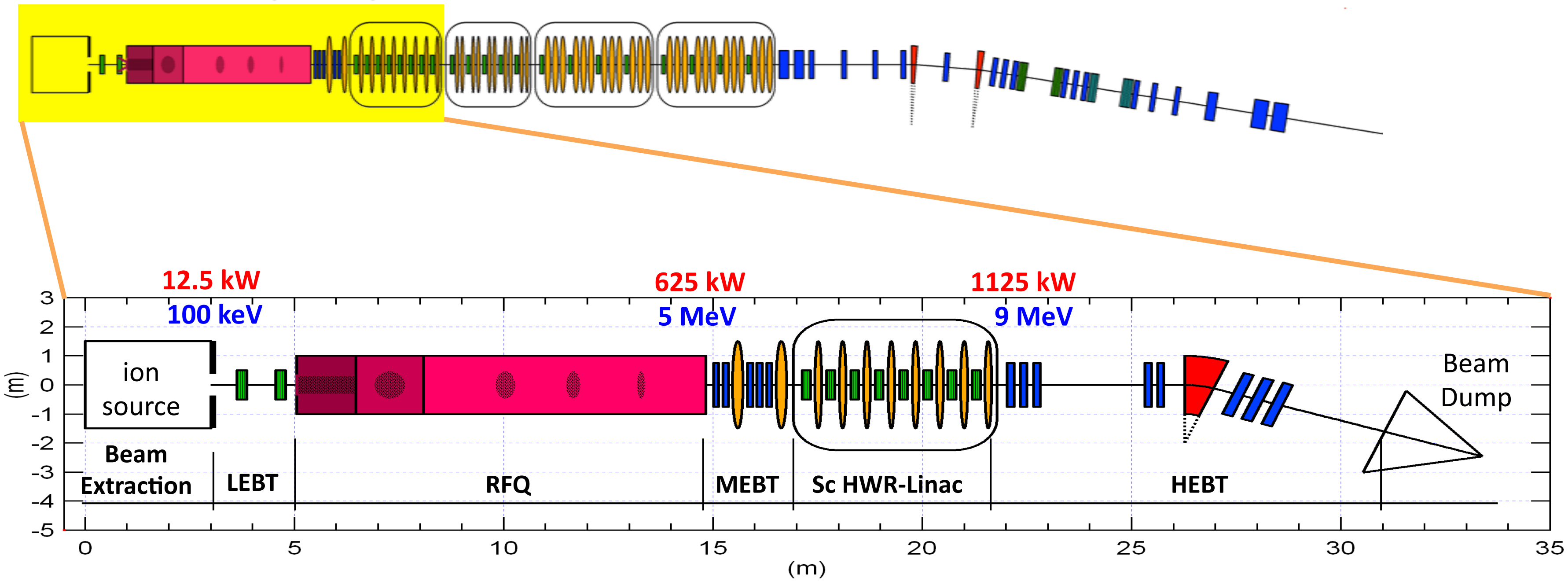
Validation phase: prototype accelerator → LIPAc*

*Linear IFMIF Prototype Accelerator

Commissioning at Rokkasho (Japan) beginning:

