MCNPX simulation for optimization of efficiency of a 4π neutron detector for beta delayed neutron emission measurements.

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IFIC- Valencia

September 2009

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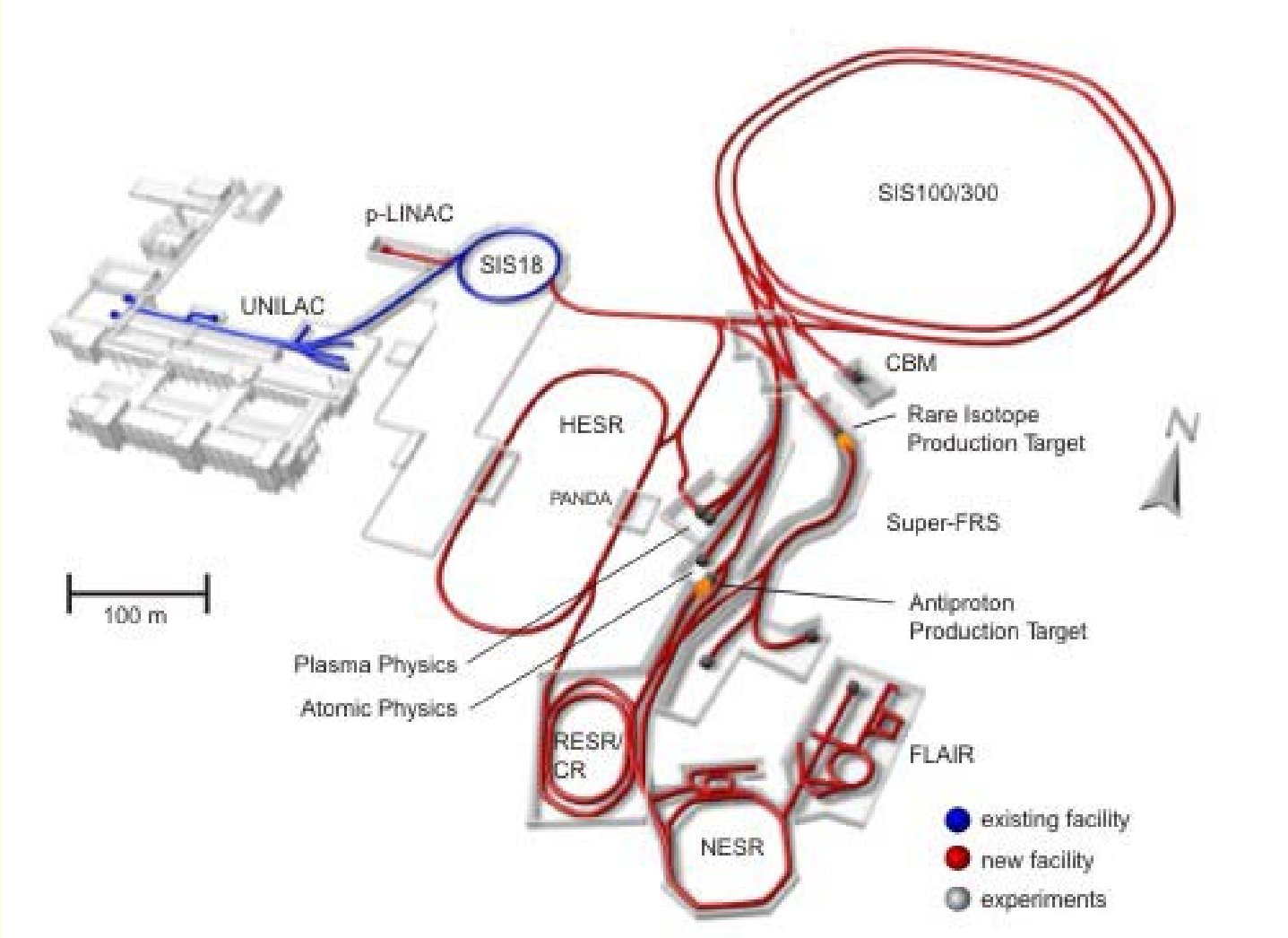
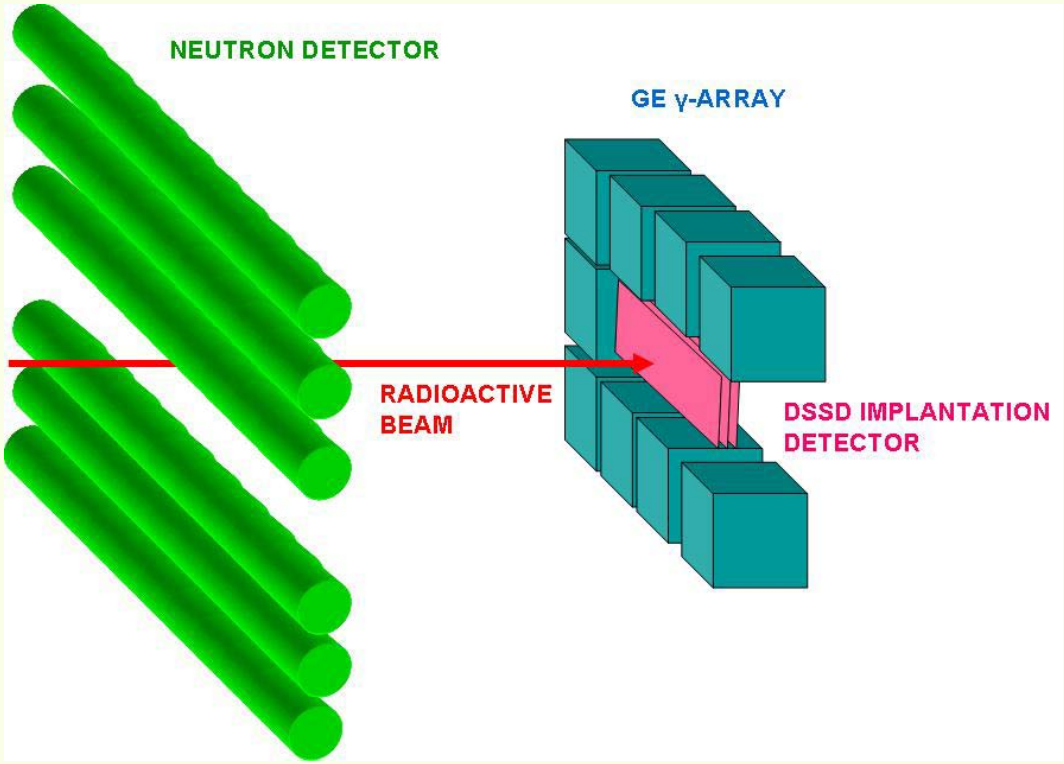
- ✓ FAIR
- ✓ DESPEC
- ✓ Delayed neutron emission
- ✓ Neutron detector for DESPEC
- ✓ Prototype of the neutron detector
- ✓ Test with Cf source
- ✓ Conclusions

INTRODUCTION



FAIR – Facility for Antiproton and Ion Research.

INTRODUCTION

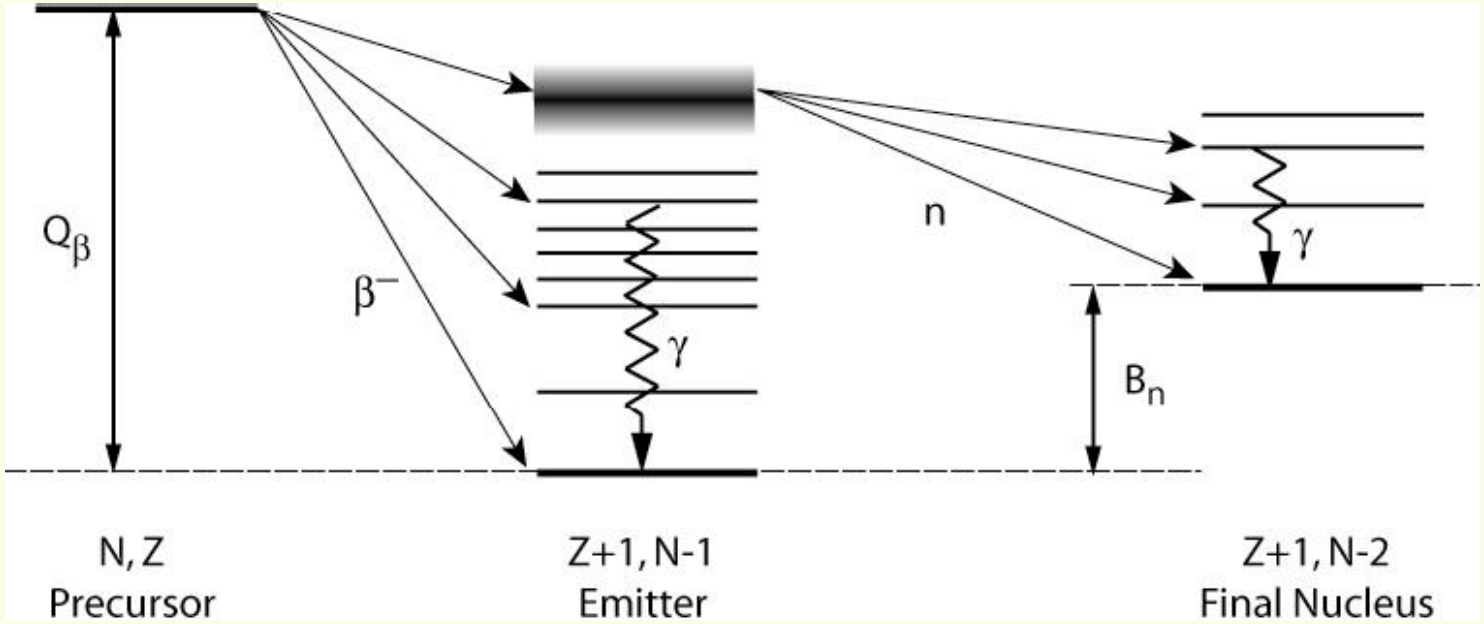


DECay SPECtroscopy.

