Istituto Nazionale di Fisica Nucleare

New Neutron Source at the Bea
Test Facility (BTF) of Frascati

design and first experimental results

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Scientific Motivation

Increasing general intrest of the scientific community for neutron facilities worldwide

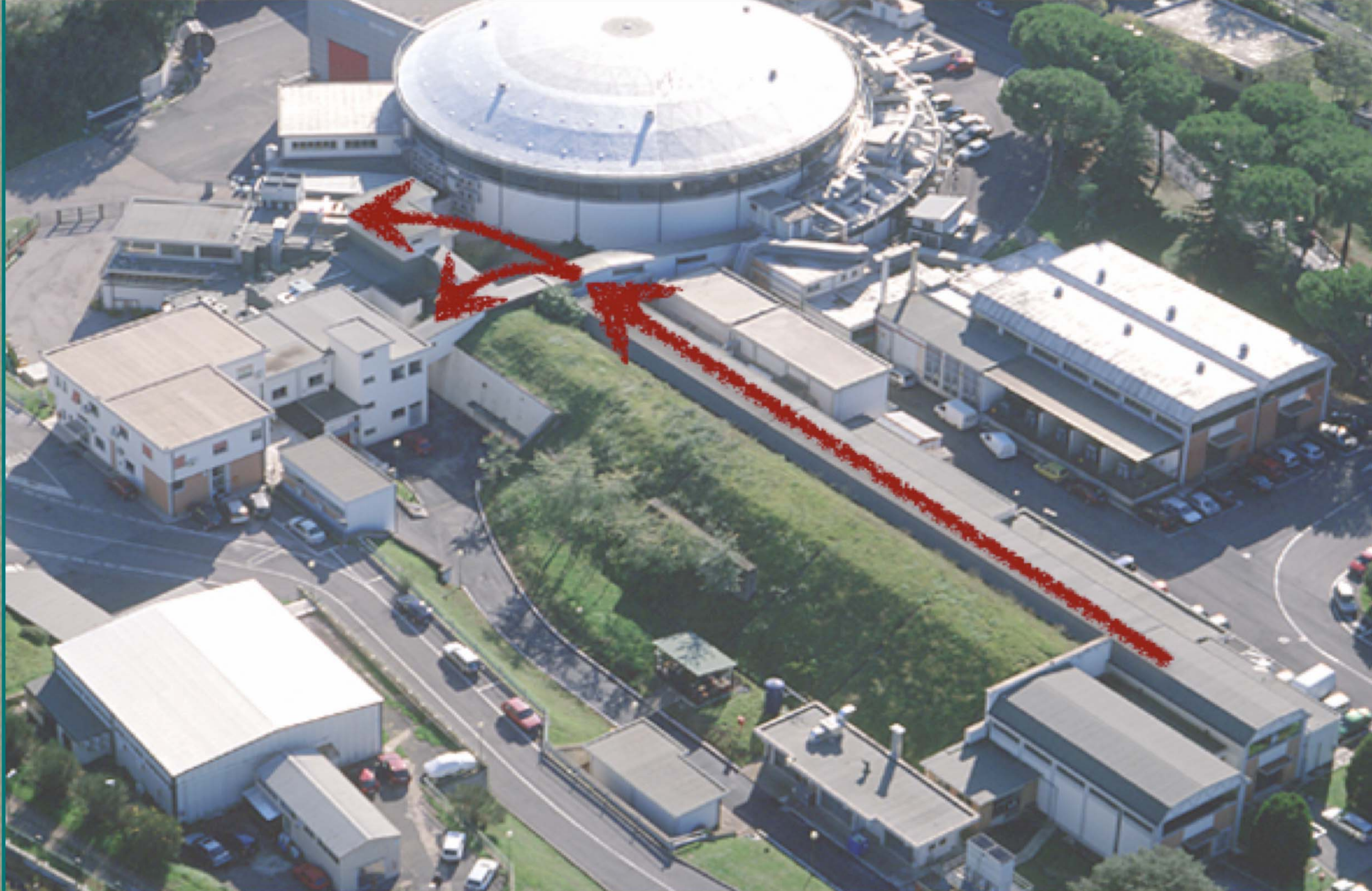
Neutron Detector R&D for very precise Spectra Measurement in high energy electron accelerator

Possibility to test diagnostic detectors for low intensity neutron flux

Acquisition of know-how needed for next generation of high intensity neutron source by photo-production and as companion activities in the context of new powerful FEL (SparcX in Italy)

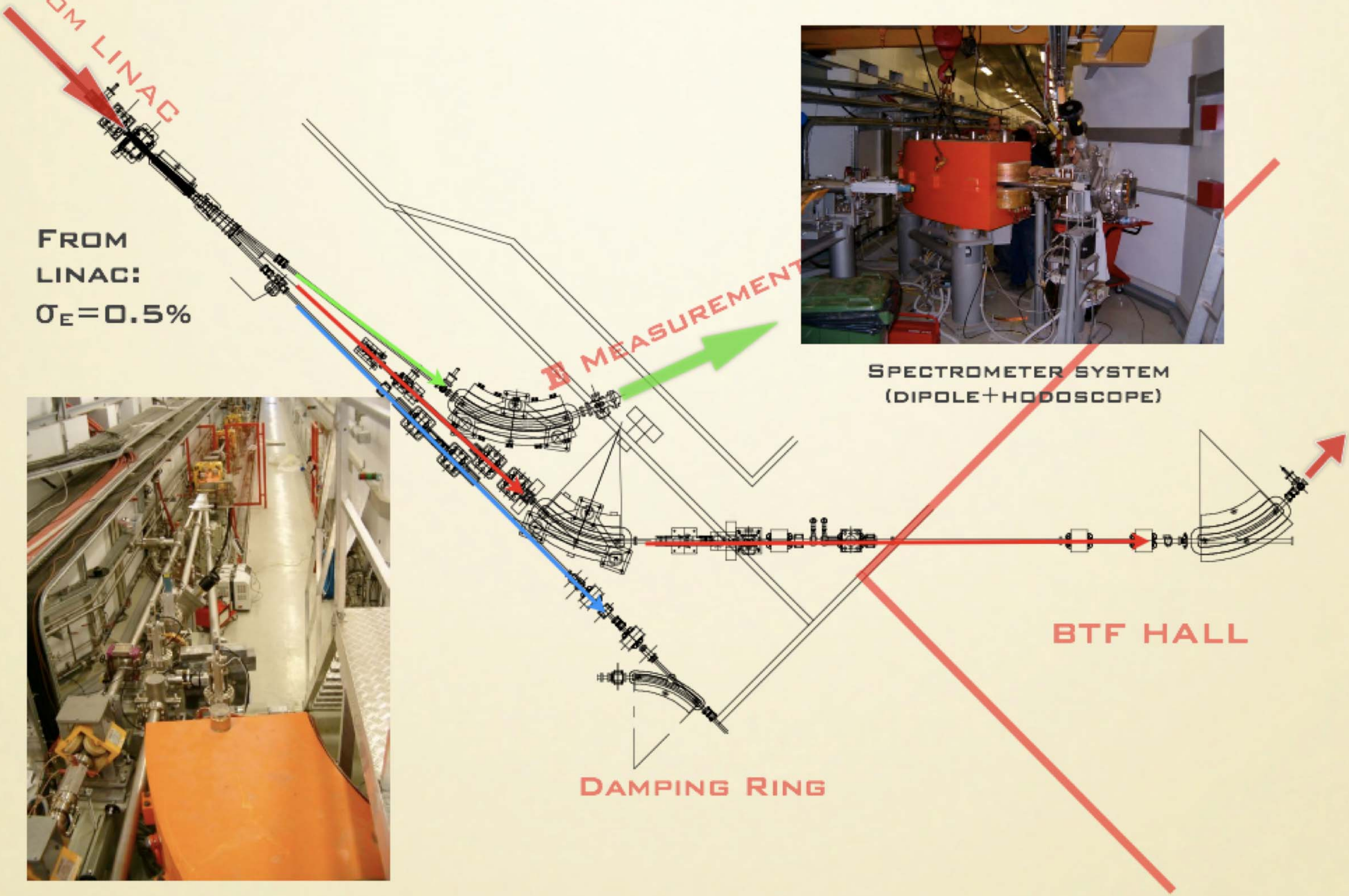
Possibility to have a new european facility in ISO Standard for study and calibration of detectors and instrumentations with application in nuclear physics and radioprotection

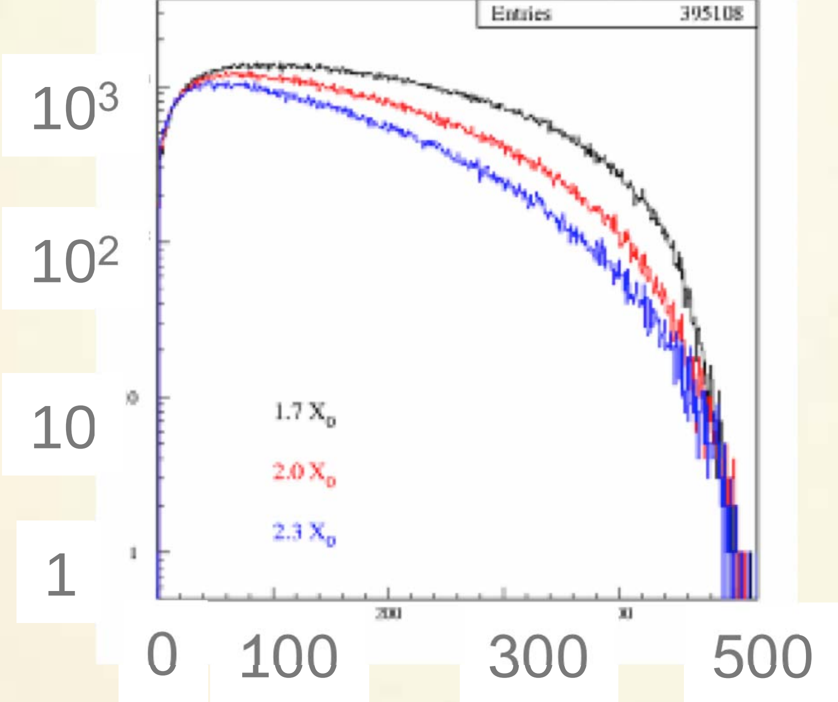
Investigate the feasibility of a cold neutron source (n energy less than 1 eV). This kind of source has a great interest both in fundamental physics and for many other application fields (nano-technology, etc)

