Beam test possibilities at JINR and Fermilab

V. Pronskikh
Fermilab
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Outline

- JINR: Accelerator and reactor park
  – Nuclotron, Phasotron, PFR-II
- Neutron production targets at JINR
  – GAMMA-3, KVINTA, GENERATOR
  – Beam tests on December 2011
  – First observations related to Mu2e backgrounds
- Irradiation facilities at Fermilab
  – MTest
  – Muon Test Area,
  – Neutron Therapy
  – ES&H Instrumentation
  – MI Collimator
- Conclusions

Joint Institute for Nuclear Research, Dubna

JINR MEMBER STATES

Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Czech Republic

DPRK, Georgia, Kazakhstan, Moldova, Mongolia, Poland

Romania, Russia, Slovakia, Ukraine, Uzbekistan, Vietnam

26 March 1956

Agreements are signed on the governmental level with (associated members)

Egypt, Germany, Hungary, Italy, RSA, Serbia

105
Db
262
Dubnium

JINR basic facilities

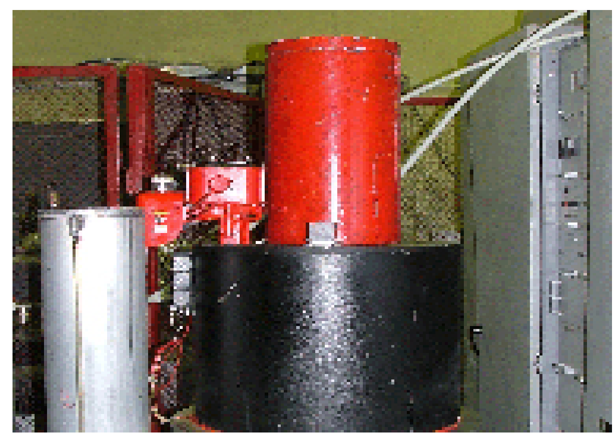
Nuclotron

U 400

U 400 M

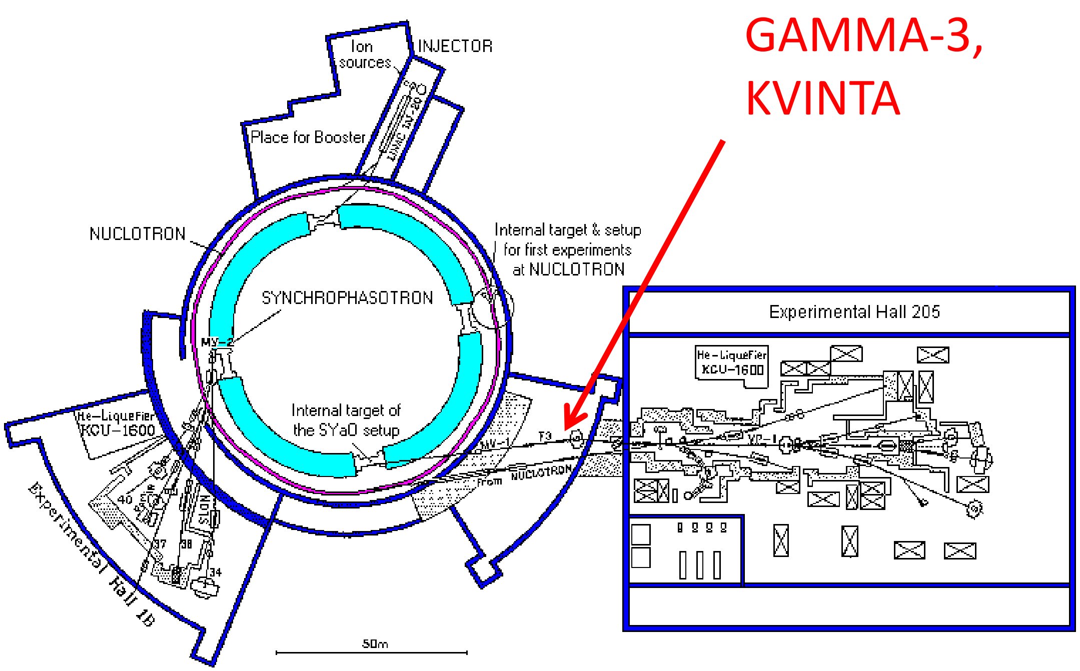
IBR-2

Phasotron



IREN

Nuclotron - superconducting synchrotron



Accelerated particles	Intensity charge/pulse	Pulse duration
p	$1.5\cdot10^{14}$	500µs
d	$1.0\cdot10^{14}$	500
$_4He^2$	$1.0\cdot10^{13}$	500
$_3He^2$	$3.5\cdot10^{11}$	500
$_7Li^3$	$5\cdot10^{10}$	15
$_6Li^3$	$3\cdot10^{9}$	15
$_{12}C^6$	$6.5\cdot10^{10}$	25
$_{16}O^8$	$6\cdot10^{9}$	10
$_{19}F^9$	$2.5\cdot10^{9}$	6
$_{22}Ne^{10}$	$2\cdot10^{7}$	40
$_{24}Mg^{12}$	$2\cdot10^{8}$	25
$_{28}Si^{14}$	$1\cdot10^{8}$	25
$_{32}S1^{6}$	$4\cdot10^{6}$	80
$_{40}Ar^{20}$	$2.5\cdot10^{6}$	80
$_{84}Kr^{29}$	$1\cdot10^{6}$	80
d (polarized)	$2.5\cdot10^{10}$	100

Max. energy 6 (4.2) AGeV, magnetic field 2 (1.5) T
Slow extraction duration 10 s,

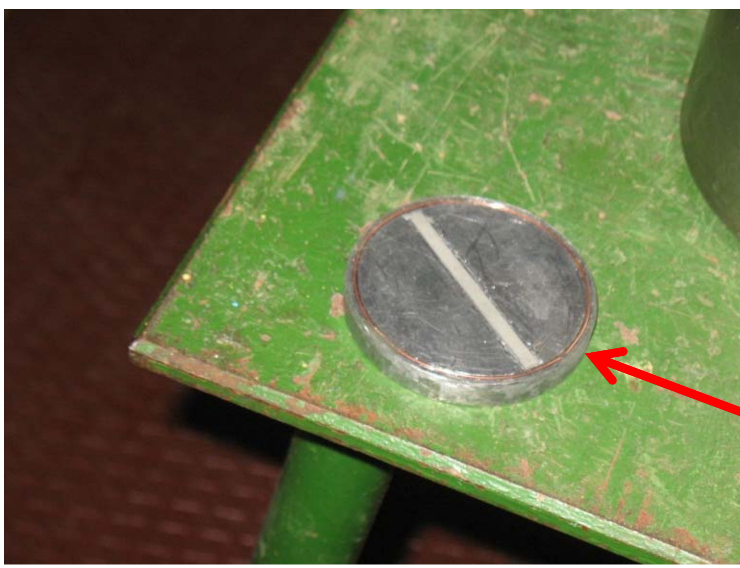
Actual deuteron intensity 1E10 d/spill (~1E9 d/s)
Run duration up to 30 hours