OBJECTIVES:

- **Nuclear structure study;**
- **Decay properties of exotic isotopes study;**
- **To study r-process;**
- **Beta delay neutron emission.**

INTRODUCTION



Beta delay neutron emission scheme

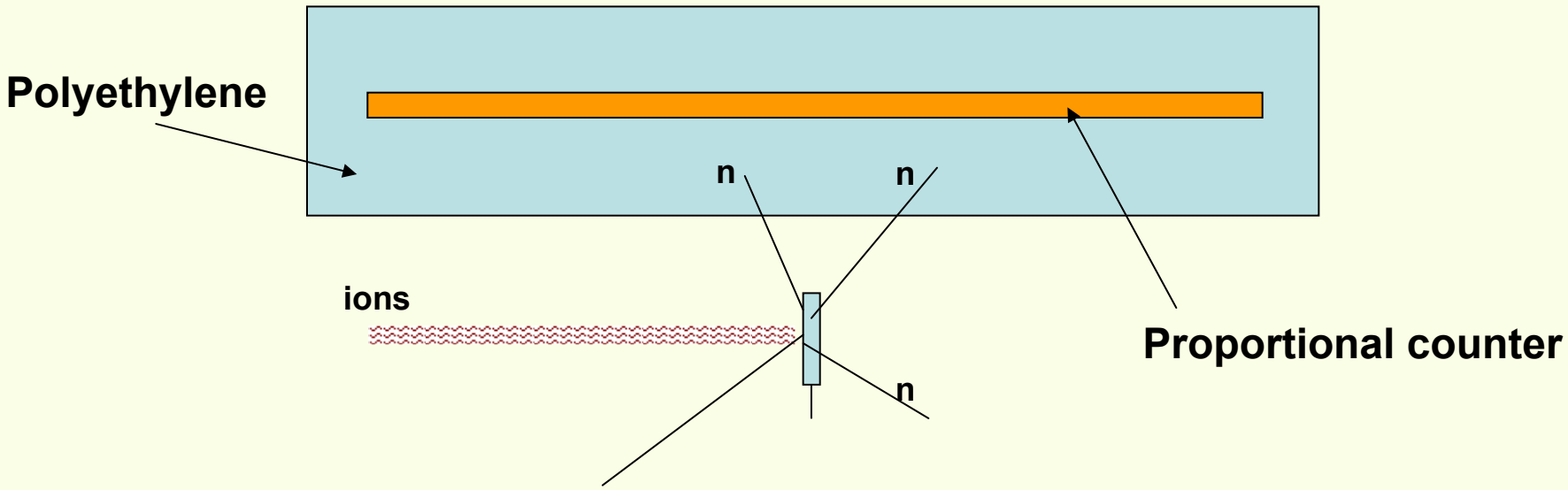
INTRODUCTION

Mechanisms of detecting neutrons are based on indirect methods

$$^{3}He + n \rightarrow {}^{3}H + {}^{1}H + 765\ keV$$

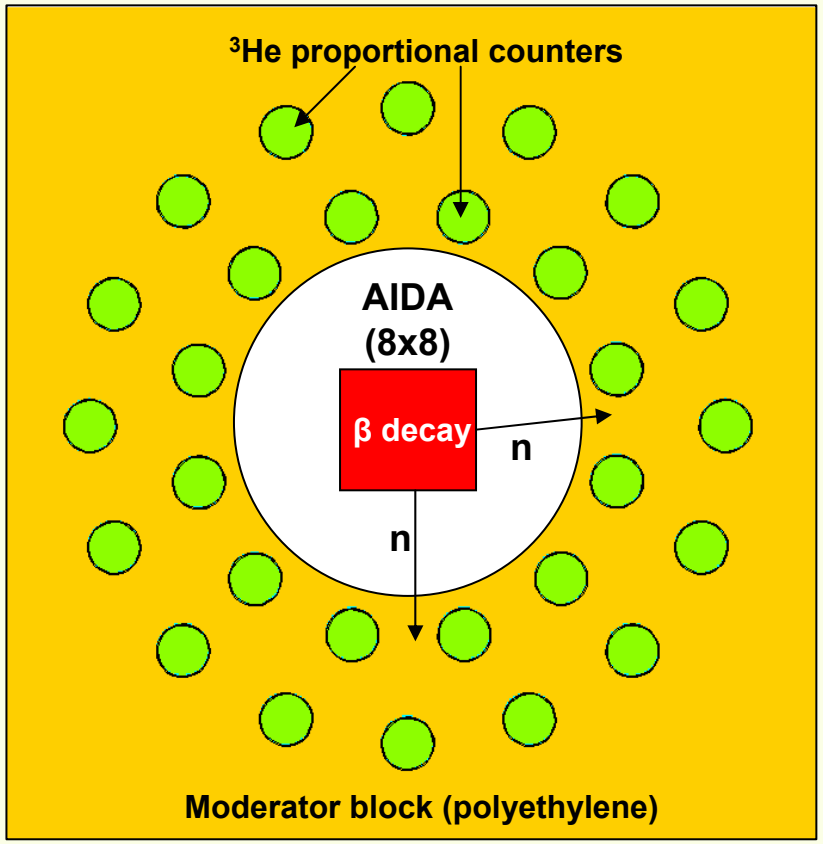
$$^{10}B + n \rightarrow {}^{7}Li^{*} + {}^{4}He + 2310\ keV\ (93\%)$$

$$^{10}B + n \rightarrow {}^{7}Li + {}^{4}He + 2790\ keV\ (7\%)$$

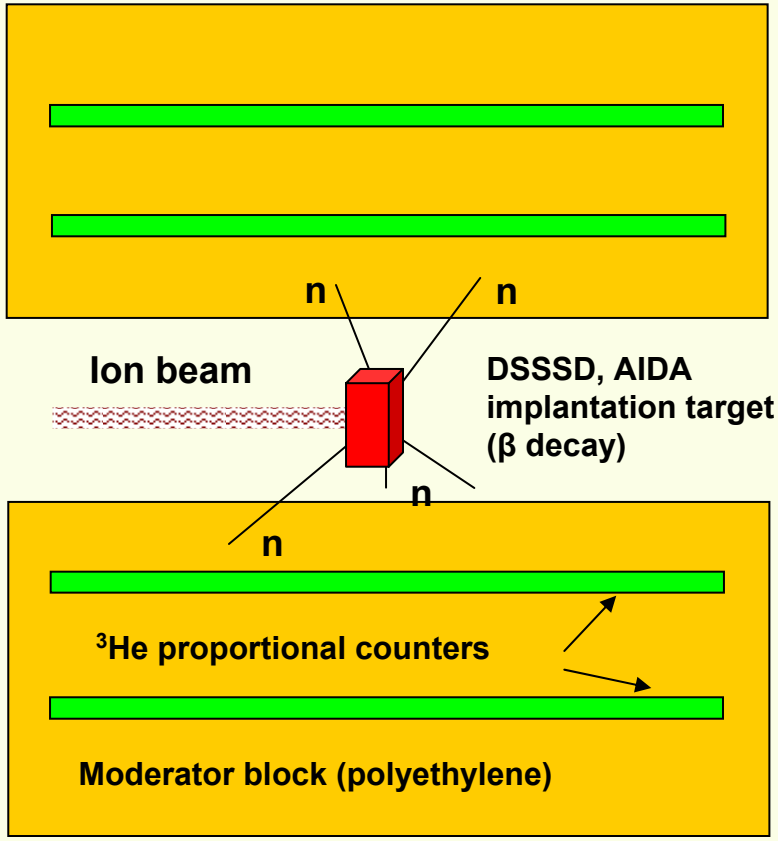


4π NEUTRON DETECTOR FOR DESPEC

Study of DEcay SPECtroscopy and associated emission



Front view

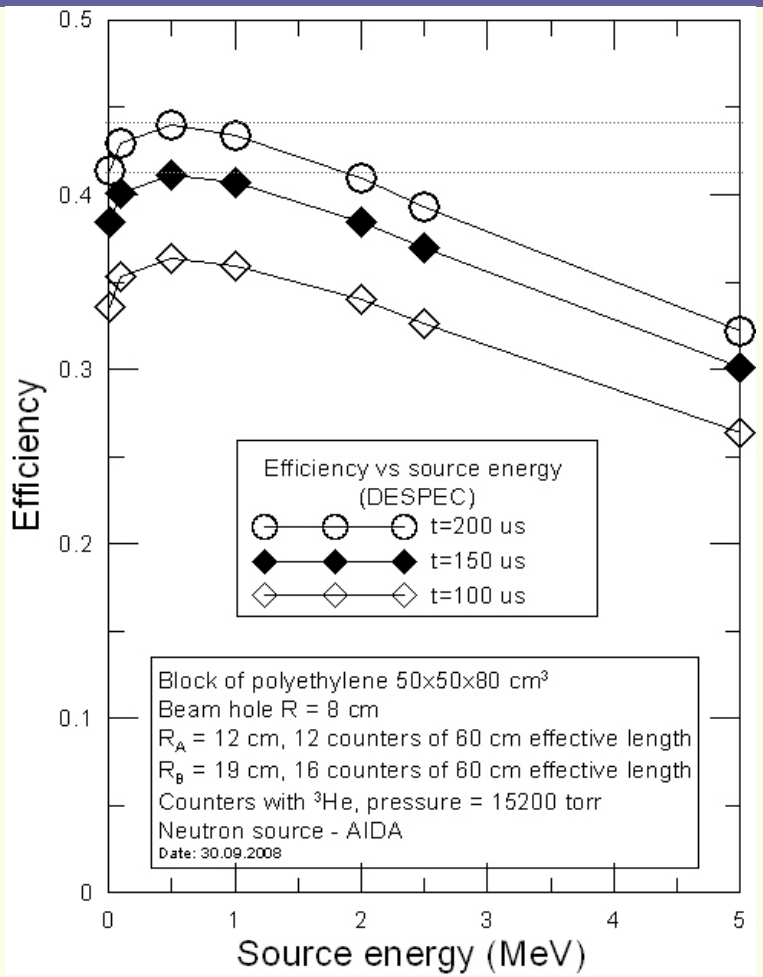


Side view

Ring A: 12 counters @ R_A=12 cm
Ring B: 16 counters @ R_B=19 cm

Beam hole radius: 8 cm
Dimensions: 50x50x80 cm^3 + shielding

EFFICIENCY FOR DESPEC DESIGN



MCNPX simulation, 100 000 events

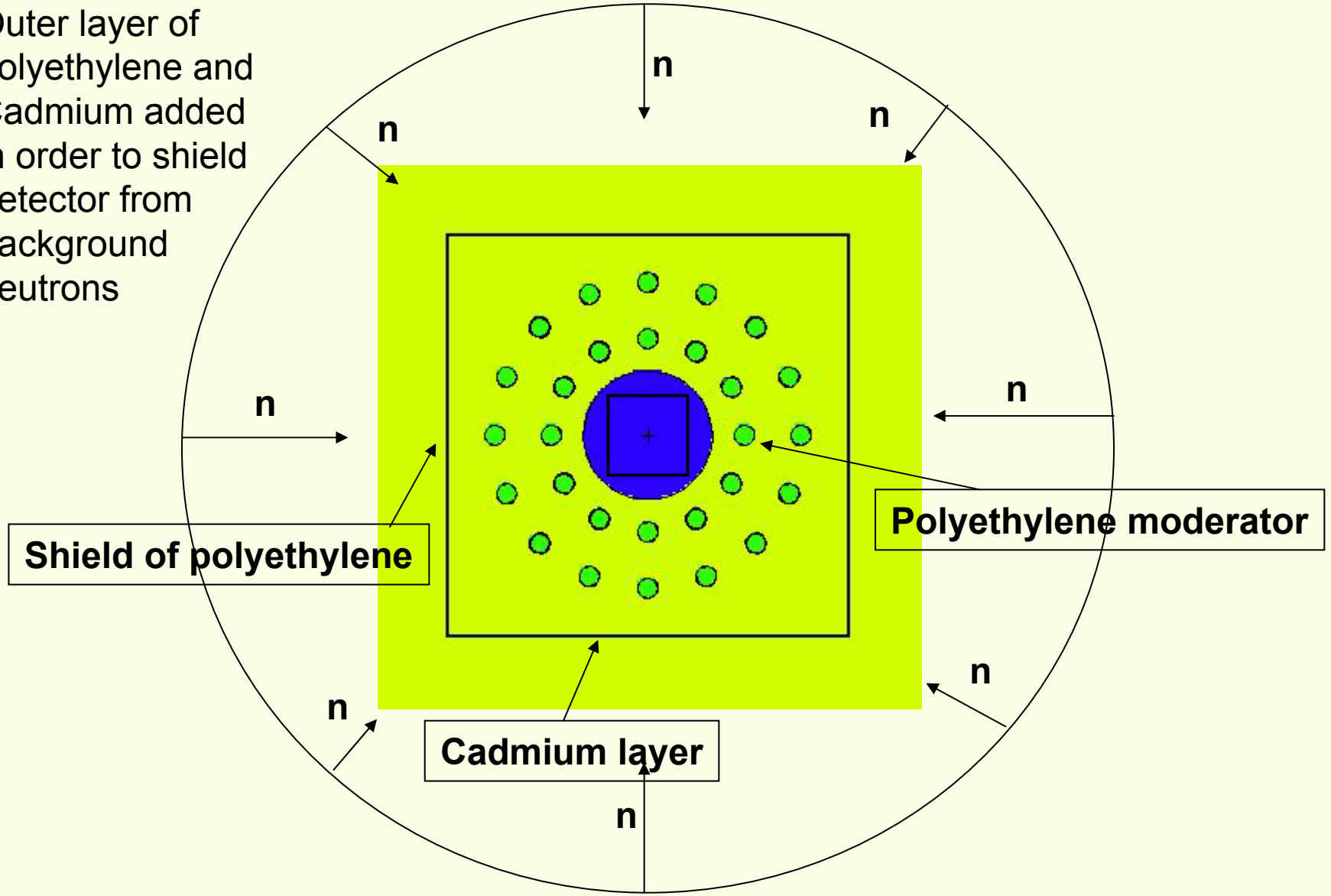
Configuration has been optimised in order to get the flattest efficiency possible.