Injector: March 2013
RFQ: July 2014
scLinac: May 2015

LIPAc = 125 mA cw, 9 MeV, 1.125 MW



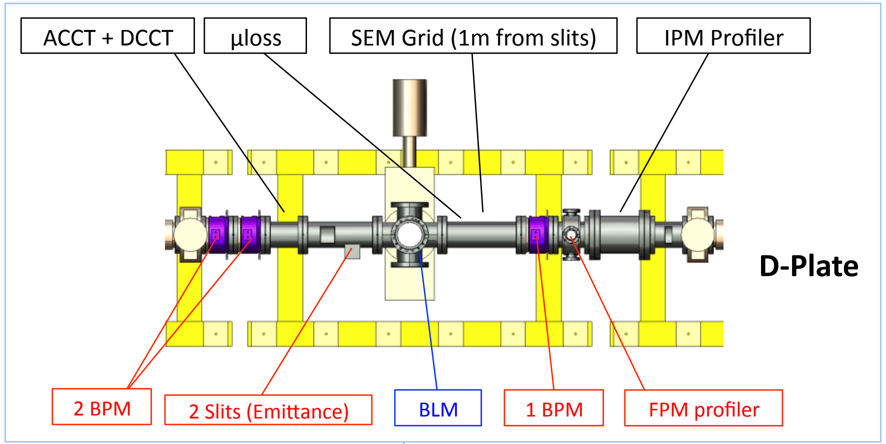
Beam Instrumentation Layout

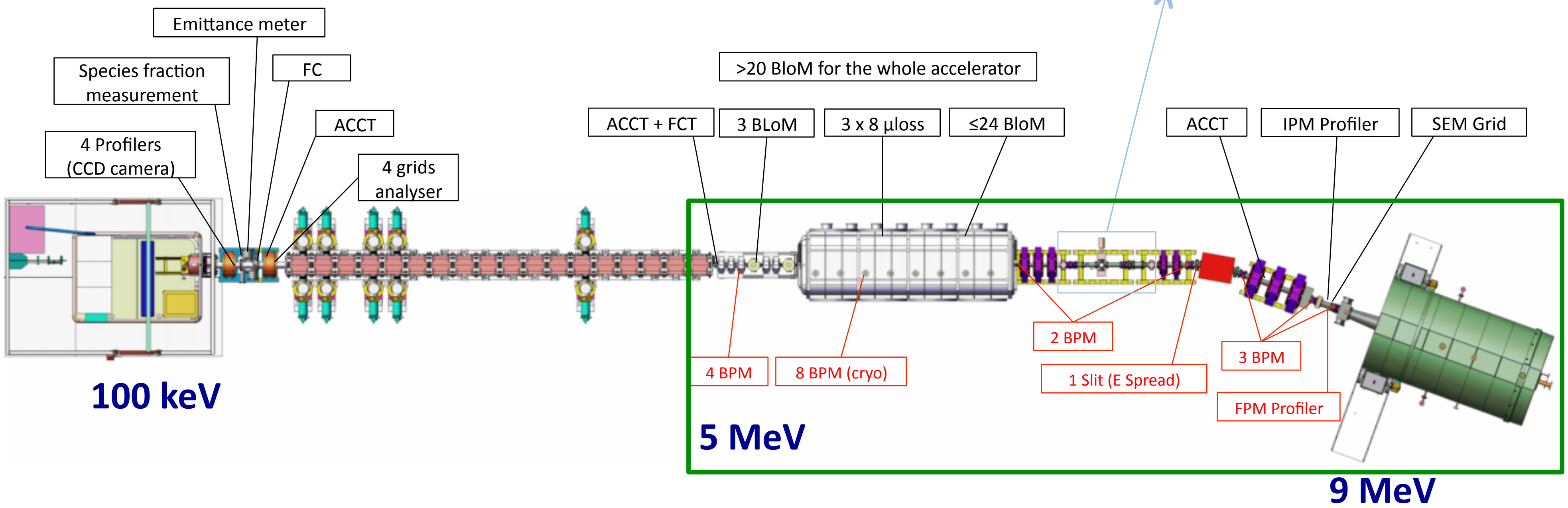
deuteron beam:

E_{max} = 9 MeV
I = 125 mA
P_{max} = 1.125 MW
Duty Cycle: <10^{-4} to cw
RF: 175 MHz (5.7 ns)

Glossary:

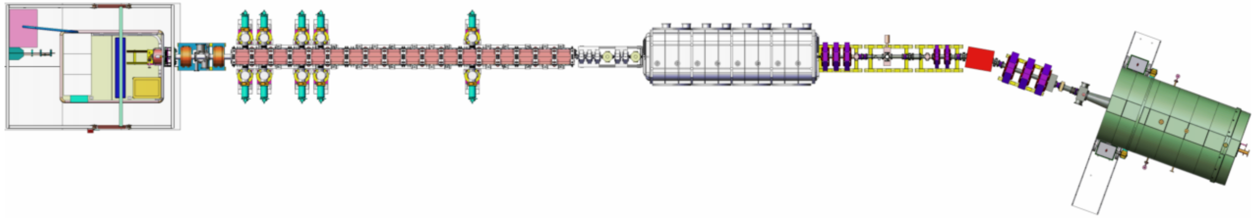
ACCT: AC Current Transformer
BLoM: Beam Loss Monitor
BLM: Bunch Length Monitor
BPM: Beam Position Monitor
DCCT: DC Current Transformer
FC: Faraday Cup
FCT: Fast Current Transformer
IPM: Ionization Profile Monitor
FPM: Fluorescence Profile Monitor