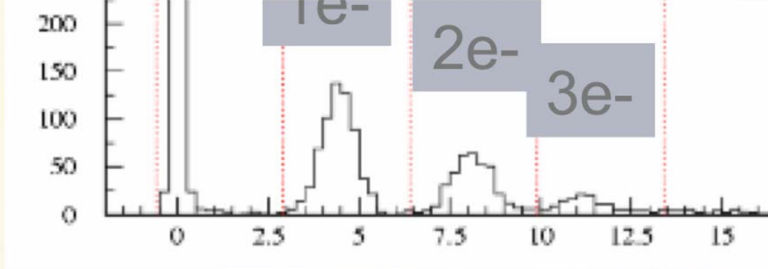


THE DAΦNE COLLIDER

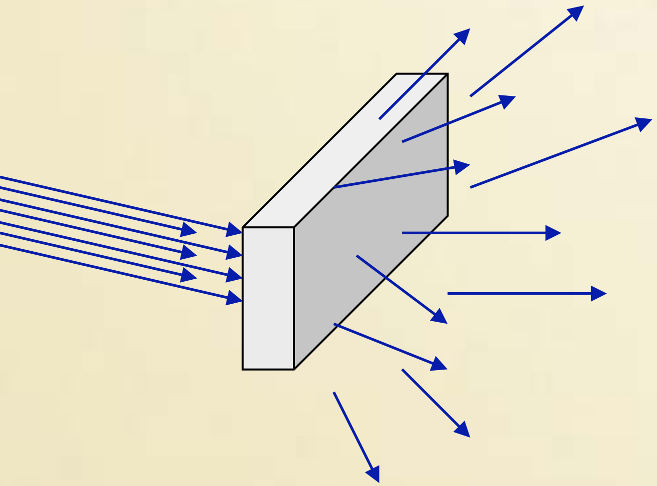
DAΦNE injection Layout

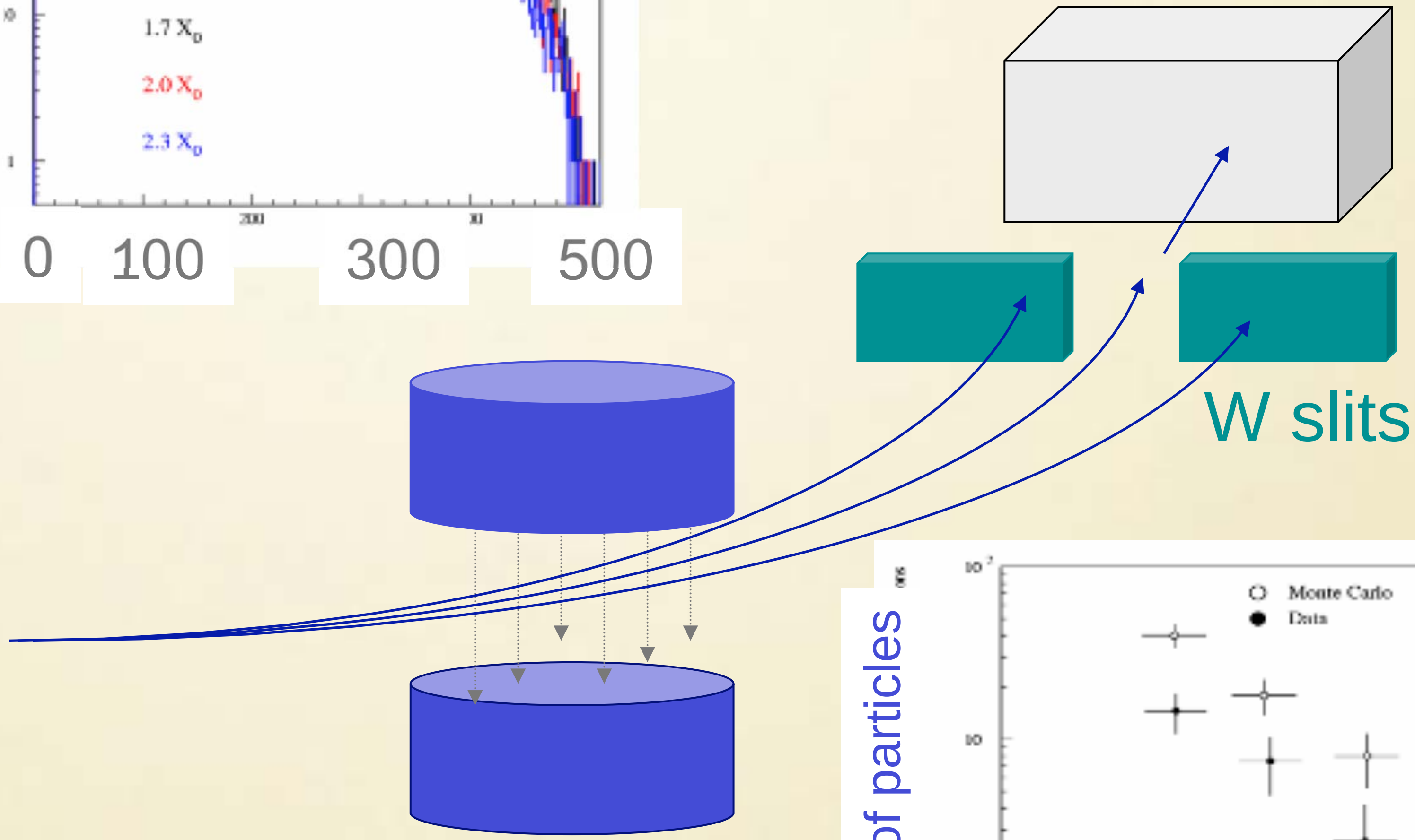




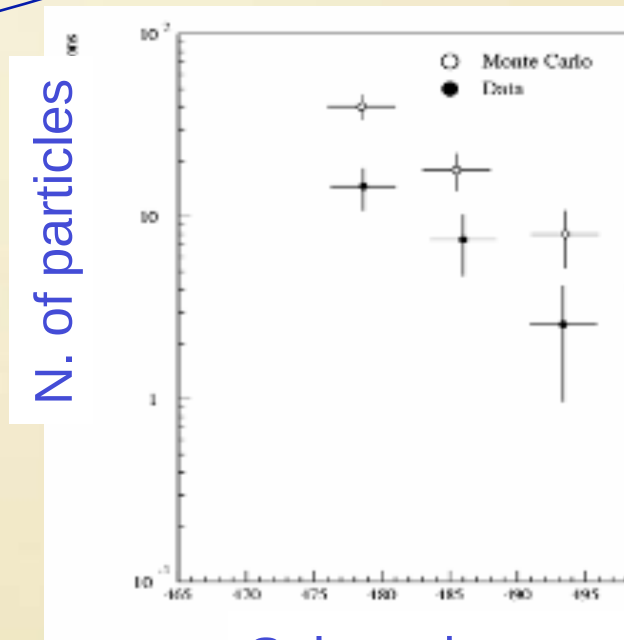


C Beam 1-500 mA



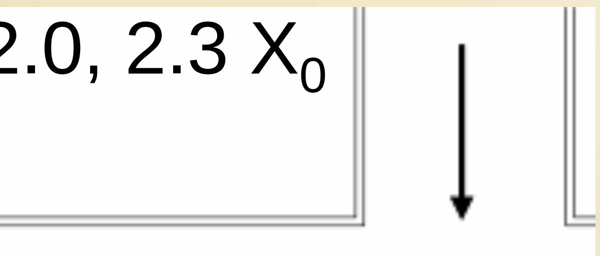


45^0 magnet



ble Cu target:

2.0, 2.3 X_0



BTF PARAMETERS

Parameter	Value
Energy Range	25-750 MeV (e-) 25-500 MeV (e+)
ansverse emittance 510MeV(both planes)	1mm mrad (e-) 10 mm mrad (e+)
ergy Spread @ 510 MeV	1% (e-) 2 % (e+)
Repetition Rate	1-50 Hz
mber of particles per pulse	1-10^10
acro Bunch duration	1 or10 ns
	2mm (single particle)

Maximum Beam Power currently deposited @ 510 MeV

-N = number of particles per bunch
(from 1 to10^{10} particles/bunch)

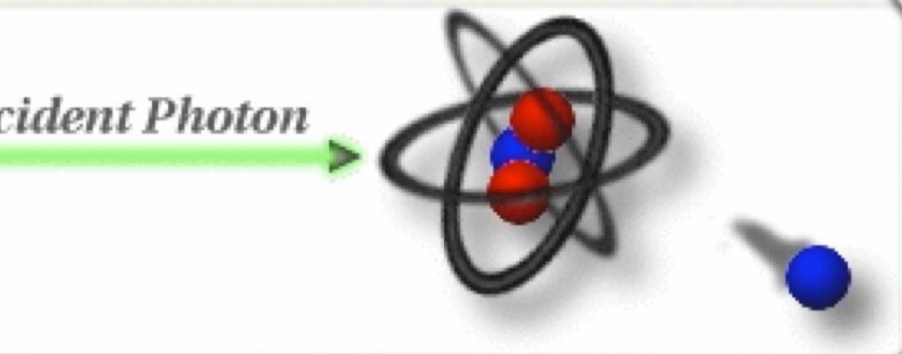
-- f = injection frequency(1-50 Hz) (bunch/s