Relative flat efficiency between 0.1MeV-2MeV (41%-44%)

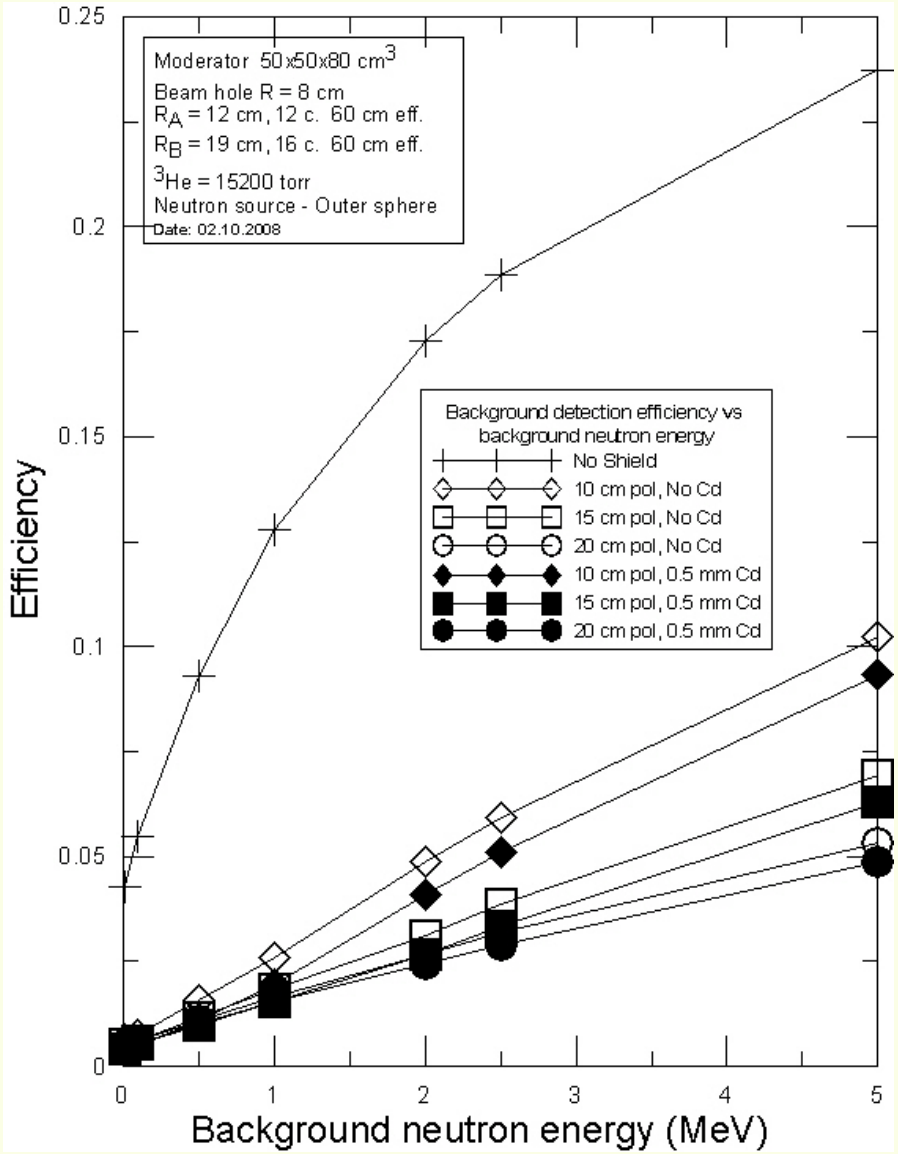
Counter	Gas	Max length (mm)	Effective length (mm)	Maximum diameter (mm)	Eff diam (mm)	Gas pressure (torr)	Cathode material
2527 LND inc	^{3}He	686.84	604.8	25.4	24.38	15200	Stainless Steel

BACKGROUND SHIELDING

Outer layer of polyethylene and Cadmium added in order to shield detector from background neutrons



BACKGROUND SHIELDING



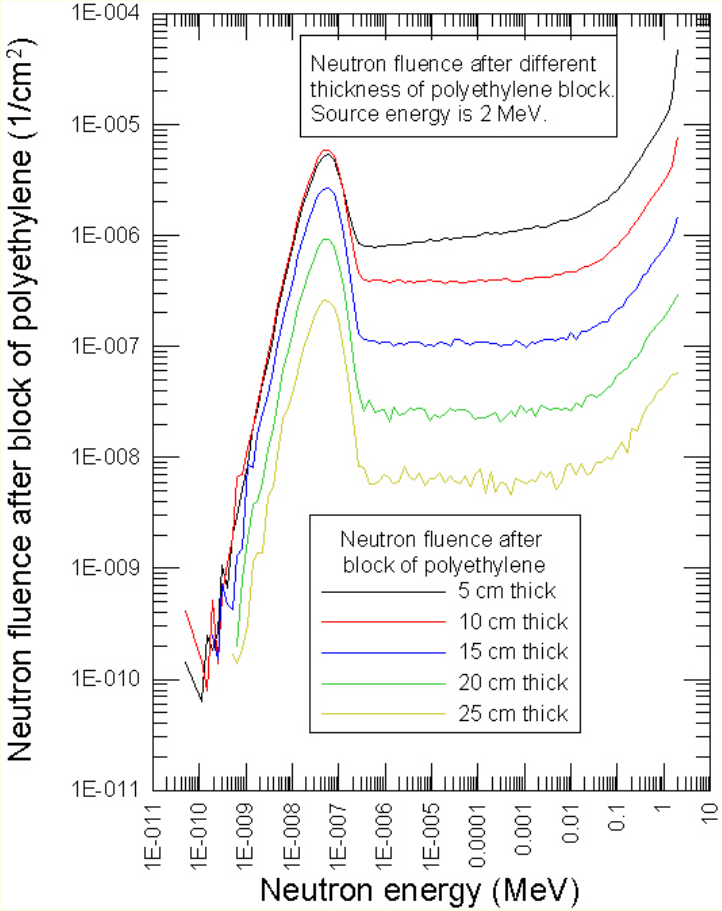
MCNPX simulation, 100 000 events

15 cm polyethylene shielding seems ok

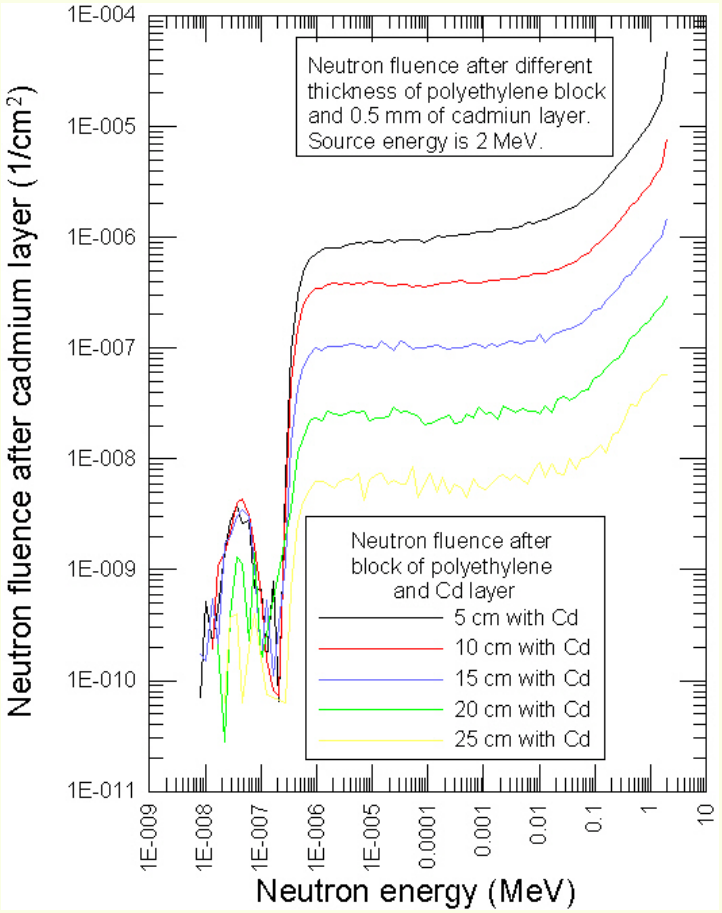
- 2.5 % detection of 2 MeV neutrons
- No need to add Cadmium according to simulations

Unknown neutron background (!?)