μ-Loss

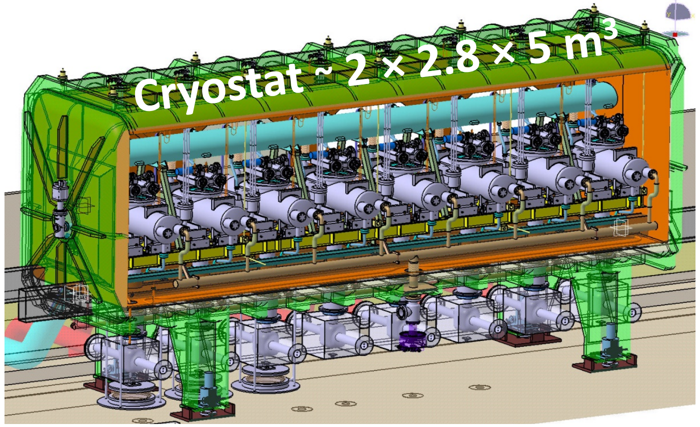
Superconductive Linac (scLinac)



scLinac:

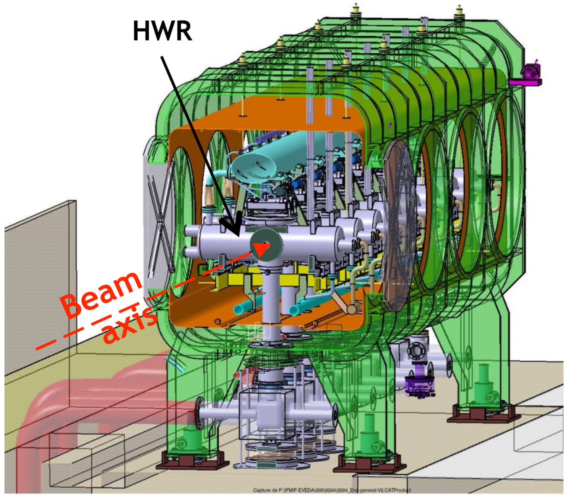
T = 4K
deuteron: 5 to 9 MeV (125 mA)
8 ensembles:
- 1 Half Wave Resonator (HWR)
- 1 solenoid
- 1 BPM

no more diagnostics
⇒ sensitive detectors to tune the beam ($<10^{-6}$ beam)
Note: HWR emits X-rays up to γ



Ideal μ-Loss:

sensitive only to neutrons → to avoid fake signals
expected time response ~ second (for good tuning sensitivity)
rough space resolution
radiation hard
ability to work at cryogenic temperature
Very good reliability (once closed, cryostat will not be re-open)



Compromise: diamond

"μ-Loss Detector for IFIMIF-EVEDA", J. Marroncle et al, DIPAC 2011

Diamond: counting rates

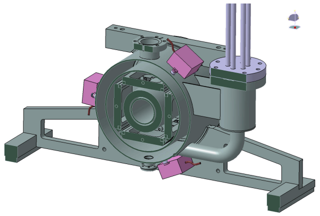
Feasibility study: Simulation *(A. Marchix, Saclay, Sept. 2010)*:

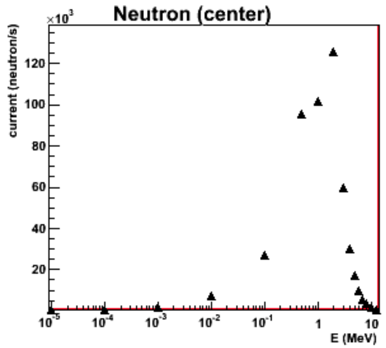
Loss: **1 W/m** with Thalis + neutron transports