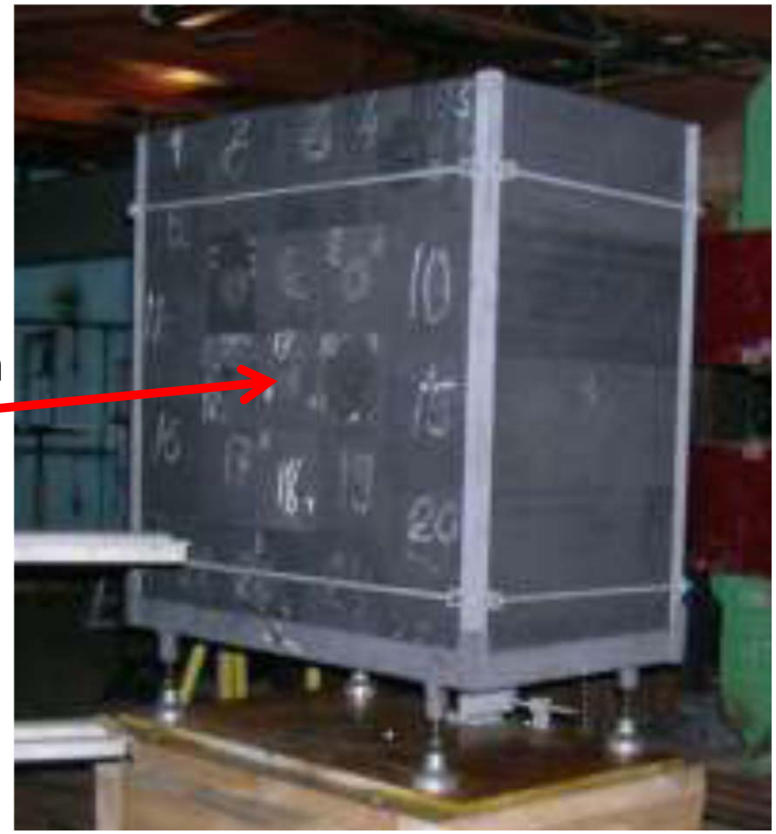
Why and how

"On proposal to measure irreversible DPA", Mu2e-doc-1996-v1, October 2011

- Residual nuclides produced in the course of nuclear transmutation at En > 30 MeV become irreversible DPA (cannot be annealed).
- There is no such process at a reactor (En<14 MeV), cannot measure at it. Will take place at Mu2e conditions.
- Need
  - Accelerator of high enough energy.
  - Spallation target.
- Can measure
  - Total DPA (need a special cryostat and dedicated experiments (special arrangements)) – future ?
  - Just samples of known (measured) RRR before and after irradiation. Can be put in an existing setup not distracting other experiments. Transmutation experiments are the best fit for such synergy.

Samples irradiated at GAMMA-3 setup @ Nuclotron





d beam

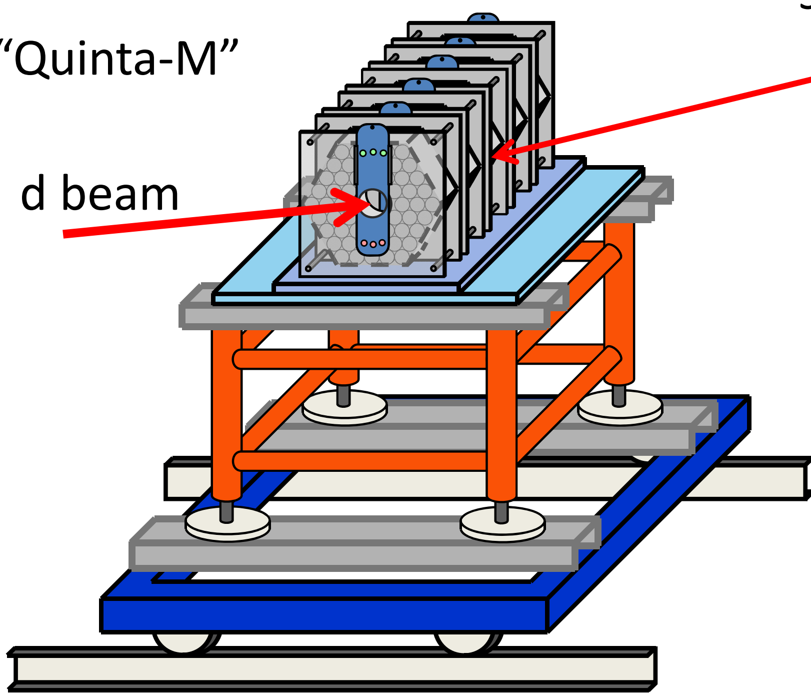
The samples were placed at the depth of 10 cm inside the target