NEUTRON FLUX AFTER POLYETHYLENE BLOCK

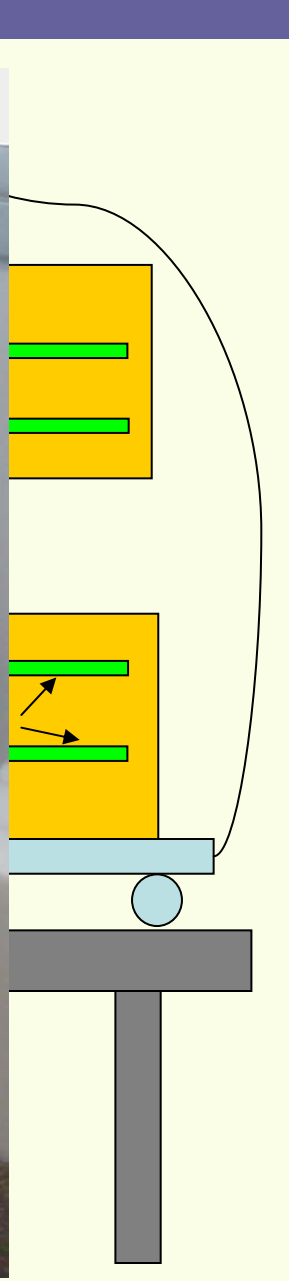


Neutron flux after polyethylene



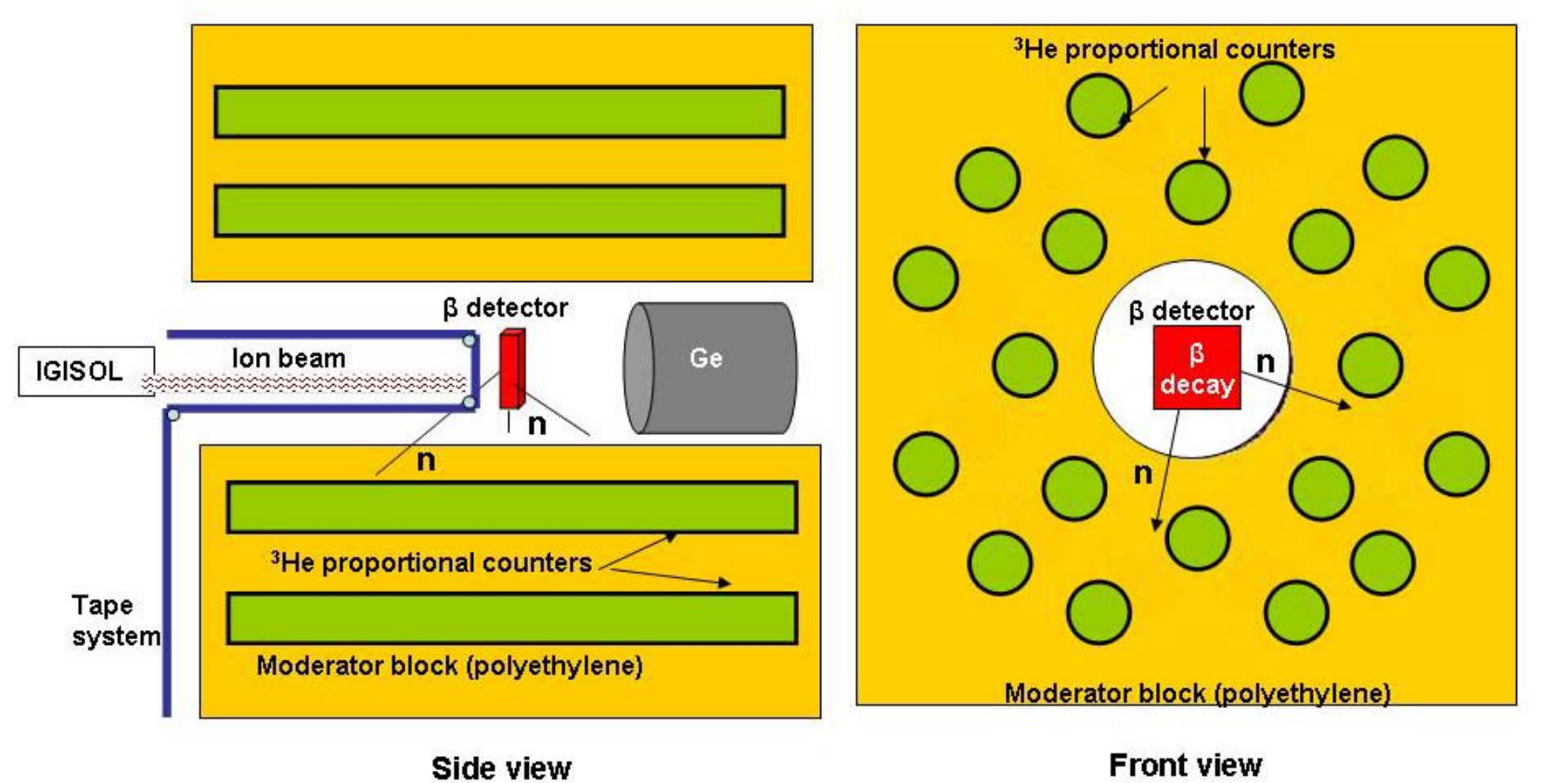
Neutron flux after polyethylene + Cd

DESIGN OF SUPPORT STRUCTURE



PROTOTYPE DESIGN

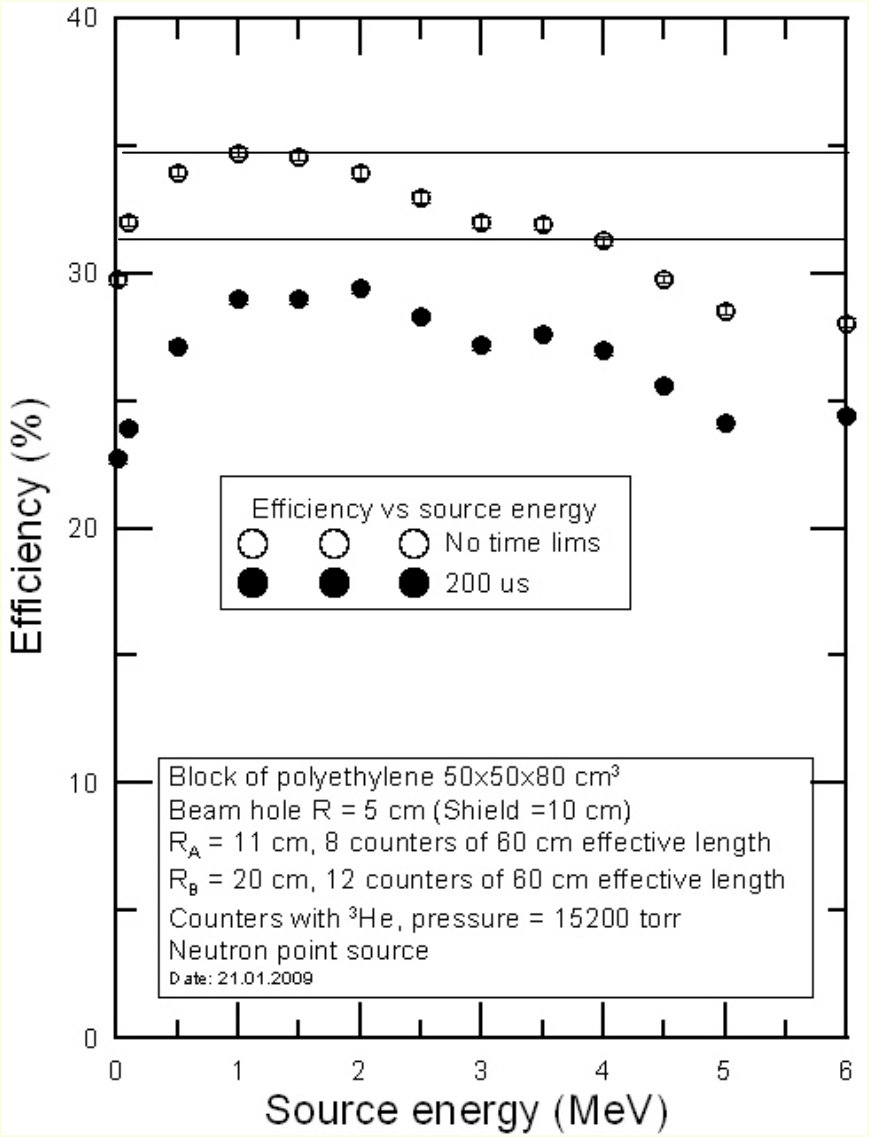
A prototype with 20 counters is being designed to be tested at JYFL-Finland