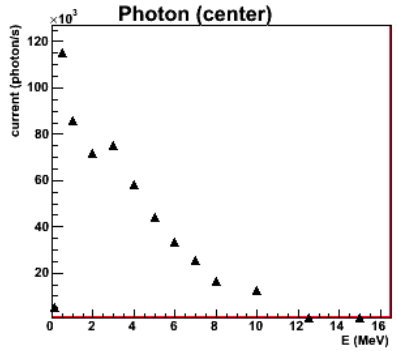
D^+ + Fe ➝ neutron (or γ) + X

3 diamonds per Solenoid

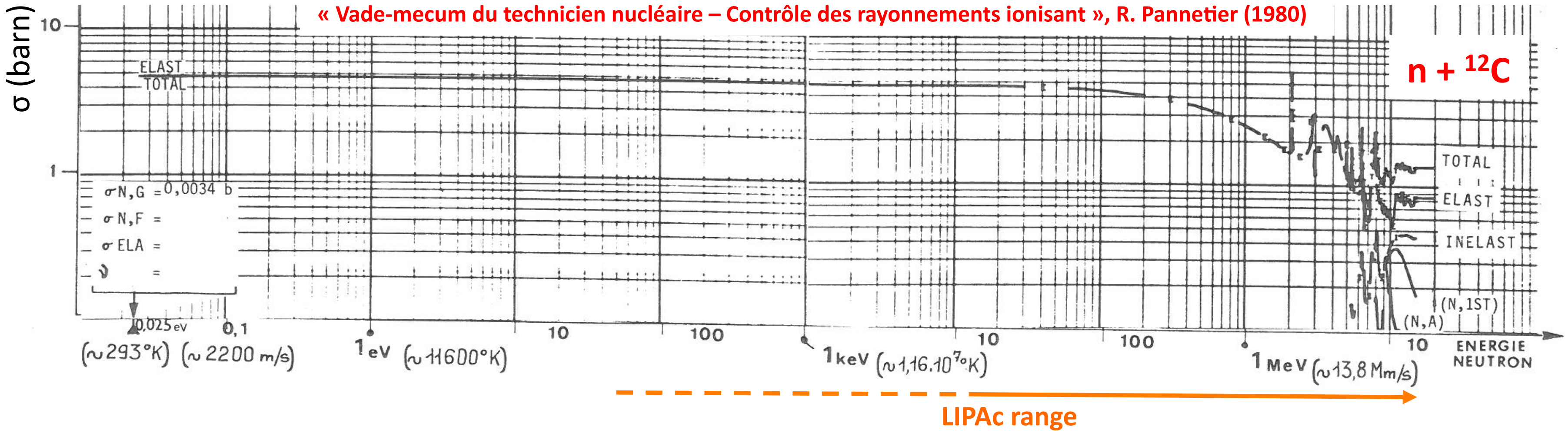
- ➝ transverse localization + reliability
- ➝ X-ray shielding
- ➝ convertor foil to improve neutron sensitivity?







« Vade-mecum du technicien nucléaire – Contrôle des rayonnements ionisant », R. Pannetier (1980)



Counting rate estimation for 1 W/m beam losses:

Neutron (only elastic process)	***γ (all processes)***
all neutron spectrum ➝ ~ 1200 Hz	all γ spectrum ➝ ~ 810 Hz
E_{neut} > 1.5 MeV ➝ ~ 400Hz	E_{γ} > 1.5 MeV ➝ ~ 250Hz
E_{neut} > 2.5 MeV ➝ ~ 190 Hz	E_{γ} > 2.5 MeV ➝ ~ 180 Hz