- E = Beam Energy (nominal energy=510Me

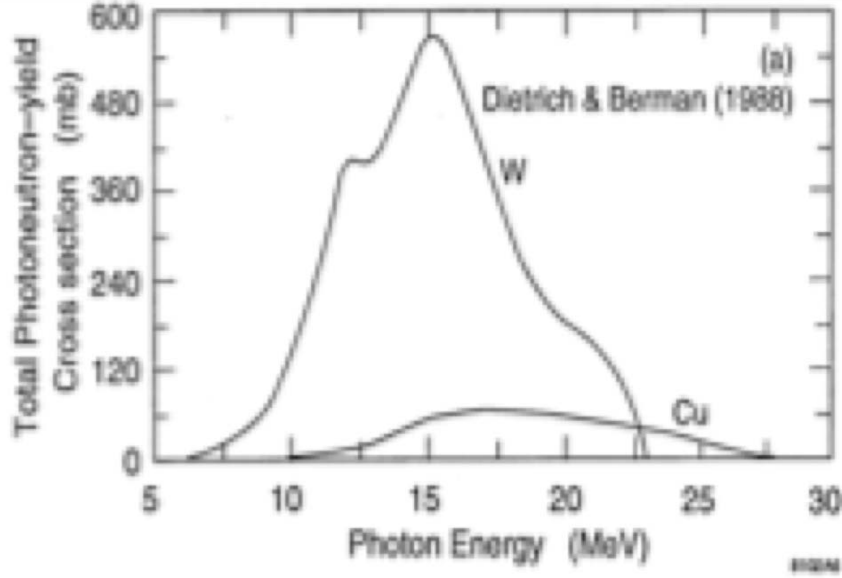
- Maximum RATE[e/s]= N*f =10^{10} *49 = 4.9 1

P_{max}=40 W

ELECTRON INTERACTION WITH TARGET



More than 80% of electron interaction
in the target produces Bremsstrahlung
with continuos spectrum from 0 to E_e.
number of photon in a given energy interval is
nversely proportional to the photon Energy



Typical Photoneutron cross section
behaviour for medium (Cu) and high Z materia

Bremsstrahlung photons are generated when high energy electrons impinge on target

These photons interact with the target nuclei, that are excited. These excited nuclei can emit neutron to come back to the fundamental status

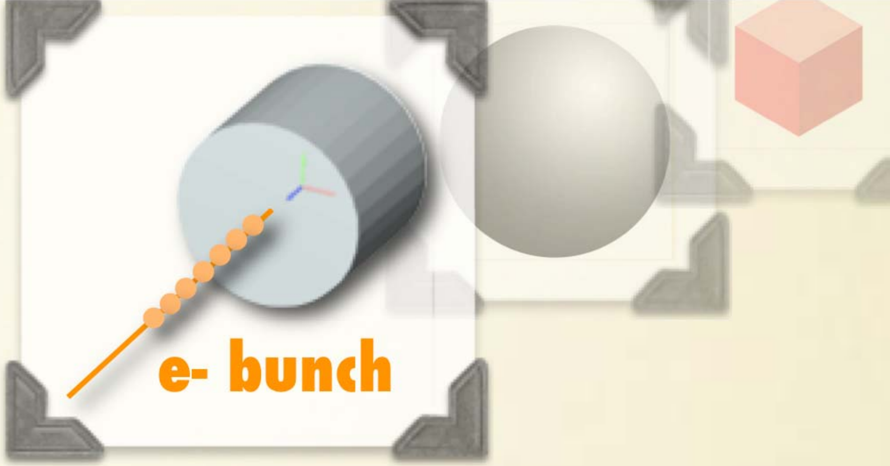
This is a threshold reaction: energy greater than binding energy (5-15 MeV) is needed to release

Protons could be also emitted but the presence of large Coulomb barrier strongly represses this rting point for MC simulations: Fluka

UKA predictions validated by means of
nson semiempirical estimations

CNPX for benchmarking (done)

eant4 Simulations are in progress



uka: Photonuclear implementation

code deals with photonuclear reactions on the whole energy . Photon reactions with nuclei show features which are strongly ng with energy, in correspondence with very different ctions mechanism at the nuclear level. For modelling purpose 4 s are distinguishable:

Giant Resonance
7<E<30 MeV

Quasi Deuteron
Resonance
30<E<200MeV

Delta Resonance
E>140 MeV

High Energy Range
E>720 MeV

REFERENCE:
A. Fassò, A. Ferrari, P.R. Sala
Photonuclear Reactions in FLUKA: Cross Sections and Interaction Models
In: AIP Conf. Proc. 769 (2005) pp.1303-1306

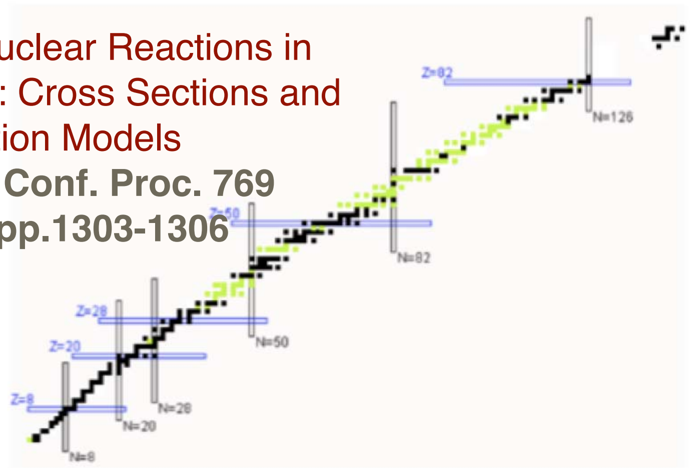
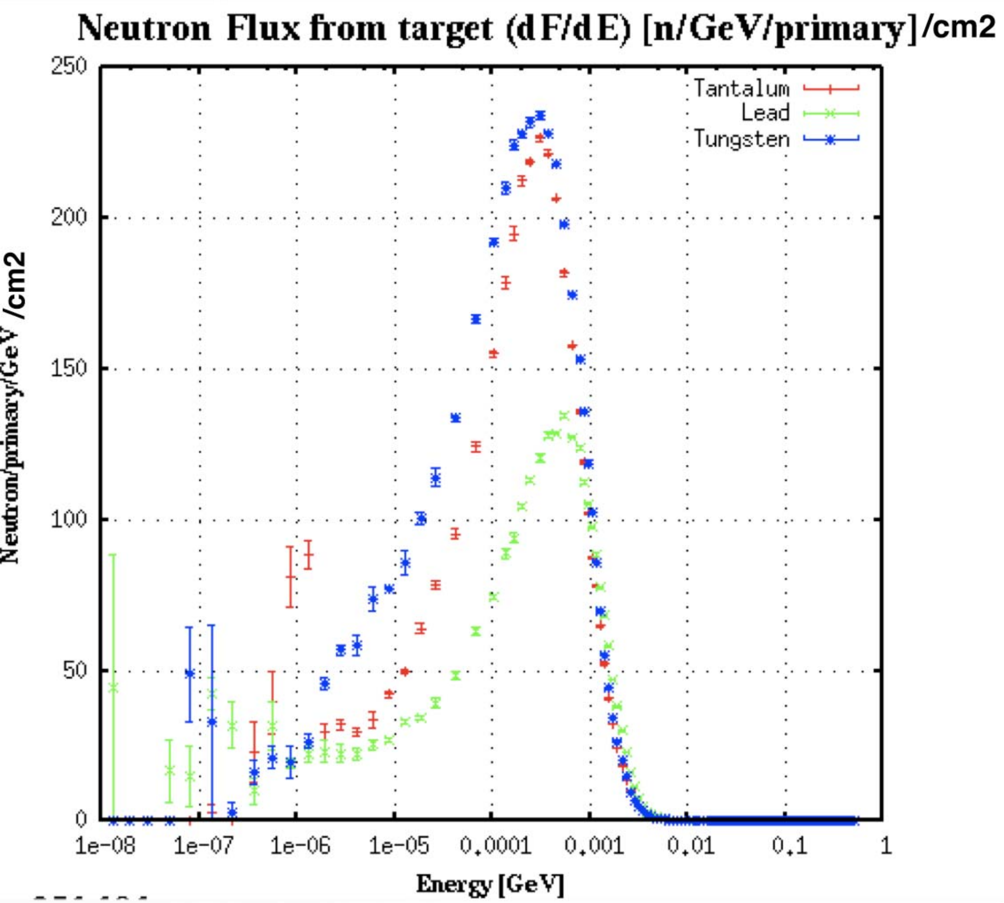


FIGURE 12. The 190 nuclides of the FLUKA GDR to cross section library (black squares). The grey squares indica the stable nuclides not included in the library

Electron beam @ 510 MeV; P_beam=0.04kW; Cylindrical Target (R=10X0, L=10X0)



consequent study of material

Material	Swanson** [n/kW s] *E+12	Fluka* [n/kW s] E +12	n_yiel
Tantalum	2.13	2.37	9.48E
Lead	1.98	2.06	8.24E
Tungsten	2.42	2.67	1.10E

Rate[n/kW/s]=(n/pr)*Ne/(Ne*(510*1.6E-19))=n

The values of Swanson refer to thick targ (≅ 10 X0) and Ee=500 MeV

Validation of Fluka predictions aagainst Swanson semi-empirical correlation**

ast version Fluka 2008.3b.0

eference: slac-pub-2042 (77)