Ring A: 8 counters @ R_A=11cm
Ring B: 12 counters @ R_A=20cm

Beam hole radius: 5 cm
Dimensions: 50 x 50 x 80 cm^3 + shielding

EFFICIENCY PROTOTYPE

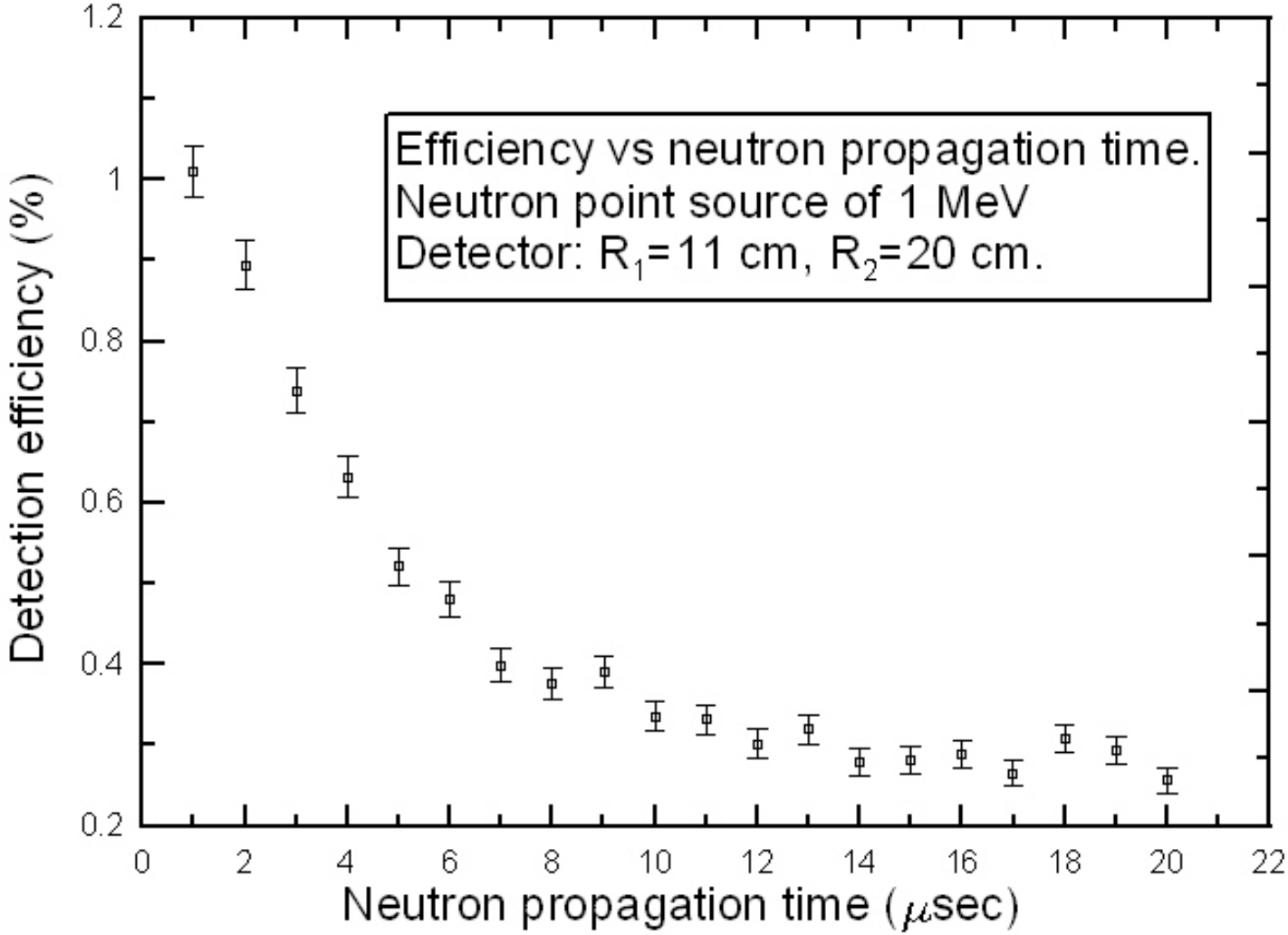


MCNPX simulation, 100 000 events

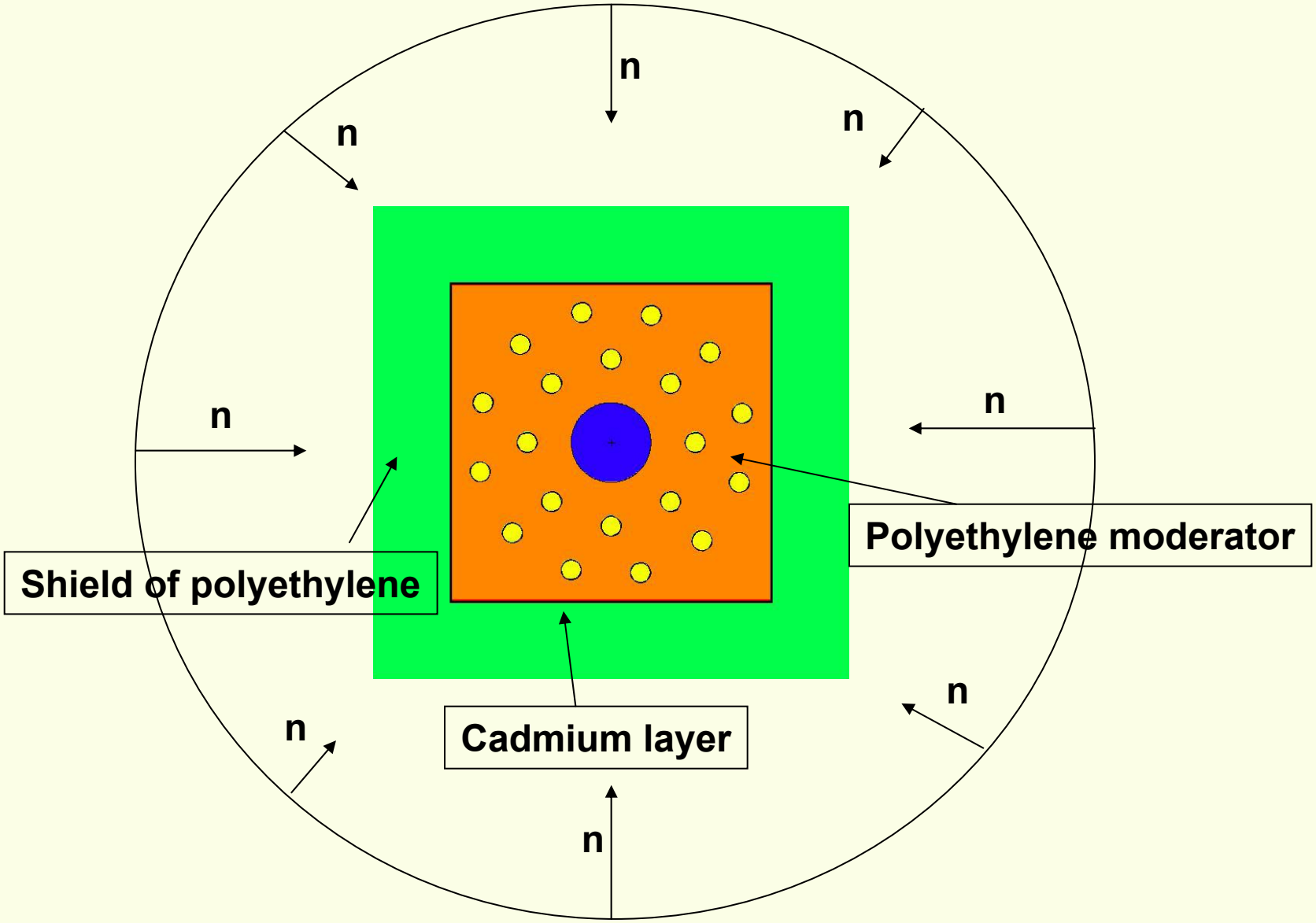
Relative flat efficiency in the range
0.1 MeV to 4 MeV (32% - 35%)

MODERATION TIME IN PROTOTYPE

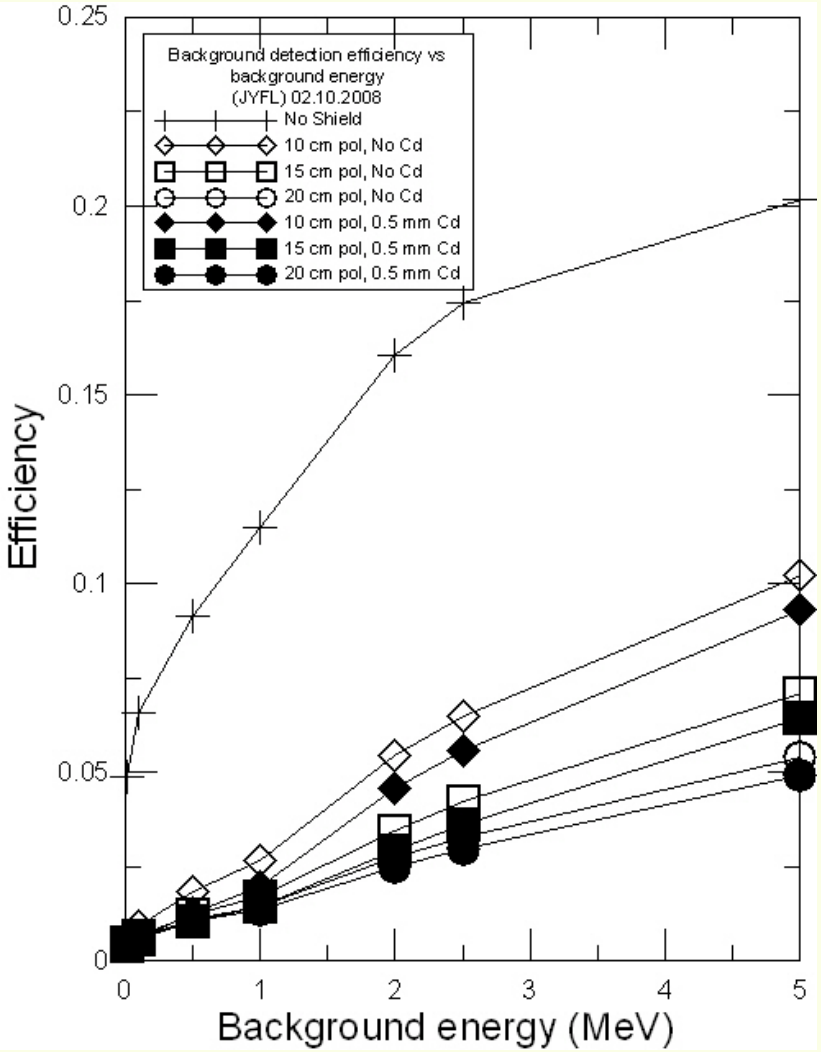
MCNPX simulation, 100 000 events



NEUTRON SHIELDING



NEUTRON SHIELDING

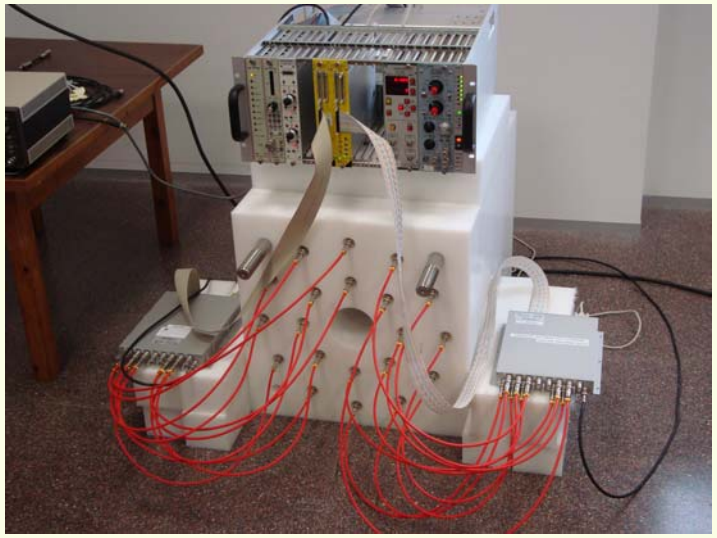


MCNPX simulation

100 000 events

Efficiency of background neutron detection. Neutron source is a sphere around the neutron detector.

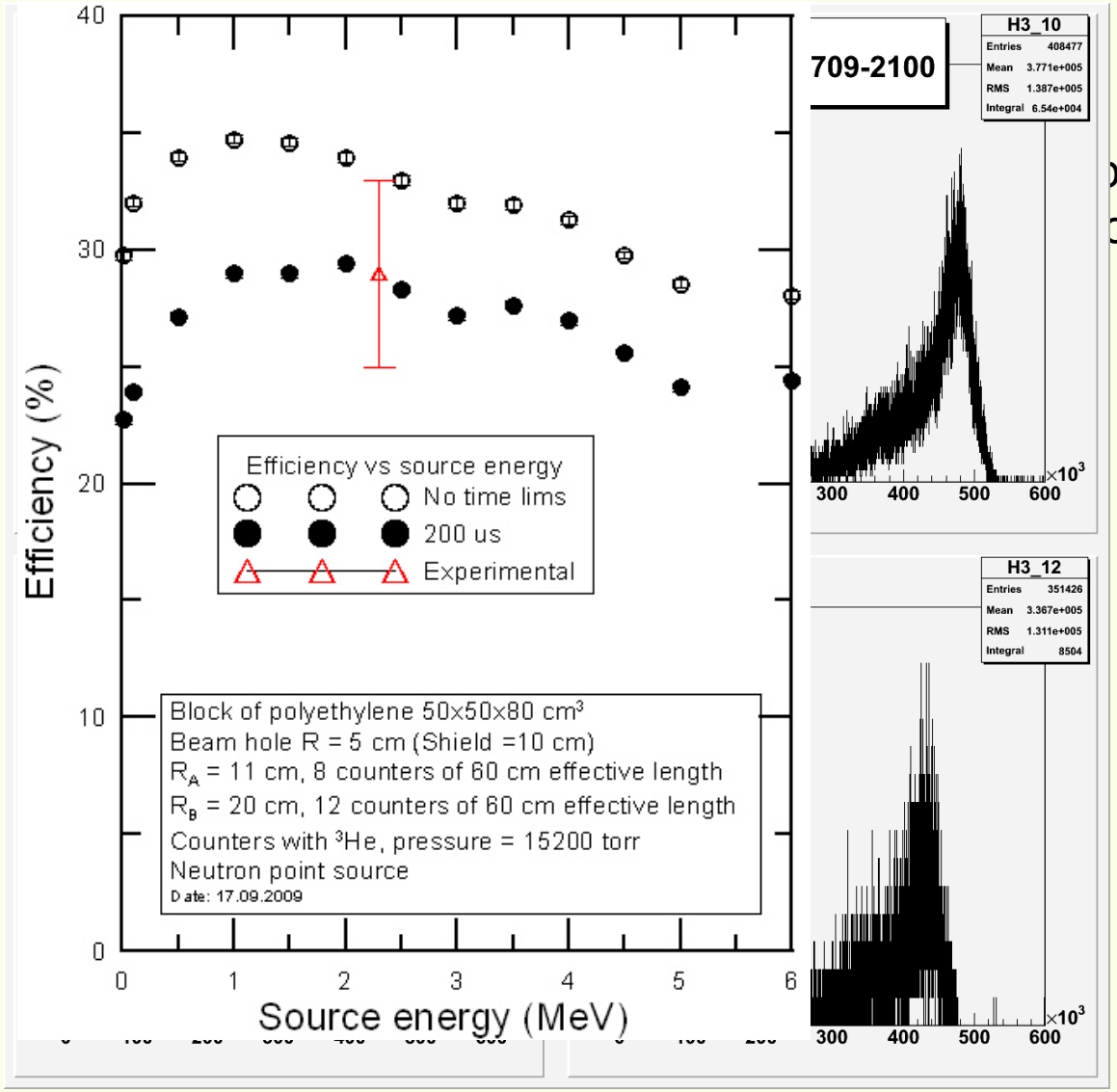
TEST WITH Cf SOURCE @ UPC



Equipment:
Neutron detector – UPC (Barcelona)
DAQ – IFIC (Valencia)
NaI(Tl) detector – CIEMAT (Madrid)