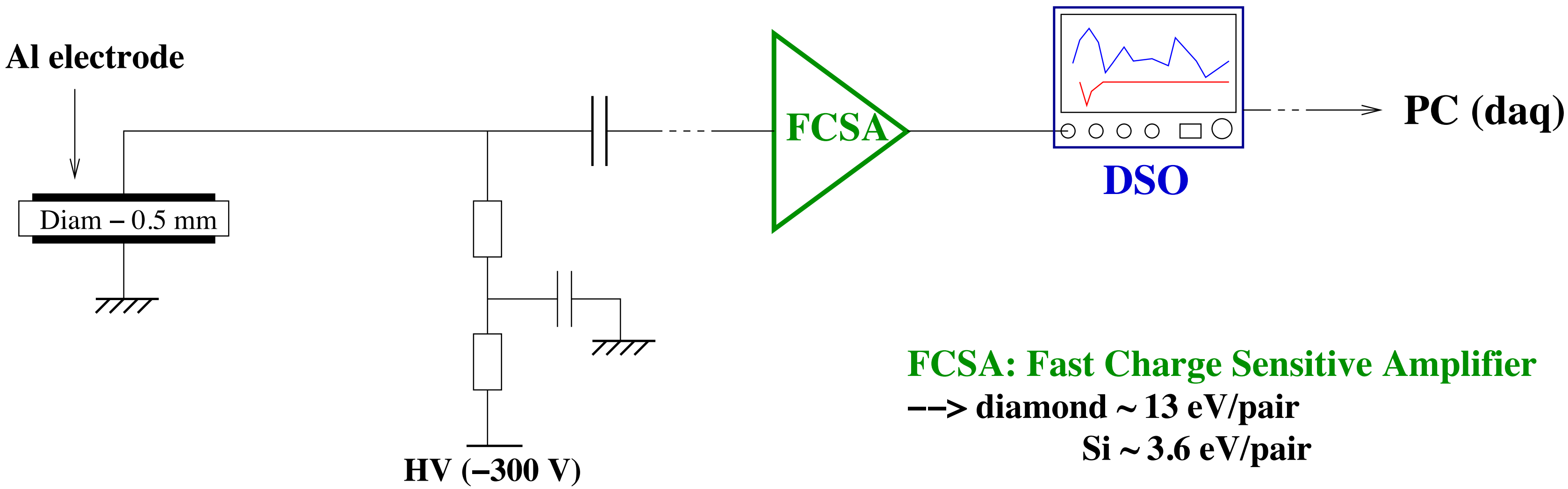
Electronics for diamond tests

μ-Loss measurement:

couting rates
energy spectra

mono cristalline CVD: 4 × 4 × 0.5 mm³

FCSA: designed by **Mircea Ciobanu** (GSI)



FCSA: Fast Charge Sensitive Amplifier
--> diamond ~ 13 eV/pair
Si ~ 3.6 eV/pair

Cryogenic test: LN_2

December 2010:

^{252}Cf: "neutrons" and γ

LN_2 → 77 K

mono CVD: 4×4×0.5 mm³

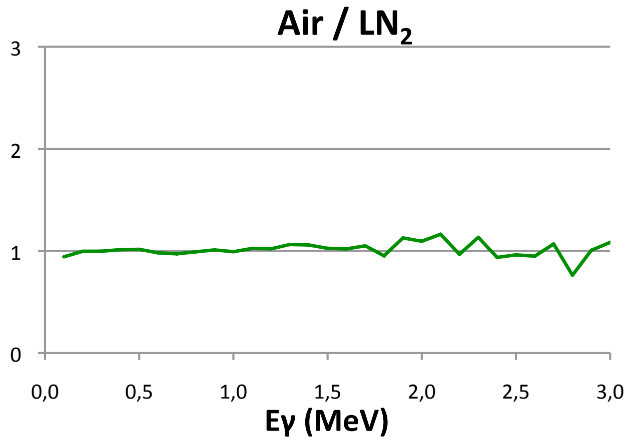
Simulation

A. Marchix, Irfu, Oct 2011

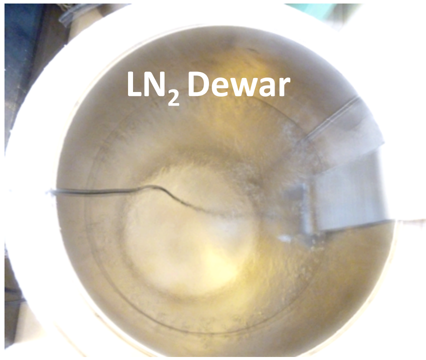
Only γ (^{252}Cf)