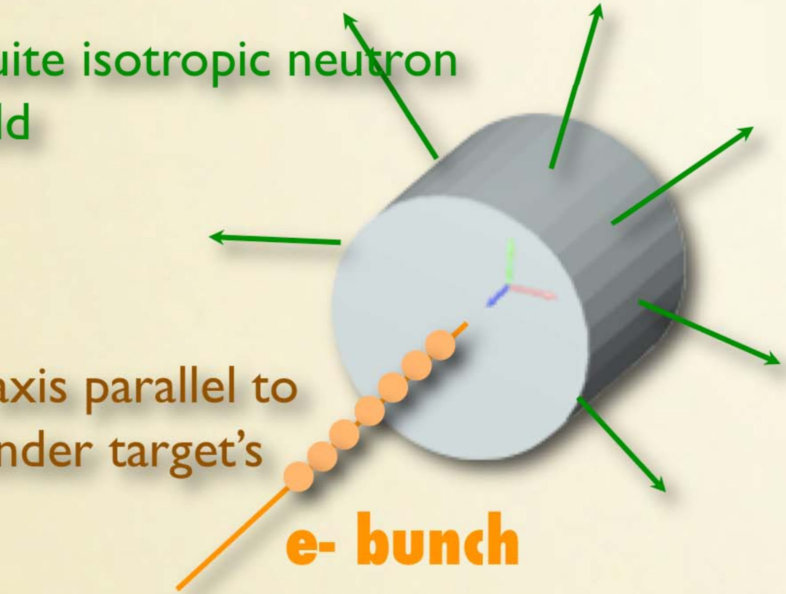
The agreement is very good (difference less than 10 %): this makes us confident in the goodness of MC neutron source

Nuclear and thermo-mechanical properties

Properties	Ta	W
lensità(g/cm3)	16.69	19.25
Z	73	74
P.M (g mol-1)	180.95	183.84
oliere radius [cm]	1.073	0.9327
Rad Length [cm]	0.4094	0.3504
ermal cond)[W/mK]	57.5	173
E(young) [GPa]	186	411
Poisson Ratio	0.34	0.28
pha microm/m*K	6.3	4.5
nelting point) [k]	3290	3695

Thermal Diffusivity
k/(ρ C)
in W ≃ 3 times larger than in Ta

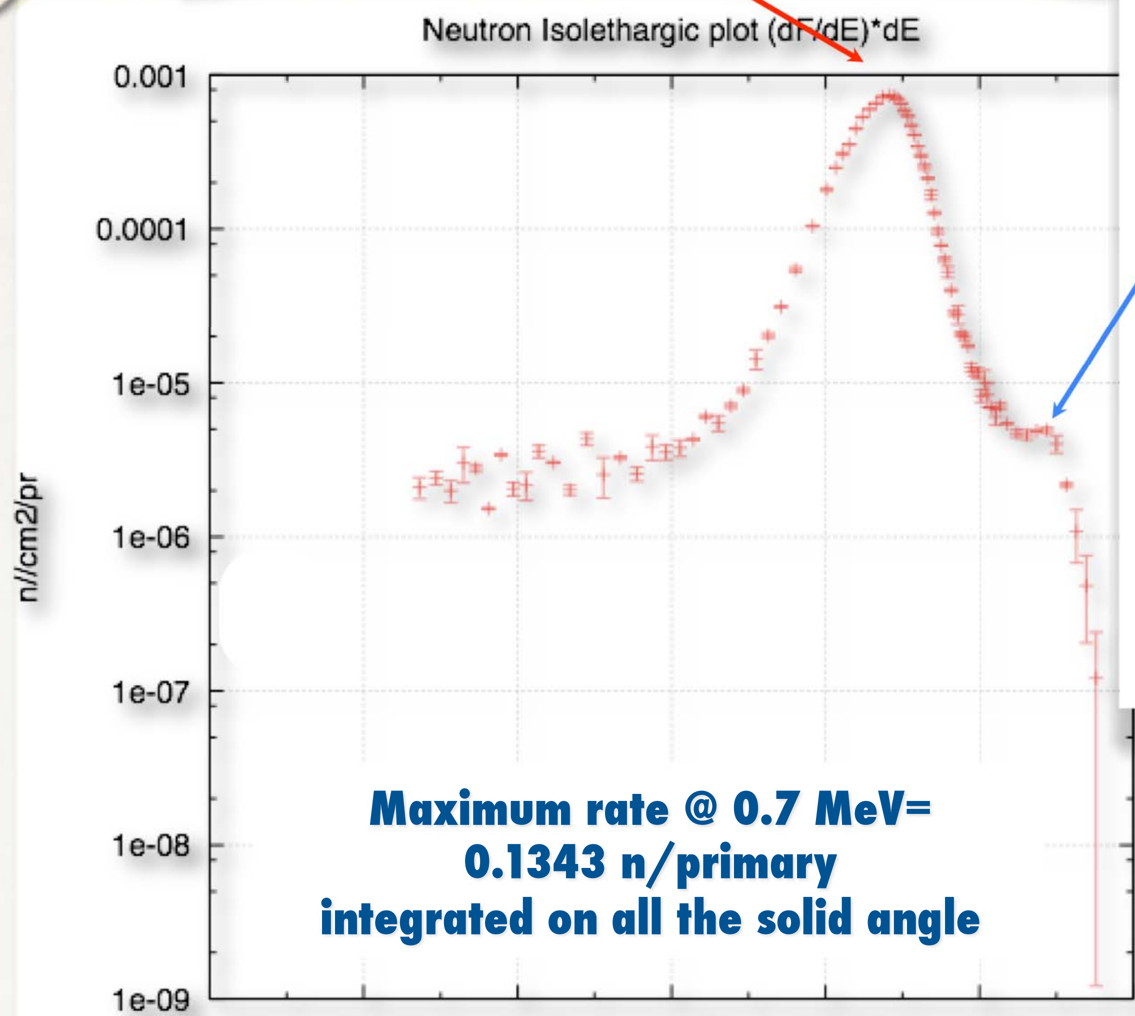
W cylinder R=35 mm L =60 mm(Z=74; ϱ=19 g/cm3; X0=0.35 cm; MR=0.9 cm)



n_yield= 2.12E-01
neutron/primary
integrated on all the
pectrum and solid angle
scaping from the target

on absorbed in the target= 3%
NEU-BAL=0.212451

Up to 100 MeV the spectrum is described as a Maxwellian distribution with average around 1 MeV



Approachin
higher ene
Quasi-Deut
Effects adds
high-energy
neutrons
Giant r
spectrum. T
becomes st
the
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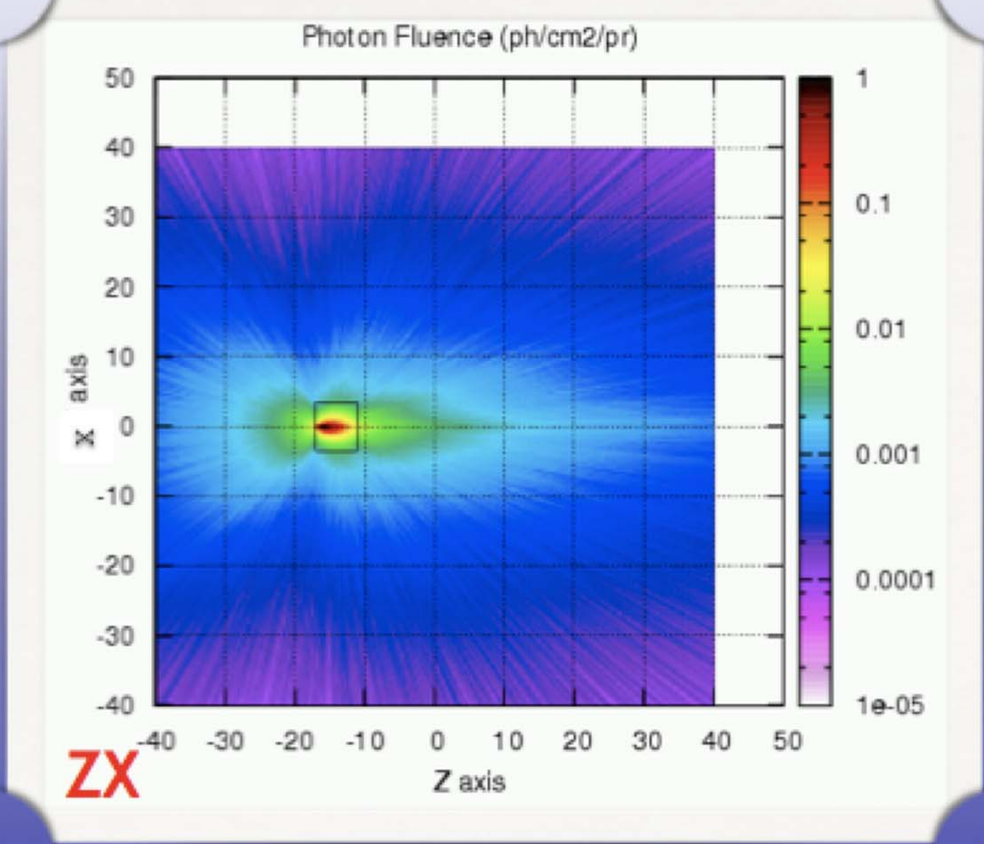
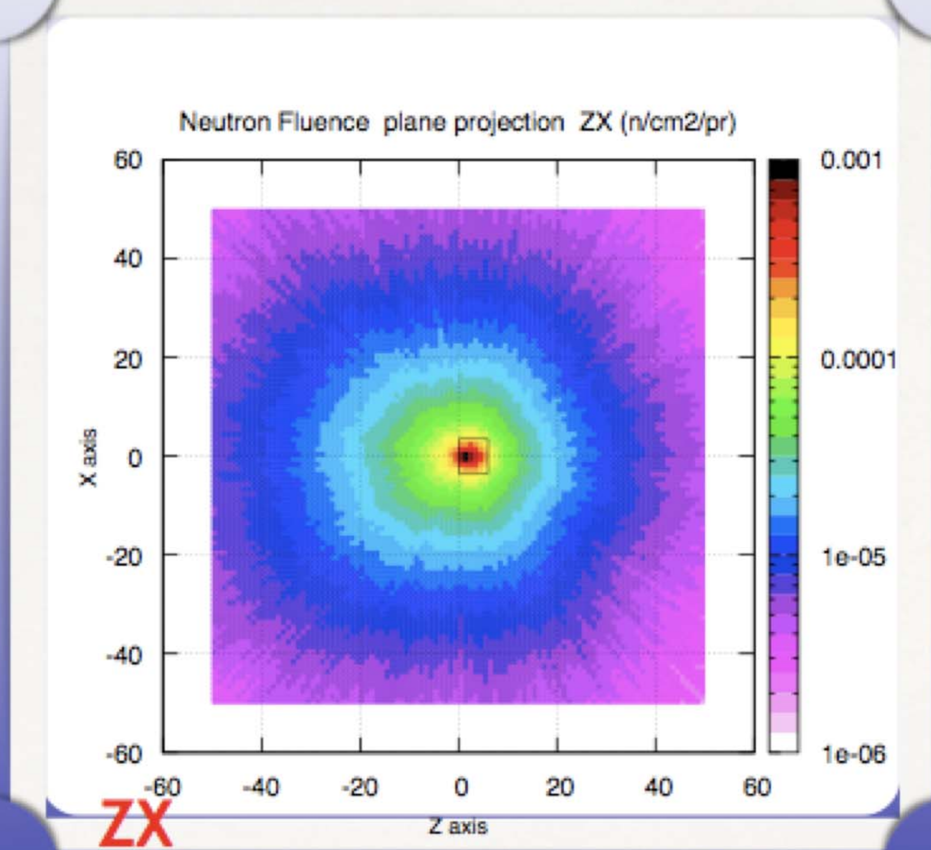
EXPECTED NEUTRONS AND PHOTONS