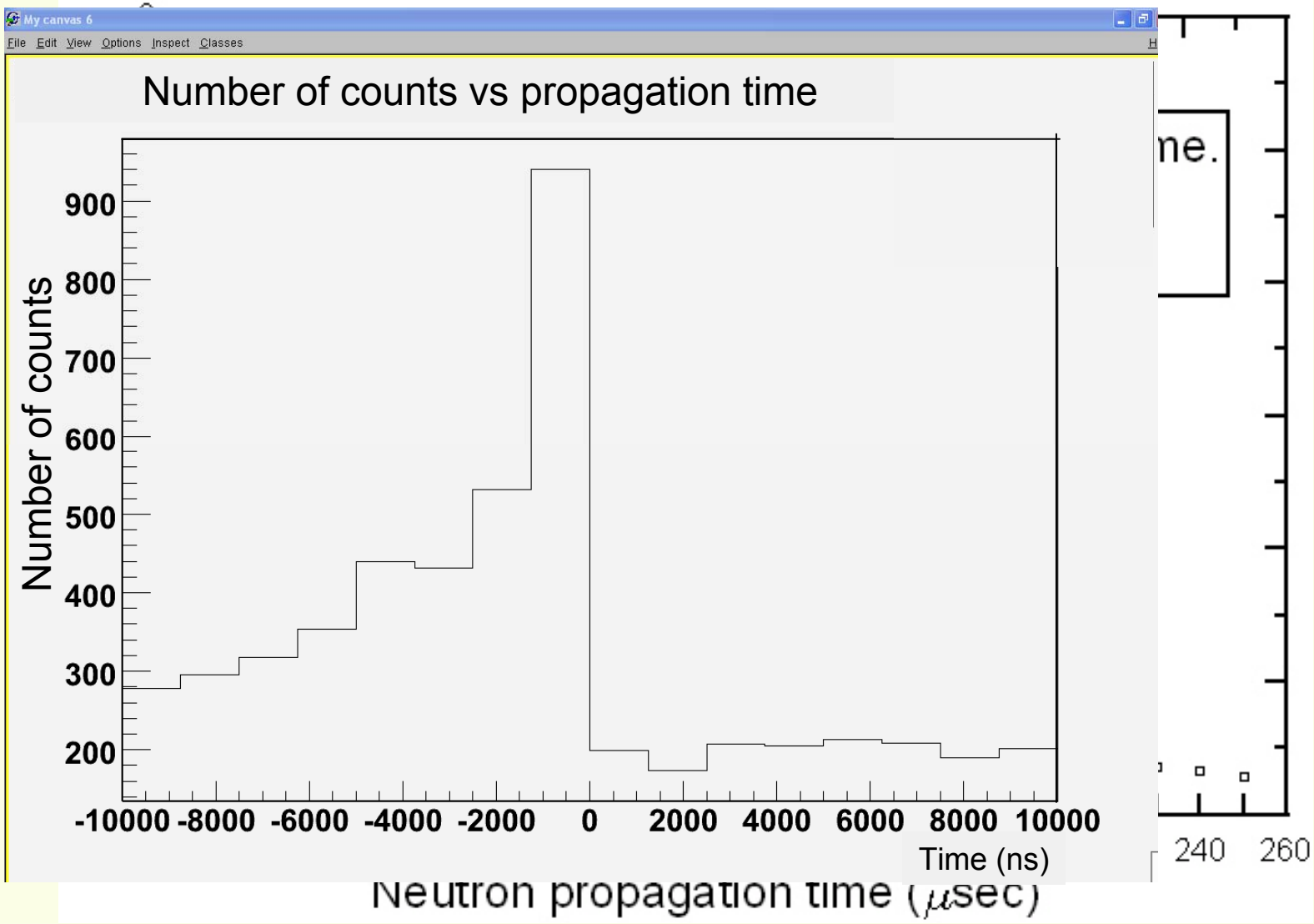
^{252}Cf neutron source. Activity:
Dec. 2007 – 9.9kBq (1100 neutrons/second)
July 2009 – 605 neutrons/second

TEST WITH Cf SOURCE @ UPC



perimental efficiency (29±4)%
orresponds to simulation

TEST WITH Cf SOURCE @ UPC

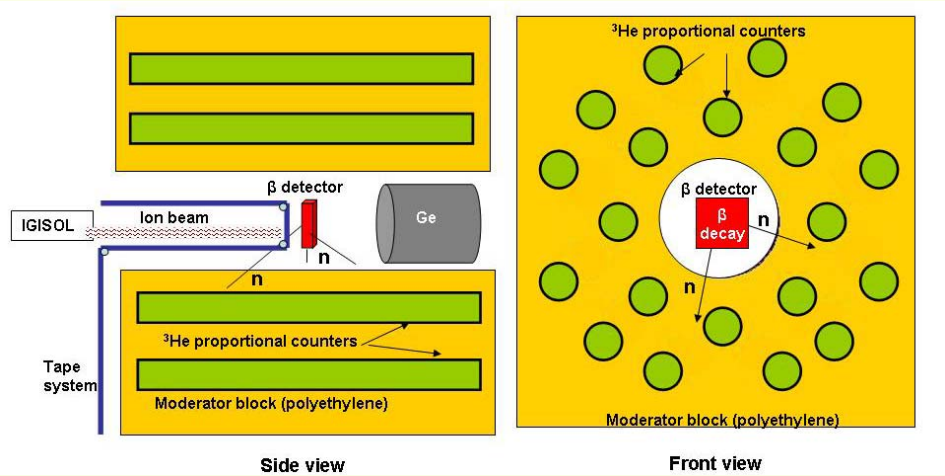


Experimental propagation time corresponds to simulation

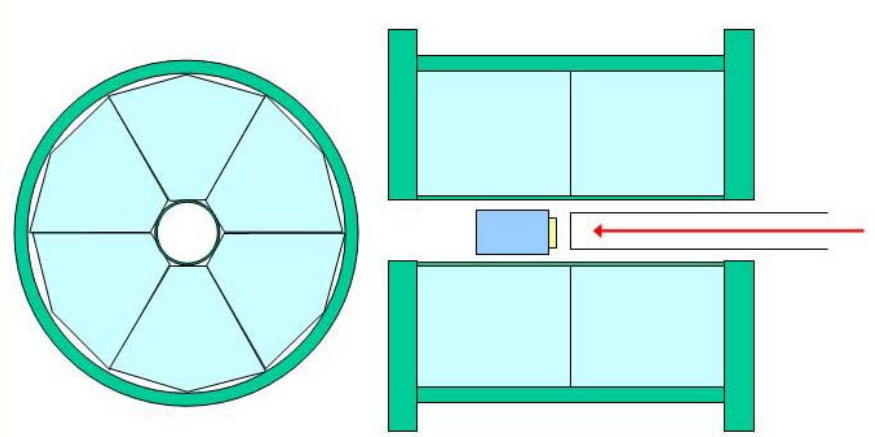
UPC, IFIC & CIEMAT EXPERIMENT @ JYFL

Decay properties of β delayed neutron emitters ^{87}Br, ^{88}Br, ^{94}Rb, ^{95}Rb,^{137}I

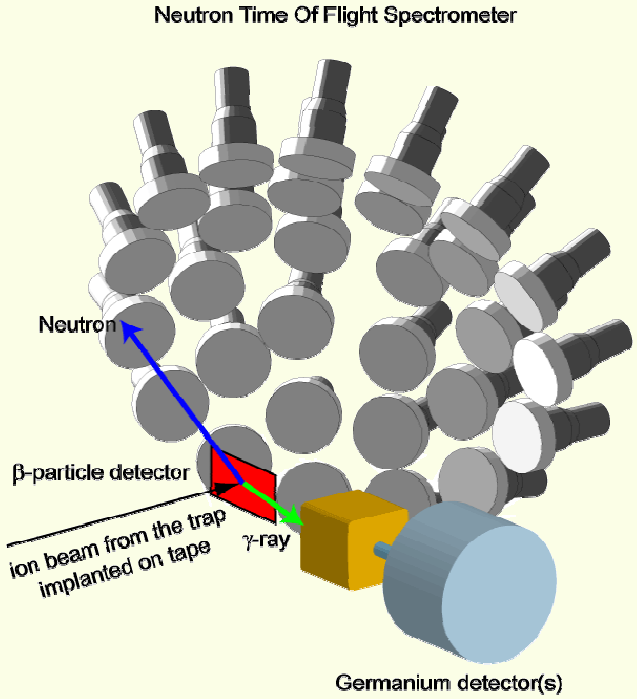
Three complementary setups to study three aspects: 15 days beam time



Neutron emission probability (4π neutron detector, UPC)



Beta decay energy (Total Absorption Spectrometer, IFIC)

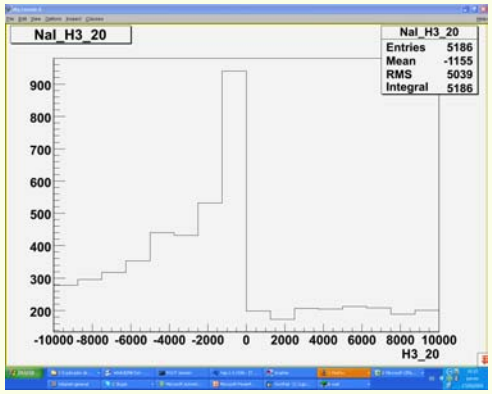


Neutron energy (ToF detector, CIEMAT)

CONCLUSIONS

- ✓ Prototype simulations were done
- ✓ Prototype construction was made
- ✓ First test with Cf source was performed in July 2009
- ✓ Experimental efficiency corresponds to simulation
- ✓ Moderation time corresponds to simulation
- ✓ Support structure was designed and constructed
- ✓ Test with prototype will be performed in November 2009 in JYFL