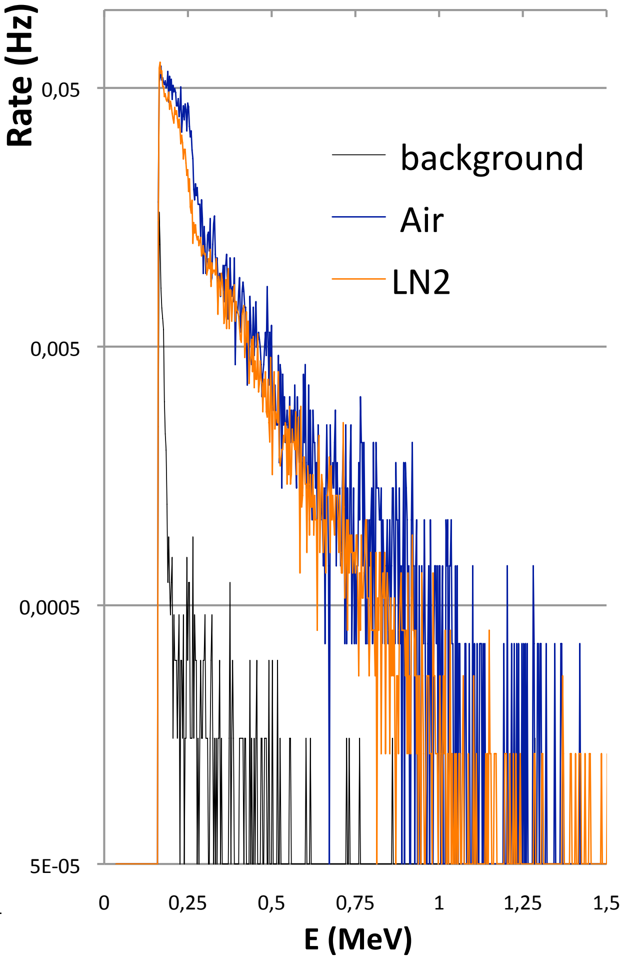
3 mm stainless steel (Dewar)

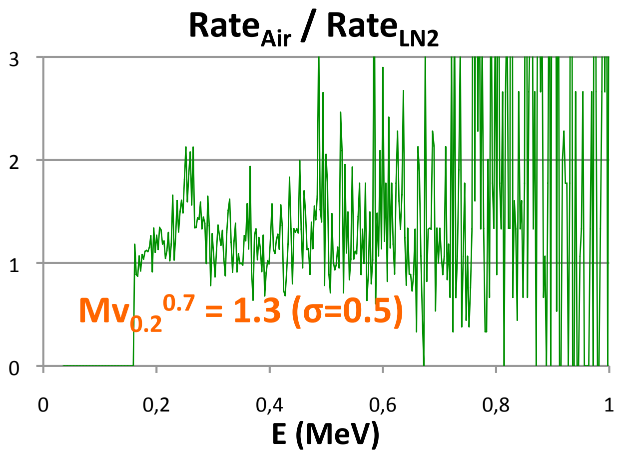
⇒ a bit more cryogenic events than expected (simulation): ok



Experimental result







Cryogenic test: LHe – 4.5 K

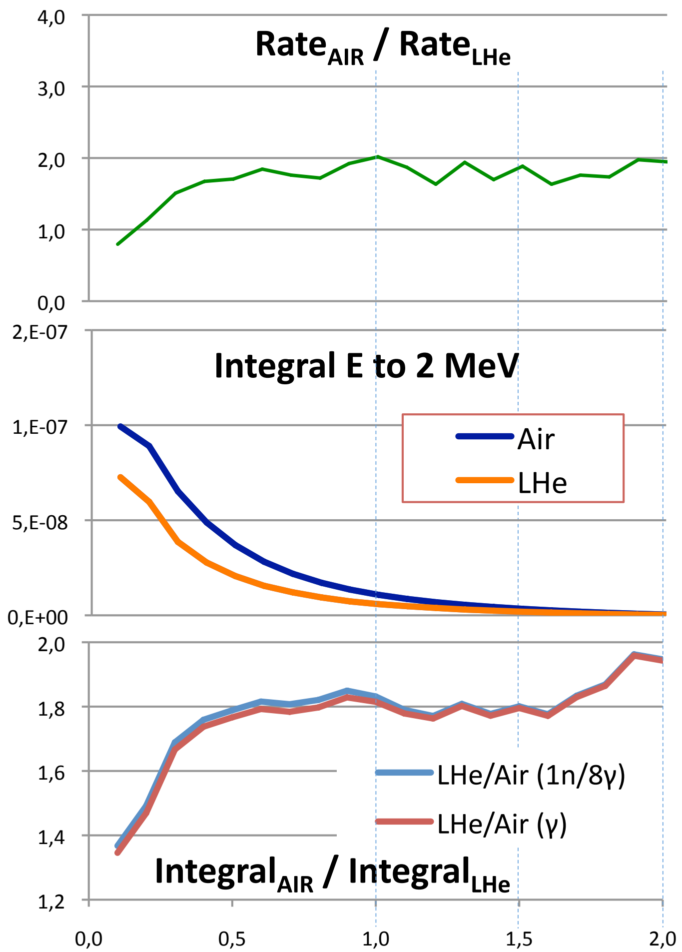
(May 2011)