Spatial distribution





Higher intensity and hardest Gammas in forward direction. More than 2 order of magnitudes of difference in photon fluxes @ 90° and 0 ° wrt beam direction

Quite well isotropic

Expected Neutrons and Photons

Neutron and Photon Flux (Target and air around).

(Calculation with 25000 primaries)

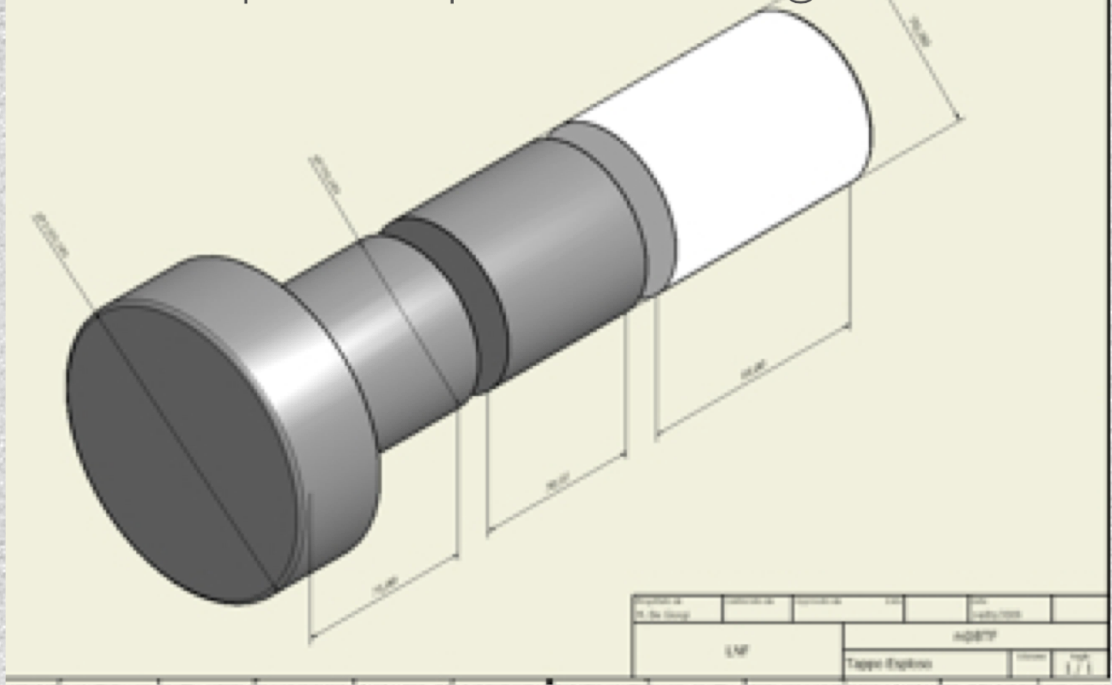
Angle wrt beam direction	Photons[ph/cm2/pr] @0.5 m	Neutron [n/cm2/pr] @0.5 m
0°	1.16559E-02 +/- 1.207616 %	5.78188E-06 +/- 0.5680834 %
-30°	3.18765E-04 +/- 2.074163 %	7.32548E-06 +/- 1.397449 %
30°	2.00091E-03 +/- 0.6900502 %	6.98712E-06 +/- 0.2340965 %
-45°	2.55639E-04 +/- 1.500333 %	6.73067E-06 +/- 1.536476 %
45	9.85524E-04 +/- 0.7157903 %	6.37311E-06 +/- 0.8208705 %
-60	1.80074 E-04 +/- 3.305821 %	5.84105E-06 +/- 1.092179 %
60°	4.76631E-04 +/- 1.785744 %	5.35342E-06 +/- 1.501851 %
90°	9.61925E-05 +/- 4.184312 %	4.37955E-06 +/- 1.058816 %

They are inversely proportional to the square of distance

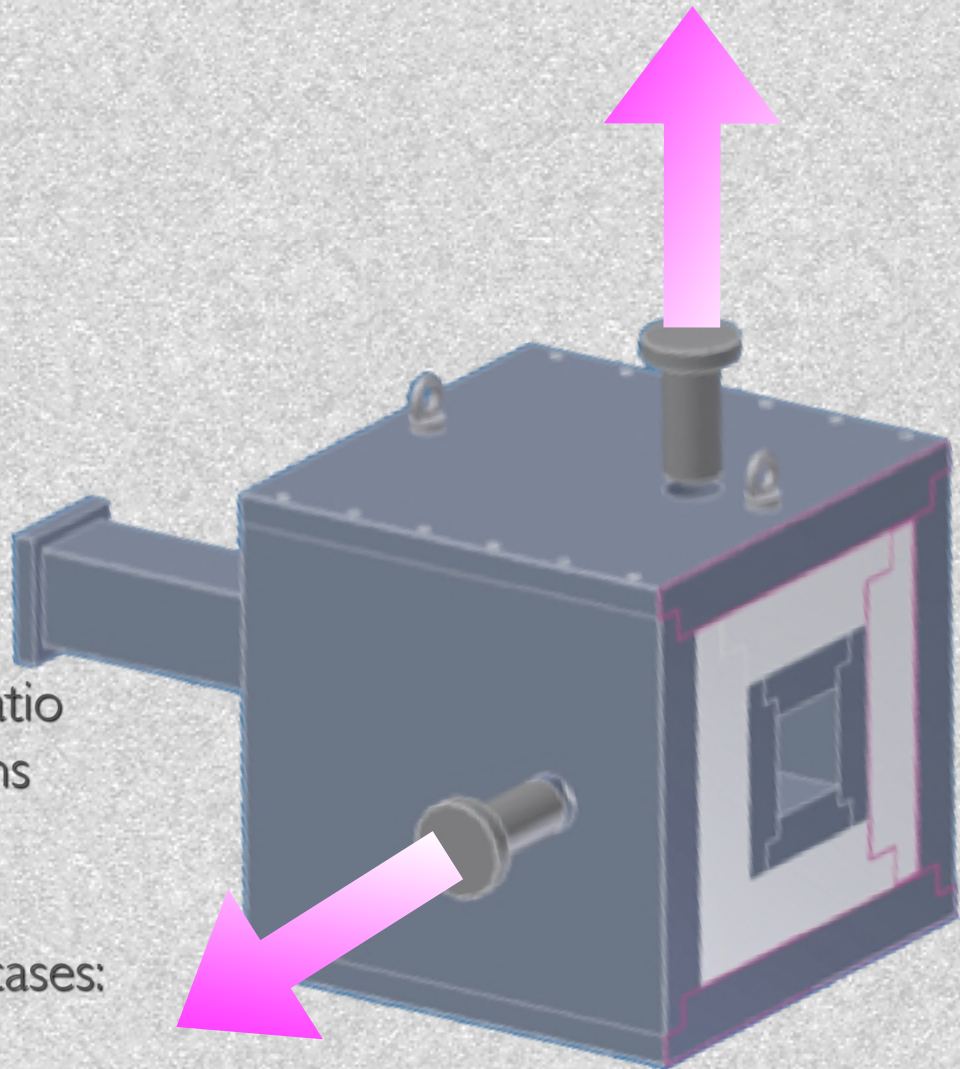
	Photons[ph/cm2/pr]	Neutron [n/cm2/pr]
@ 0.5 m	6.2910217E-04 +/- 0.3605311 %	5.8066257E-06 +/- 0.5866572 %