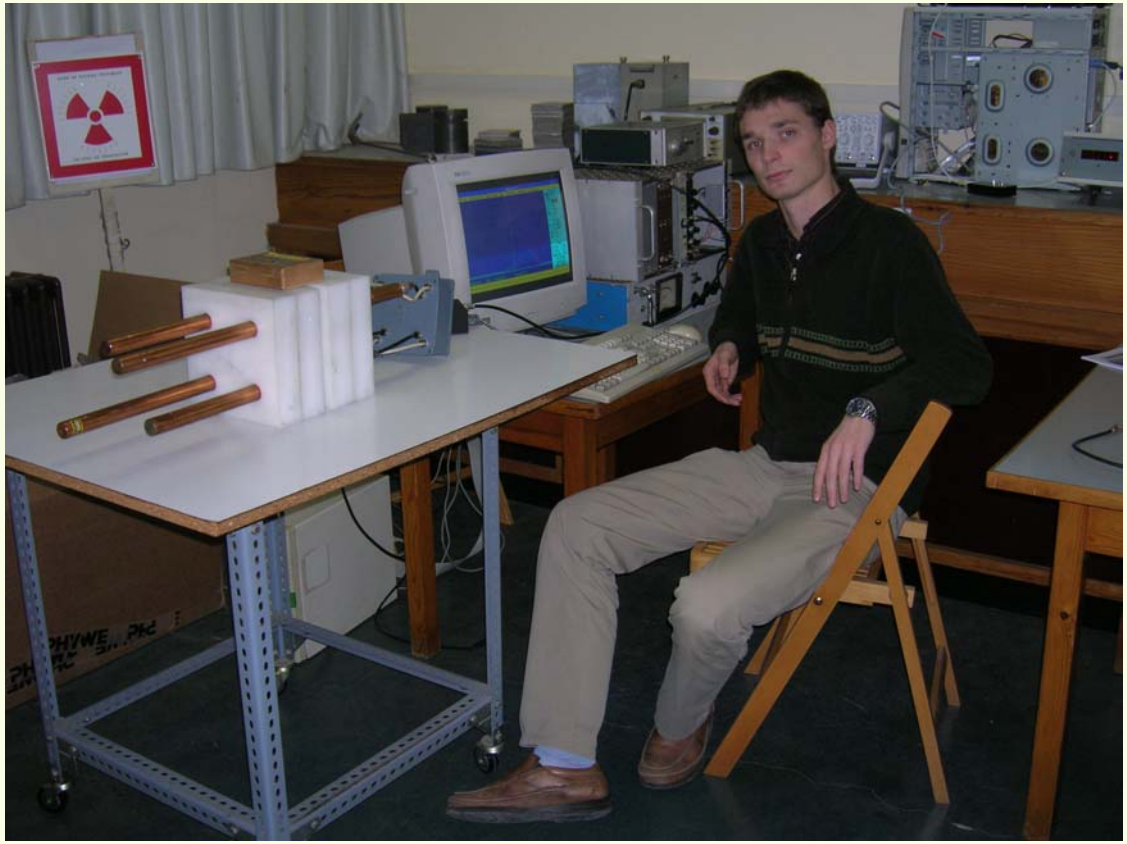
4π NEUTRON DETECTOR FOR DESPEC



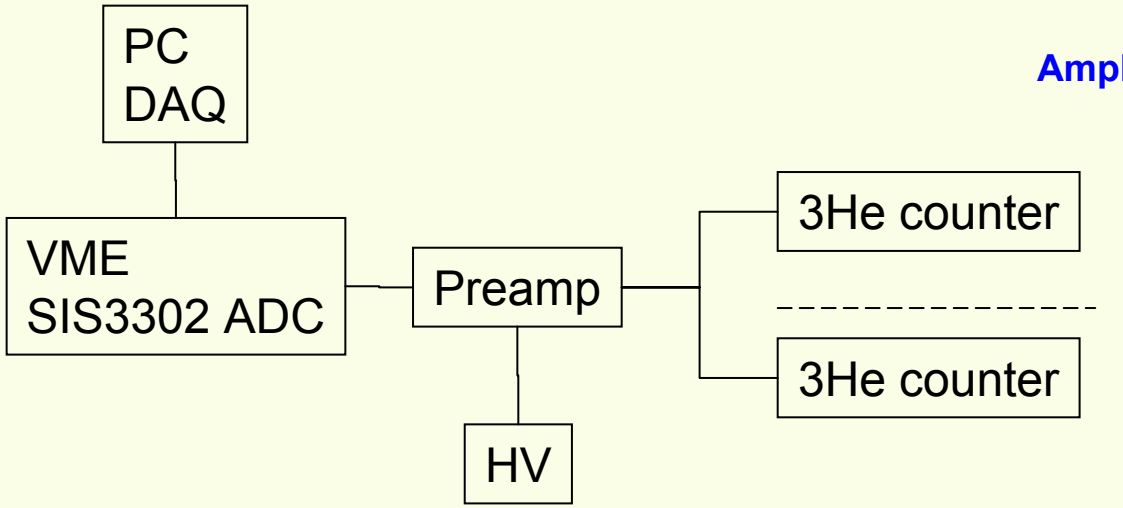
4π NEUTRON DETECTOR FOR DESPEC

4π NEUTRON DETECTOR ELECTRONICS

NEXT IN THE LIST: Test electronics and counters with a ^{252}Cf source



TEST WITH Cf SOURCE @ UPC



Amplifiers (STM-16 MESYTEC)

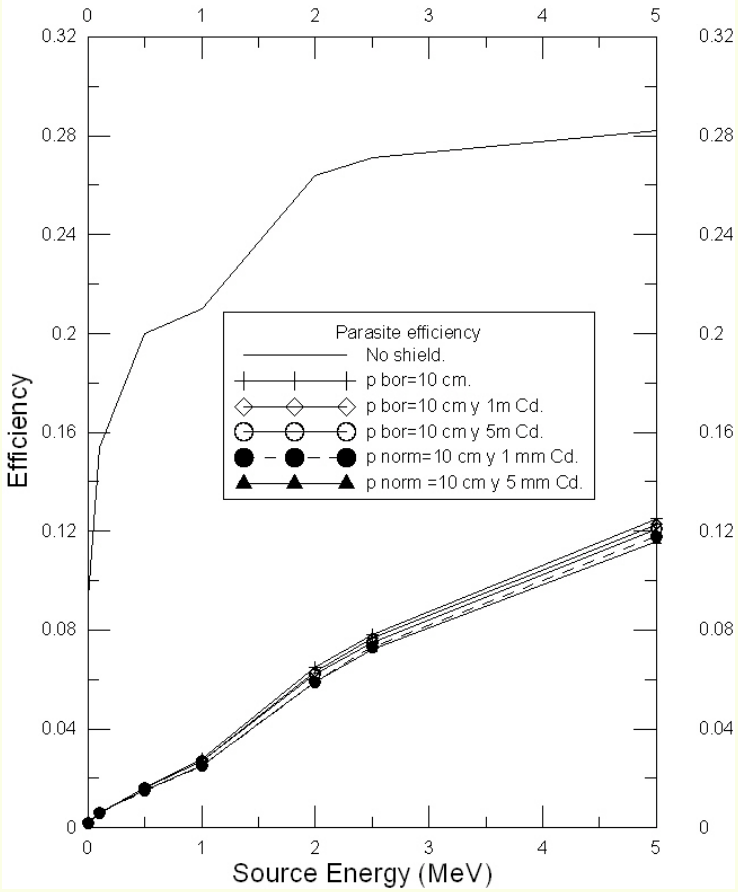
PLANNING

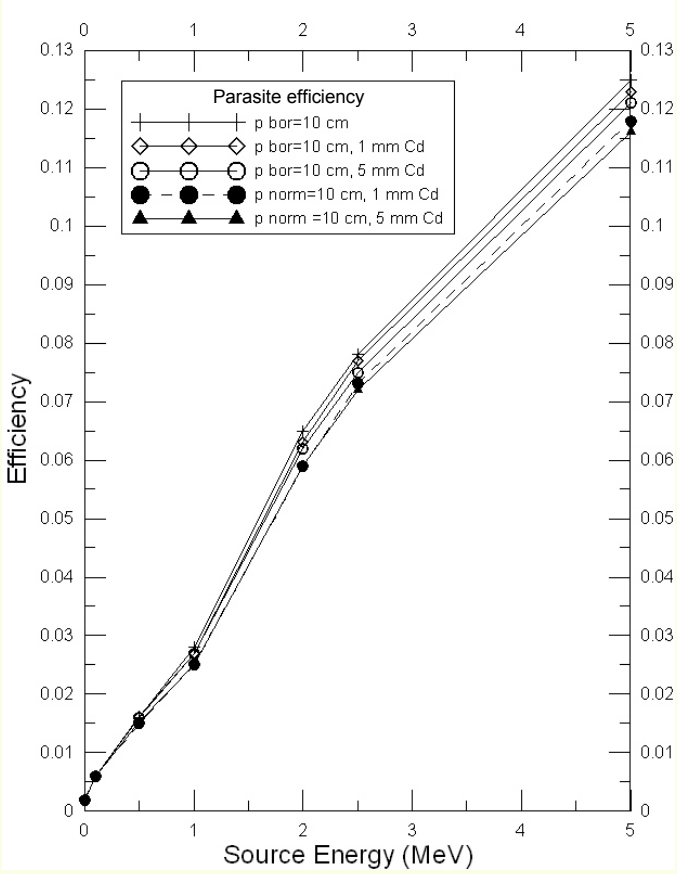
	2007	2008				2009				2010	
	4º	1º	2º	3º	4º	1º	2º	3º	4º	1º	2º
Simulation of detector											
Definition of counters											
Electronics definition											
Electronics setup and test											
Prototype construction											
First tests of prototype											
Experiment JYFL											
Analysis of experiment											
Tuning of final design											
Construction of final detector											

4π NEUTRON DETECTOR FOR DESPEC

NEUTRON SHIELDING

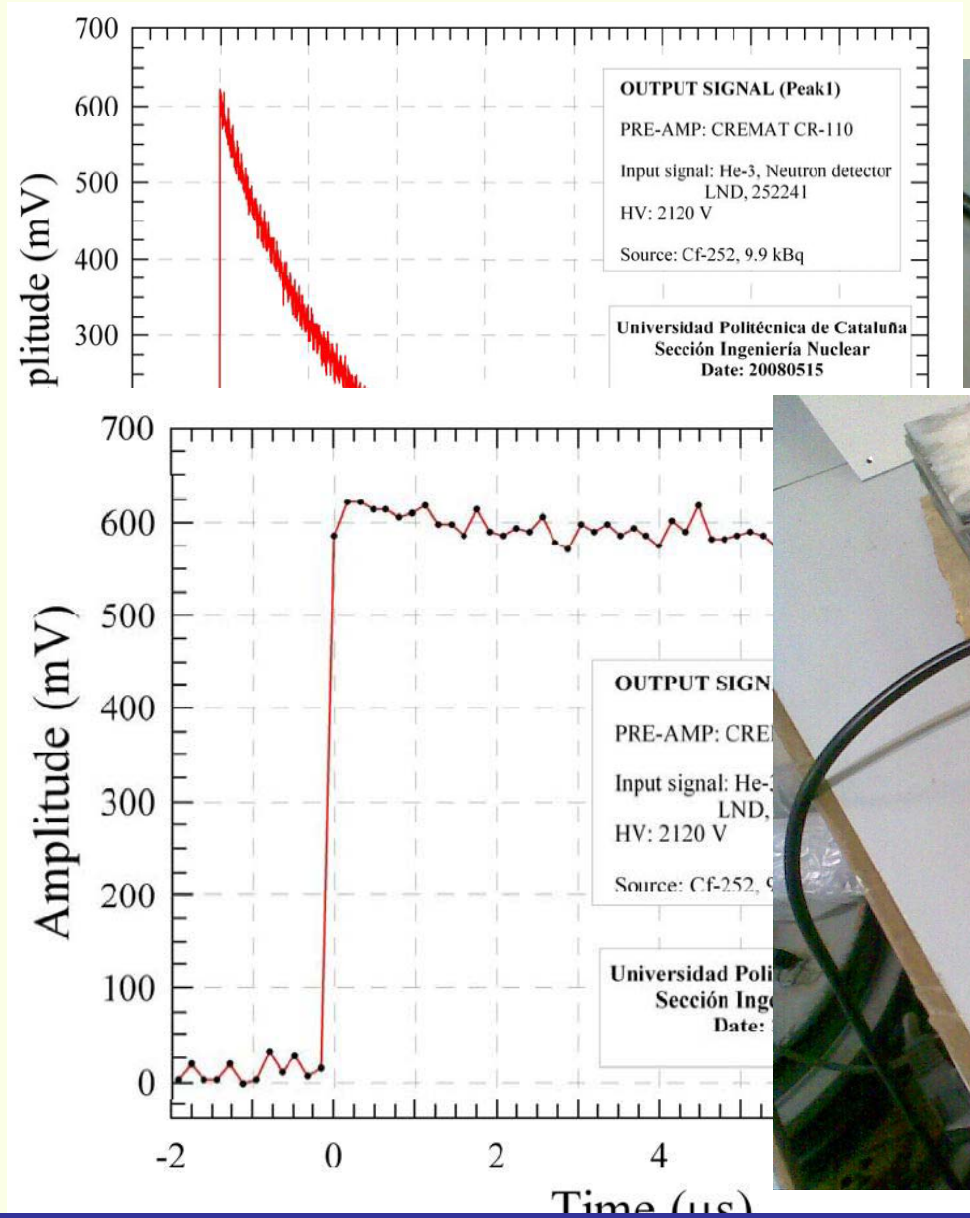
Not optimised need new





Efficiency of background neutron detection. Neutron source is a sphere around the neutron detector.