Simulation

A. Marchix, Irfu, Oct 2011

Only γ (^{252}Cf)

Dewar thickness taken into account



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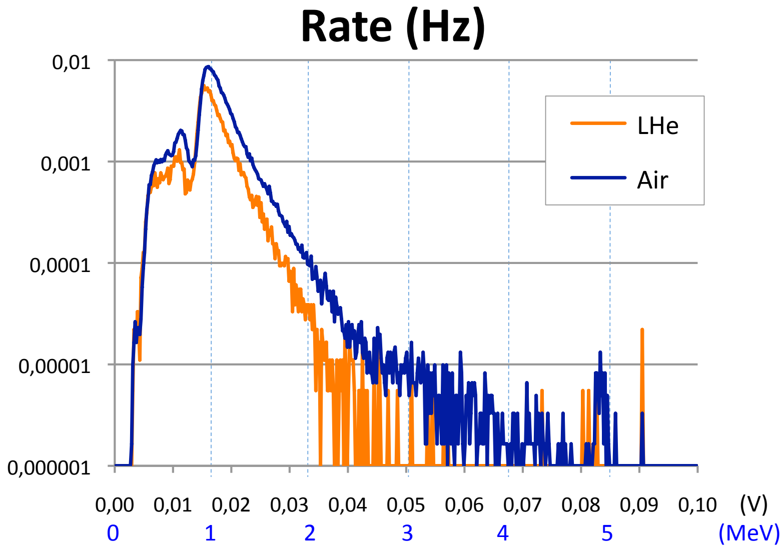
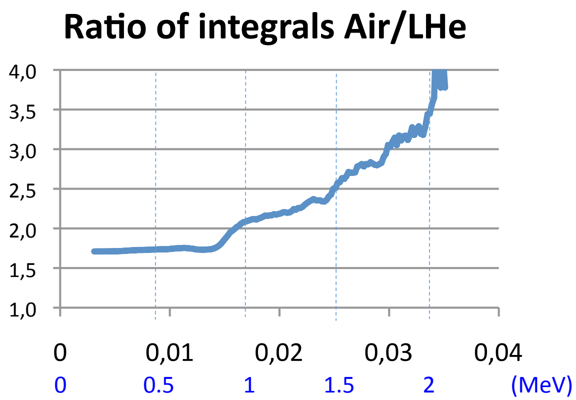
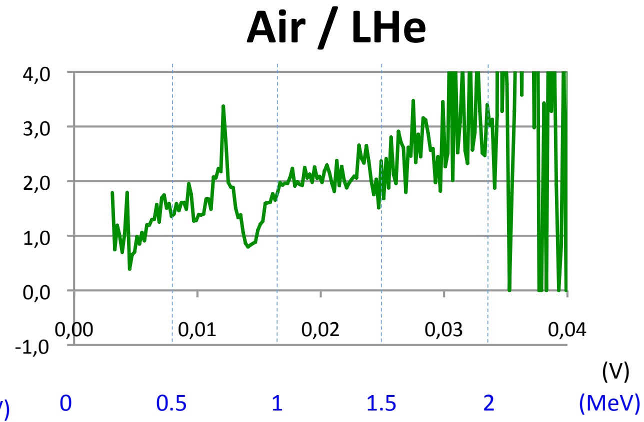