Experimental set-up

Example of a possible configuration



Extraction lines



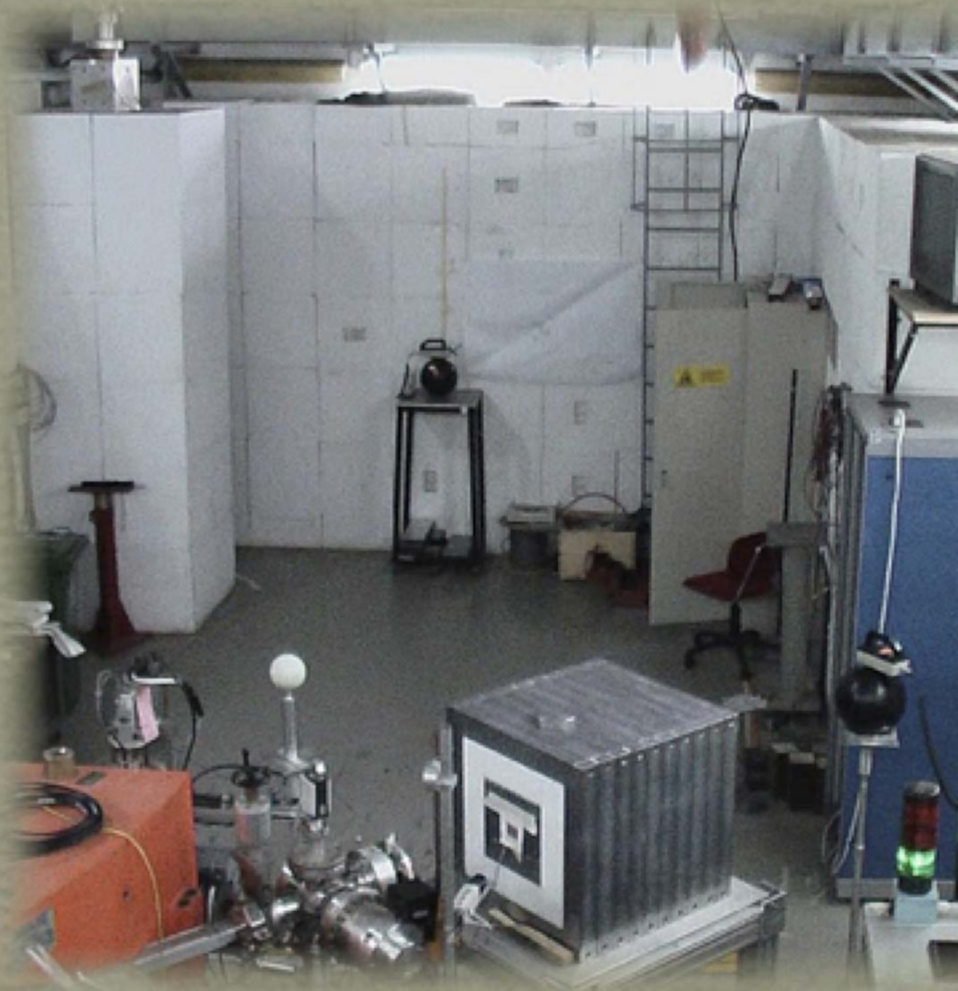
In order to enhance the (n-signal/ph-background) ratio along the extraction lines, several cover configurations have been foreseen and studied and other solutions are under investigations.

In particular we report the results for the following cases:

- 25 cm Lead Cover
- 10 cm Lead Cover
- Fully in air

April 2010

First Measurement May 2010



The inner detecto
thermal neutron) co
passive or active one

•Gold or Disprosiun
(activation foil)
(well suited in pres
high photonic backgr

•ILi(Eu) Scintillator

•TLD

All spheres are designed to hold the scintillator

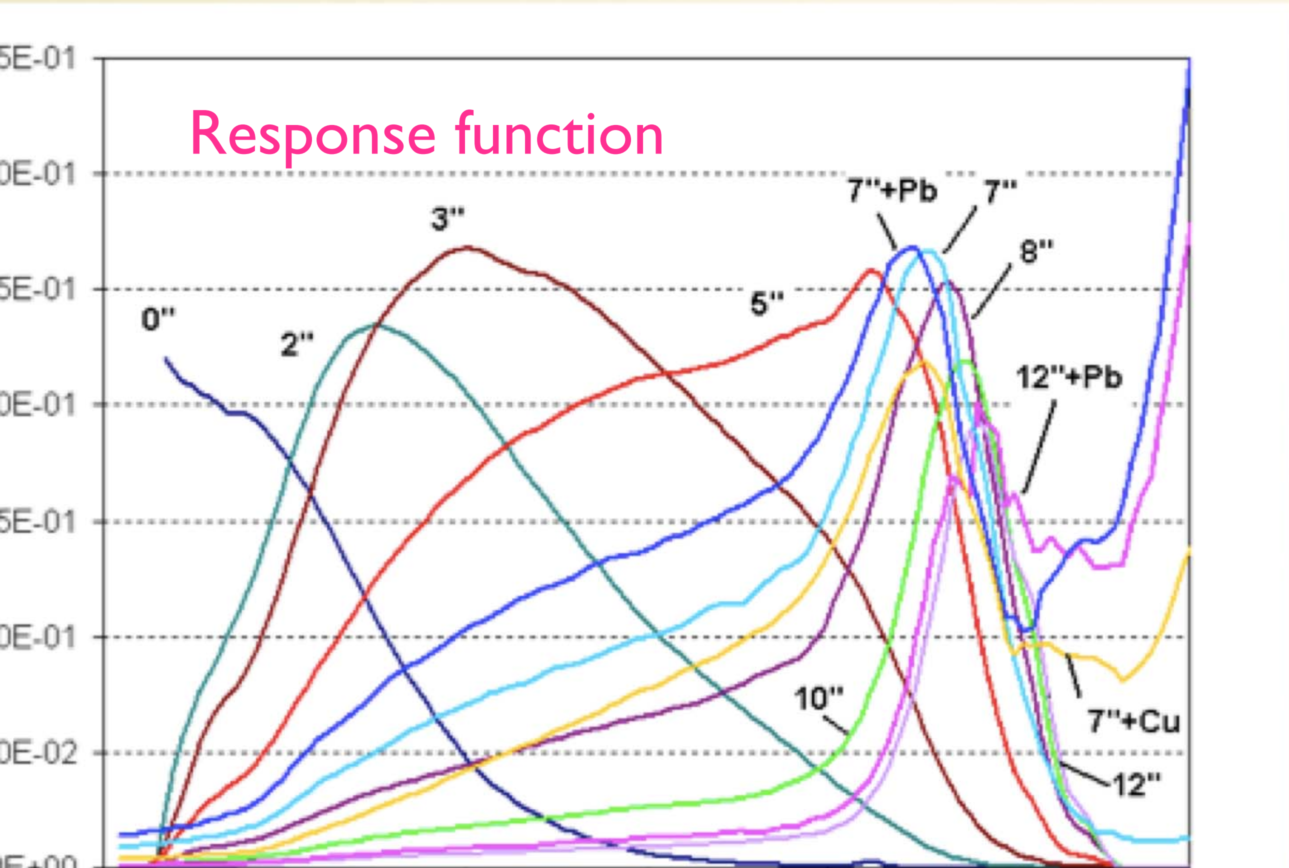
The LNF-ERBSS includes:

- 8 polyethylene spheres (density 0.95 g $\cdot$cm^{-3})

- 3 polyethylene spheres (density 0.95 g $\cdot$cm^{-3}) loaded with copper and lead will work in integration modality using the spheres in sequence (one after another).

exposition time is supposed to be about 2 h for each sphere and it depends on the pr
on beam intensity (and on the effective neutron field if different from prevision).

he responses of the detectors have to be normalized with respect to the primary bear
s to make available a reliable diagnostic instrumentation for the beam current moni



Response functions of the ERBSS were calculated with MCNPX Monte Carlo transport code.

The response matrix of the ERBSS validated in reference neutron fields anc overall uncertainty was estimated to ±3%.