4π NEUTRON DETECTOR FOR DESPEC



Number of channels = 1
Rise time = 7 ns
Decay time =140 μs
Gain = 1.4
Power Supply = +/- 12V

4π NEUTRON DETECTOR FOR DESPEC

4π NEUTRON DETECTOR FOR DESPEC

4π NEUTRON DETECTOR FOR DESPEC

- Detector overview
- Results of simulations with MCNPX
- Prototype design and first experiment
- Status of detector components
- Time planning

DESIGN OF 4π NEUTRON DETECTOR FOR DESPEC

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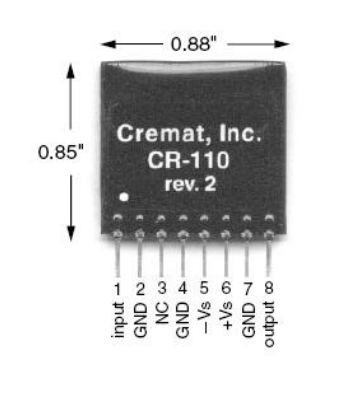
UNIVERSIDAD POLITÉCNICA DE CATALUÑA

December 2008

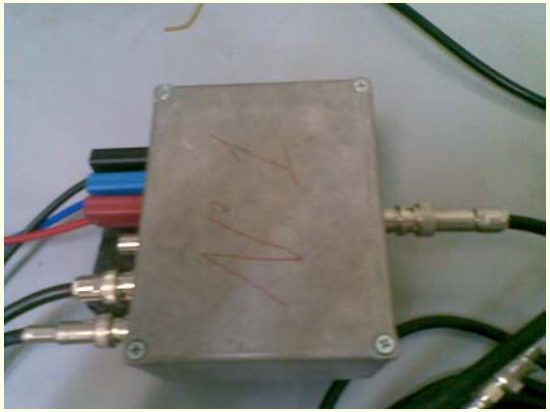
4π NEUTRON DETECTOR MATERIAL

Pre-amplifiers (CREMAT)



Amplifiers (STM-16 MESYTEC)

Pre-amplifiers (MPR-16 MESYTEC)

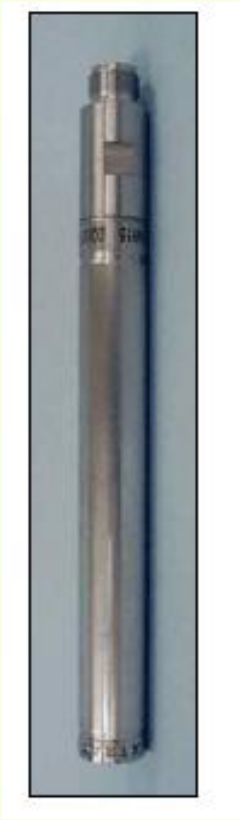


4π NEUTRON DETECTOR MATERIAL

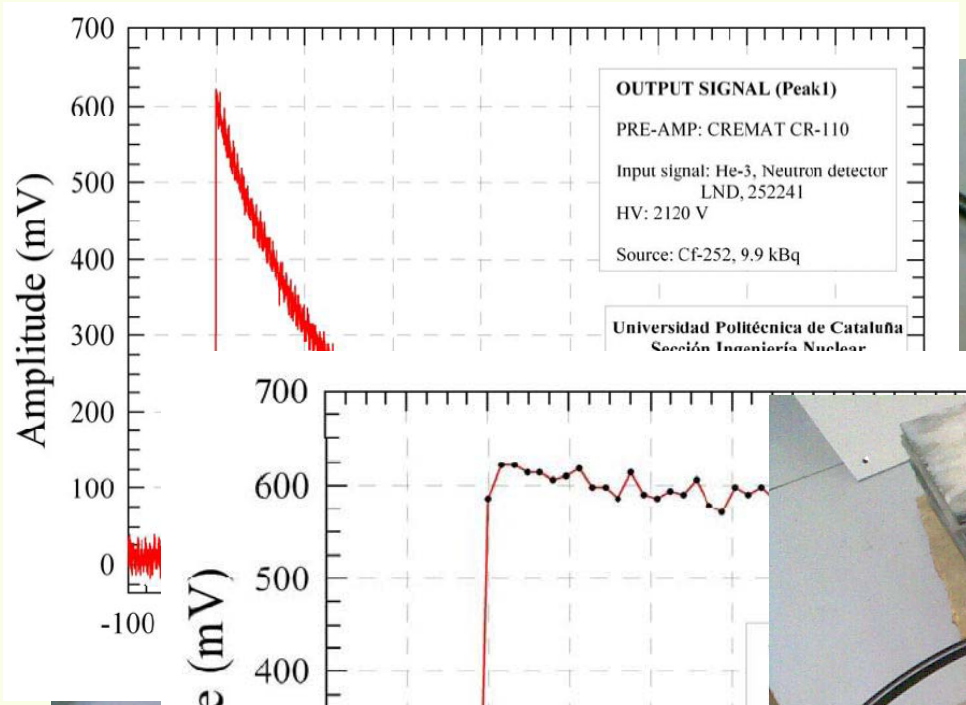
TDC (V767 CAEN)

Power Supply (ISEG 203)
NIM crate (WIENER)

20 ^{3}He counters (LND)
Delivery shortly

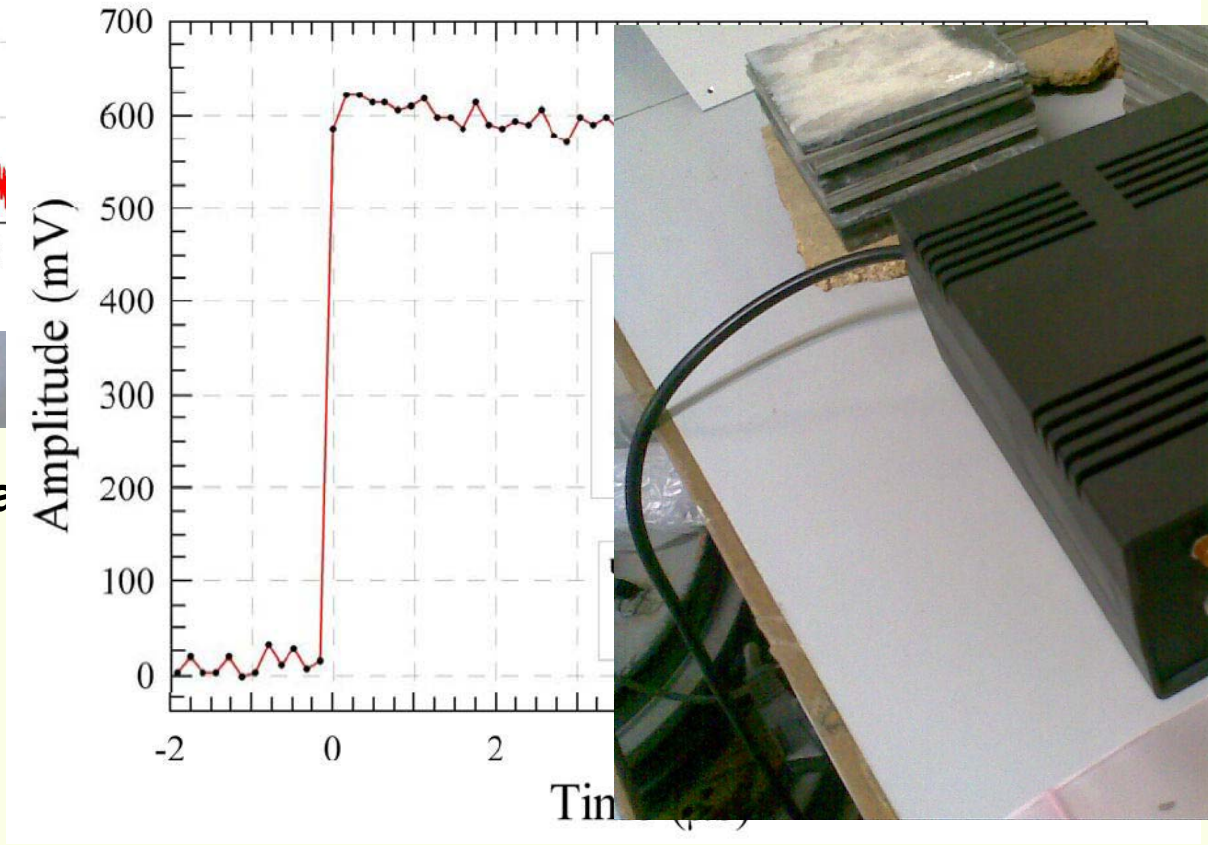


CREMAT PRE-AMPLIFIER TEST

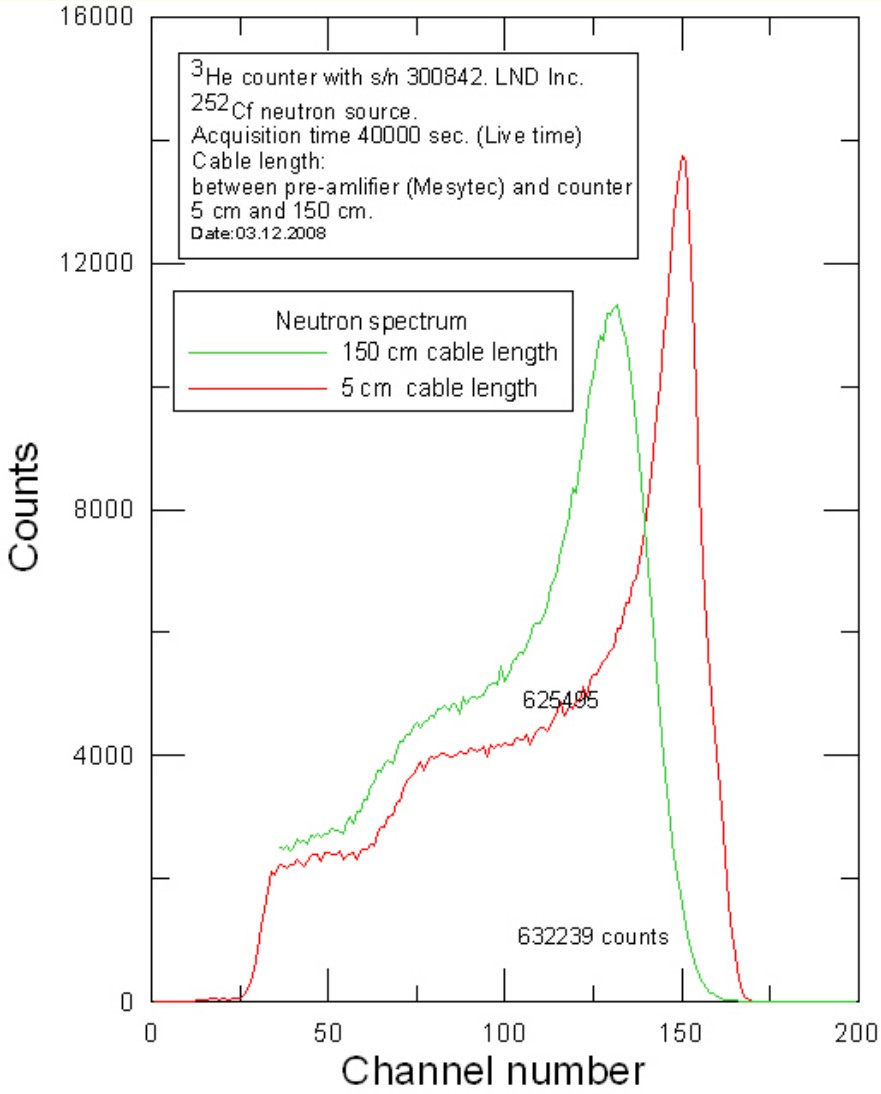


Number of channels = 1
Rise time = 7 ns
Decay time =140 µs
Gain = 1.4
Power Supply = +/- 12V

Pre-a



CABLE LENGTH TEST



Neutron spectrum for Mesytec pre-amplifier and amplifier chain for different cable length

It seems the cable length does not have large influence