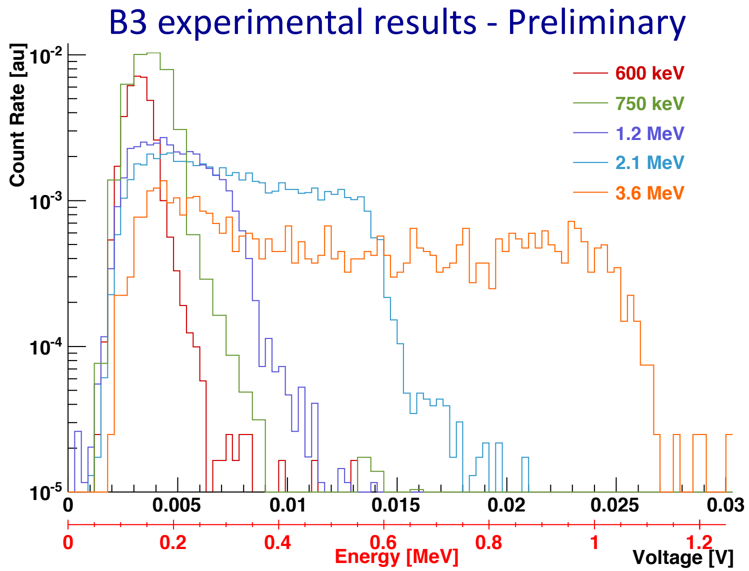
Neutron test at room temperature

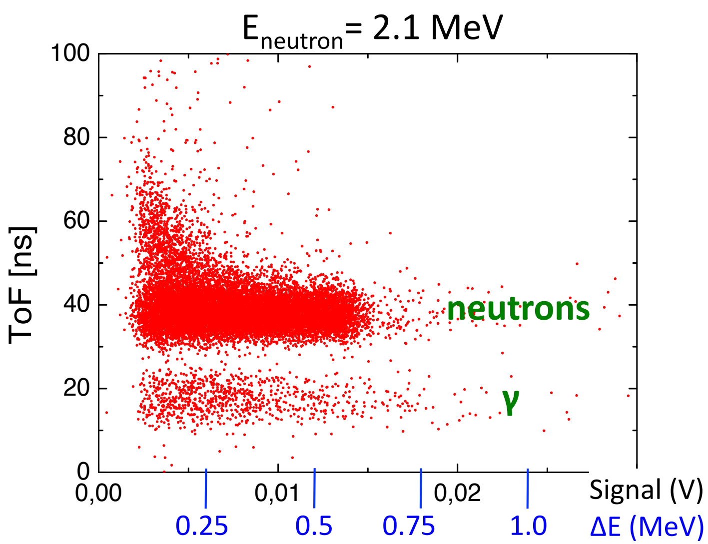
Van de Graaff (CEA Bruyères-le-Châtel):

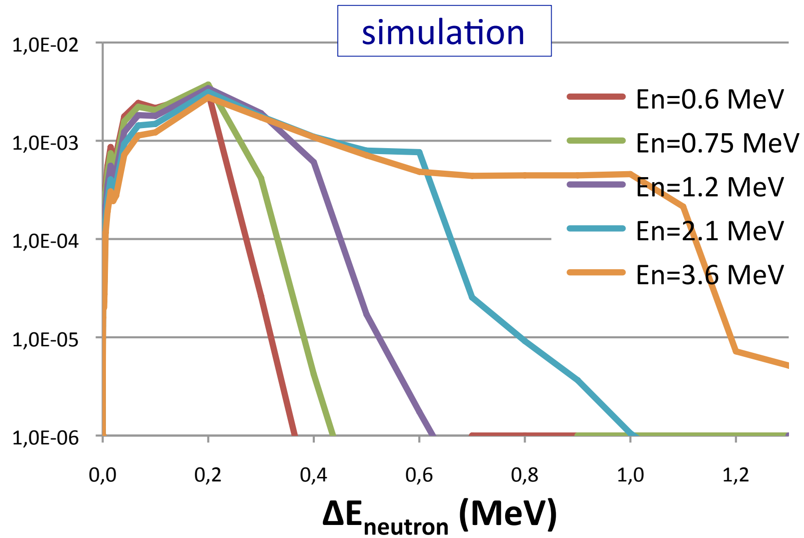
E_n = 0.2, 0.6, 0.75, 1.2, 2.1, 3.65, 6, 16 MeV
Goal: recoil energy spectra
ToF for neutron/γ discrimination

Analysis in progress:

neutron energy deposition in diamond well simulated
normalization to be understood!







Summary

μ-Loss: CVD diamond

Cryogenic tests:

Dewar LN_2 and LHe

⇒ quite good agreement between experiment and simulation

Diamond seems to work properly at cryogenic temperature

Neutron tests at room temperature:

Analysis in progress

Implementation in cryostat:

X-rays shielding

Electronics design (amplifier, cables…)