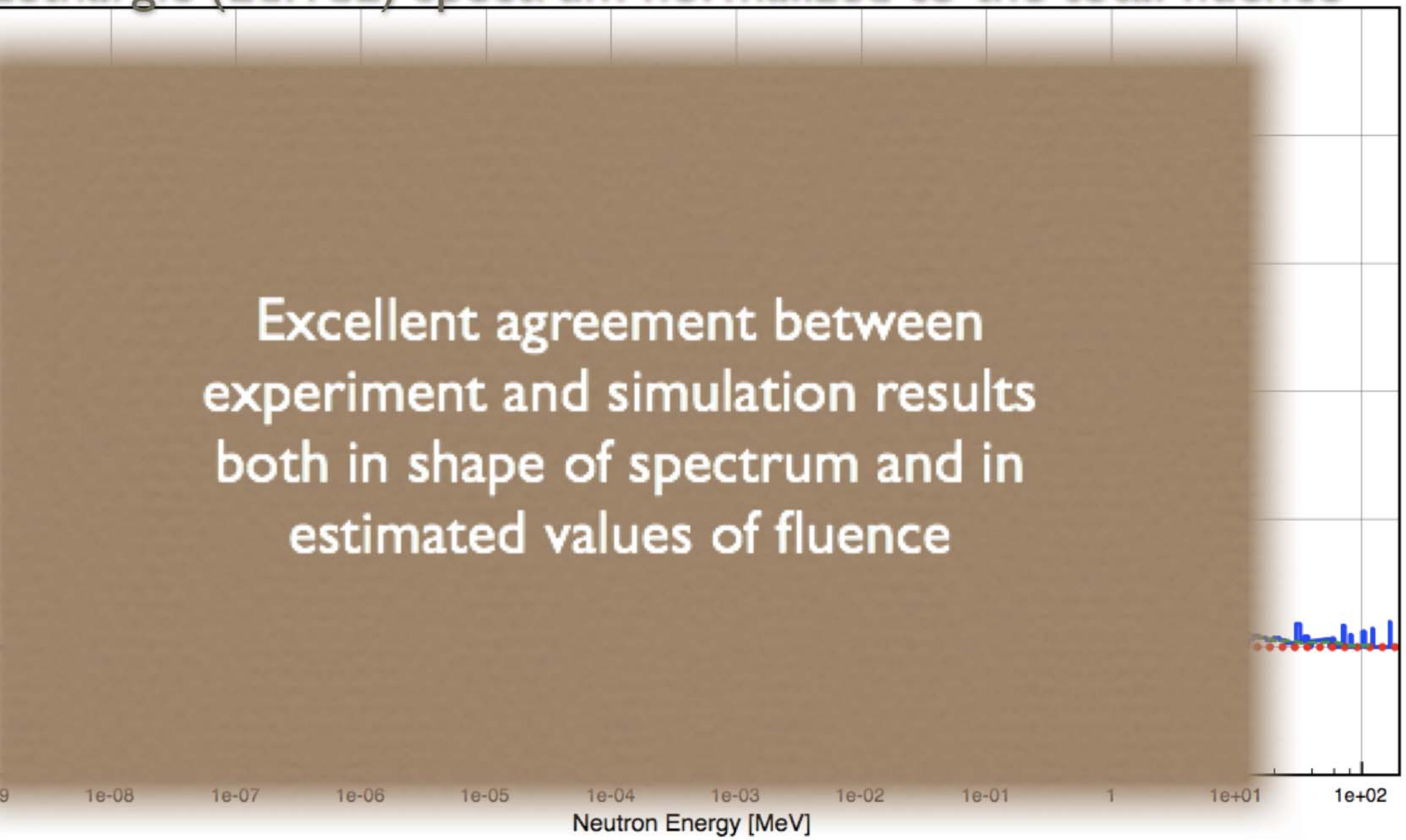
In order to obtain the neutron final spec from the raw data of each sphere a spe unfolding program has been developed Frascati:

FRUIT**
(FRascati Unfolding Interactive Tool)

NEUTRON SPECTRA

int of test was at 150 cm from the target and at 90° wr to the impinging electron beam

Lethargic (EdF/dE) spectrum normalized to the total fluence



The fluence above 10 keV
6.53E-7 cm-2

More than 80% is
around the Giant resonan

Max neutron Flux currently available in BT

- Neutron Flux at 1.5m from
  4E+5 n/cm2/s

corresponds to

otal Neutron Fluence per primary particle		
Measurement	*FLUKA*	*MCNPX*

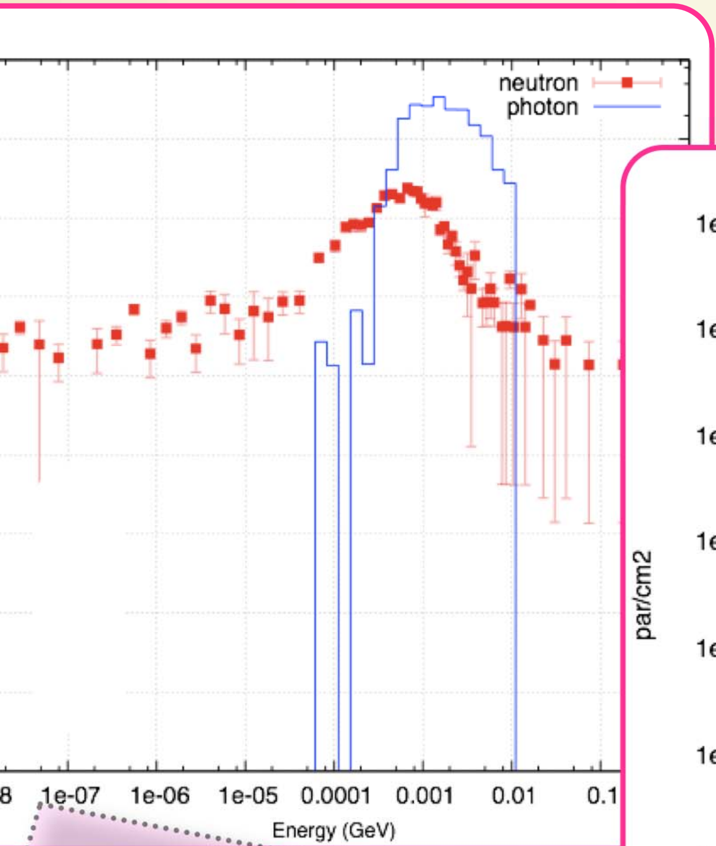
extraction lines

SNR=(R_n/R_{ph})=(ϕ_n*A/ϕ_{ph}*A) where A= accep_detector

These tests are preliminar res
(low statistic: only 3000 primar

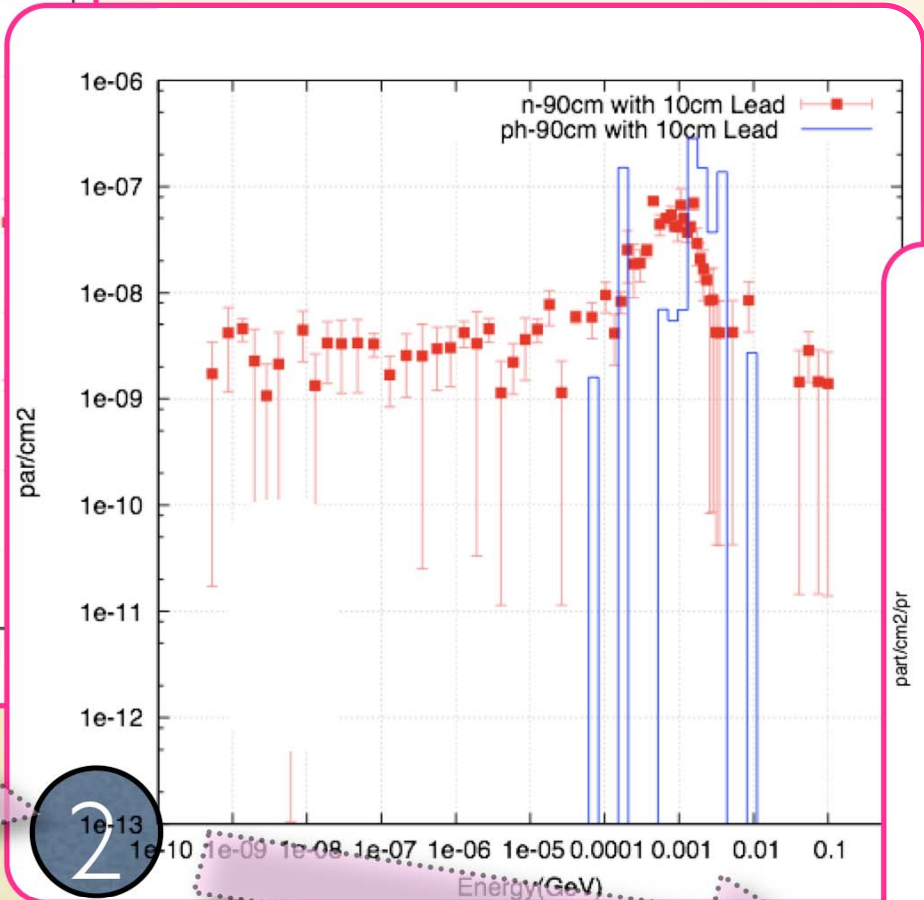
case 1: hole in air

$$R = \frac{1.6319249 \cdot 10^{-3}}{1.5751485 \cdot 10^{-2}} = 0.104$$



case 2: hole cover (10 cm Pb)

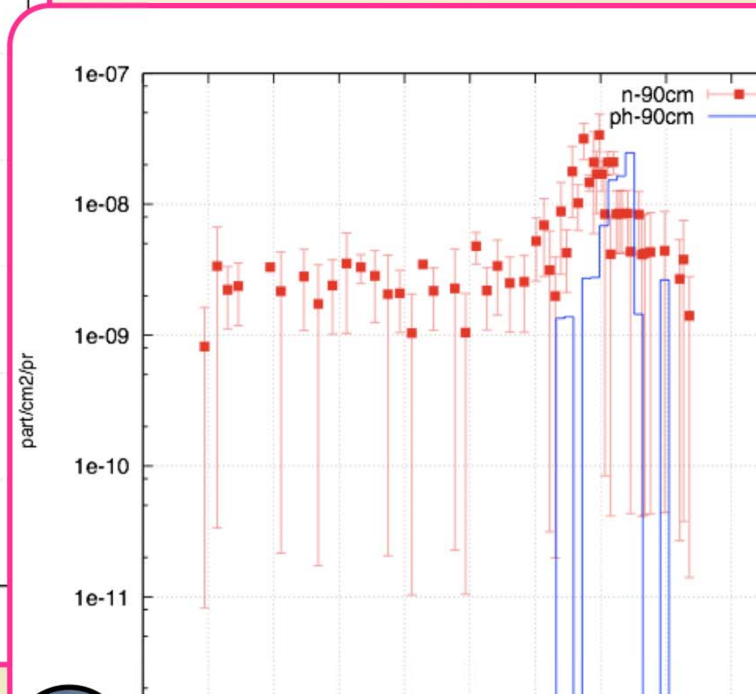
$$SNR = \frac{6.4360496 \cdot 10^{-4}}{6.4834551 \cdot 10^{-4}} = 1$$



2

case 3 hole cover (25 cm

$$SNR = \frac{3.8569755 \cdot 10^{-4}}{6.1961604 \cdot 10^{-5}} =$$



al to noise

e test performed are in very good agreements with
pectation and the facility is starting to operate host
the first users, in the mean time we are:

Benchmarking simulation code

mproving extraction line SNR

ncrease the neutron component shielding
boron chloride 70%)

Testing different solution – materials/thickness – to optimize
eutrons spectra for users (es. hd polyethylene)

mplementation of neutron diagnostic (nescofee@BTF)

Channeling 2010

New BTF operation value

mode	positrons		
Energy range [MeV]	25-500 25 – 750 (*)	100-500 100-750(*)	10^{-9}-2
Repetition rate [Hz]	20 – 49 49 (*)		
Pulse duration [ns]	10 1 or 10 (*)		
Multiplicity	1 up to 10^5 1 up to 10^{10}		4.9 1 n/cm2/el
Duty cycle [%]	~ 80% ~ 96 % (*)		~ 40 ~ 96
Spot size (σ_xxσ_y) [mm]	~ 2×2 ~ 5.5x5.5	>20	-
Divergence [mrad]	~ 1 - 1.7	> 15	-
Energy resolution	< 1%	7%	-

SPARES

w many neutrons exit the shield?

w many neutrons arrive to a spherical detector (D=60 cm) with center at 1m of distanc

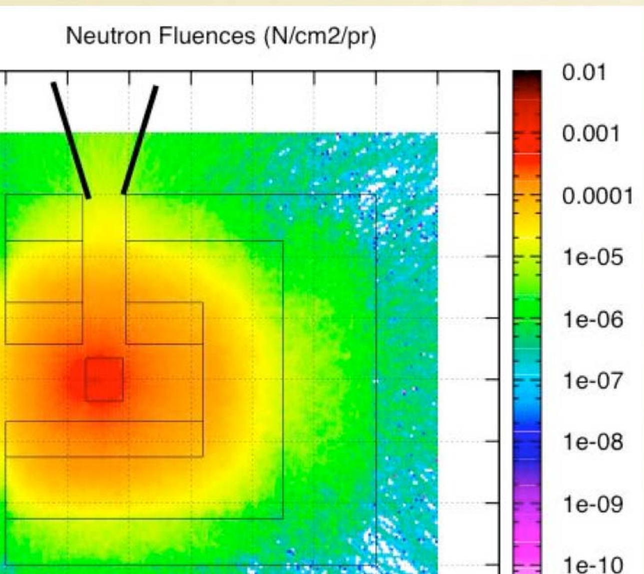
n@BTF	FLUX n/cm2/s (all spectrum)	CURRENT[n/s] (on all solid angle and spectrum)
ing the get=ϕ1 (A)	8.80E+08	1.10E+11
ering the ld=ϕ2 (B)	2.30E+08	7.70E+09
ing the ld=ϕ3 (C)	2.50E+07	9.60E+08
m from ld=ϕ4 (D)	3.0E+5	8.00E+08

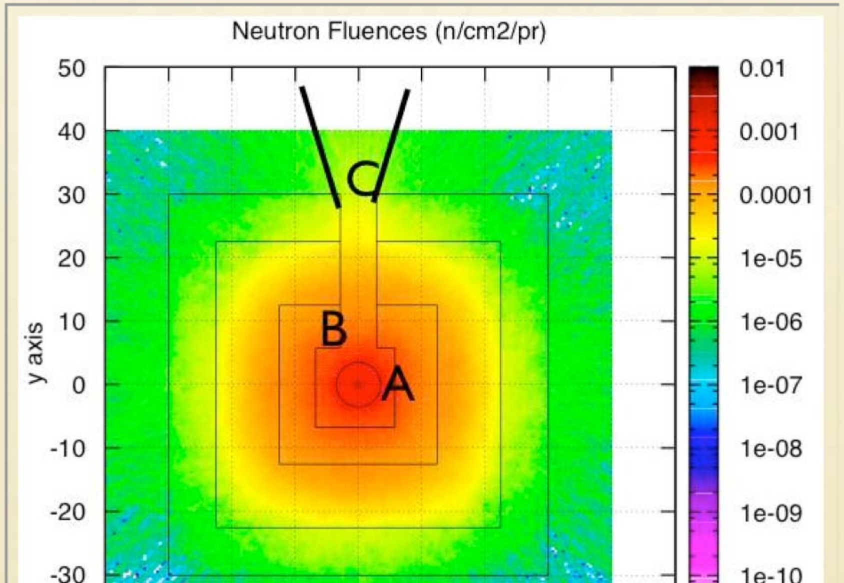
Max Neutrons Available @ BTF (on extraction line)

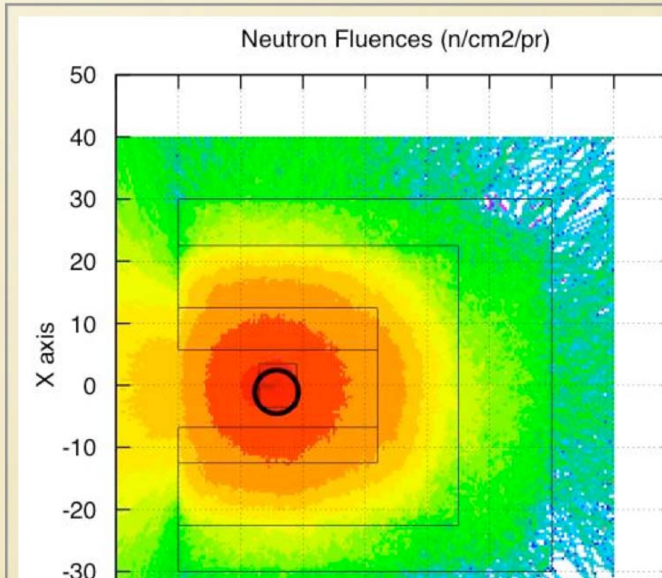
- Neutron Flux at 1m from shiel
  3E+5 n/cm2/s

corresponds to

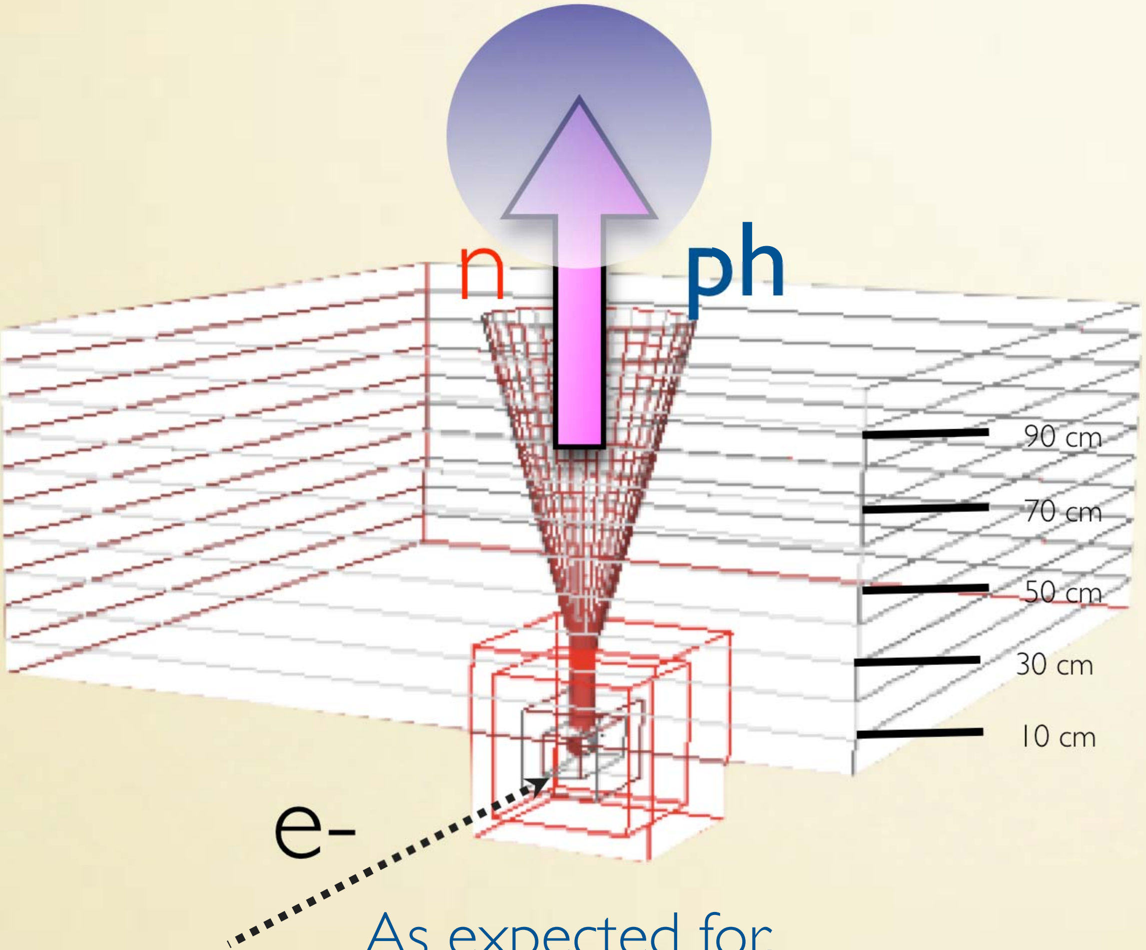
- Equivalent Dose=**43 mSv/**







the BTF Maximum Electron Beam= 5E+11 e/s, the neutron current (integrated o
rum) entering on a spherical detector (Bonner Sphere) of 60 cm diameter at 1m from
has been estimated to be **I_n= 8.E+8n/s**



As expected for,
the neutron spectrum shape along the
traction line in air remains essentially unmodified
whereas, the intensity of fluxes decreases
ccording the inverse of square distance from
the neutron source