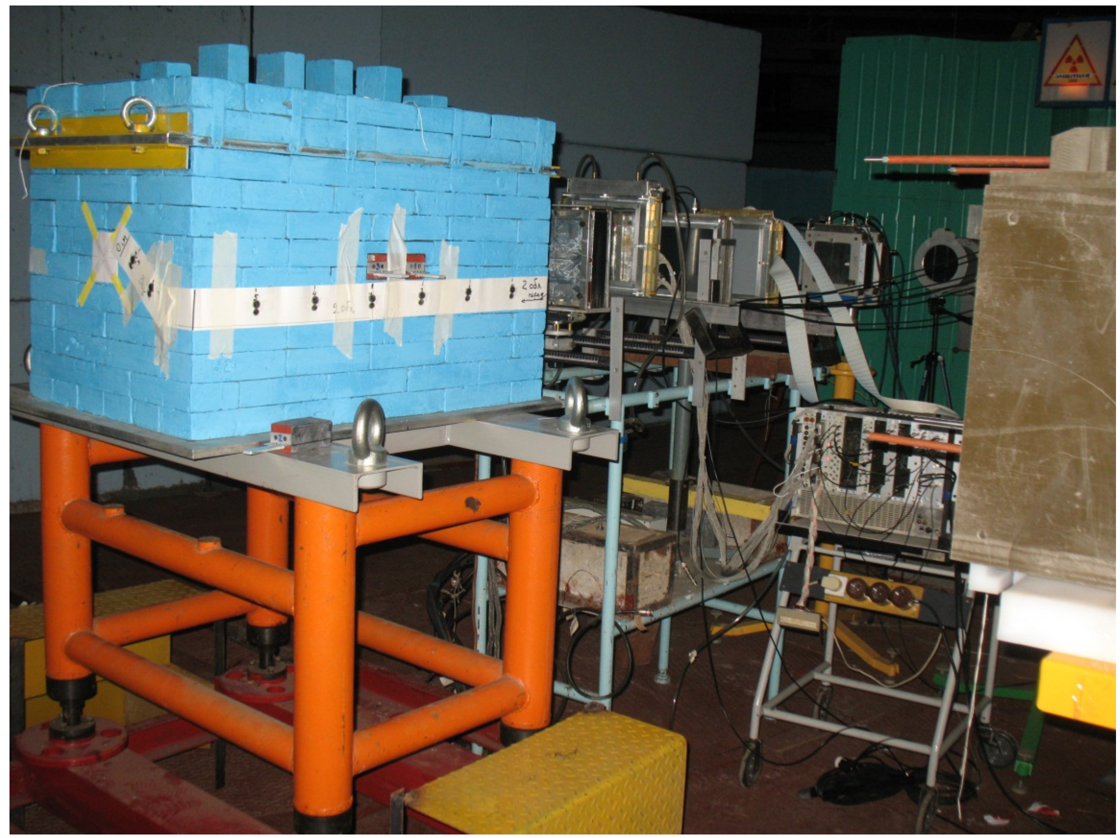
KVINTA setup at the deuteron beam

samples

“Quinta-M”

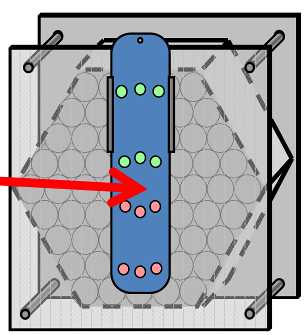
d beam





samples

$m_{section} \approx 111$ kg



Irradiation schedule for December 2011 at Nuclotron accelerator

Setup	Deuteron kinetic energy per nucleon	Deuteron fluence
GAMMA-3	0.8 AGeV	~1.7E13
KVINTA	0.5 AGeV	~1E13
KVINTA	2.0 AGeV	~1E13

1-st set of samples has been irradiated at GAMMA-3

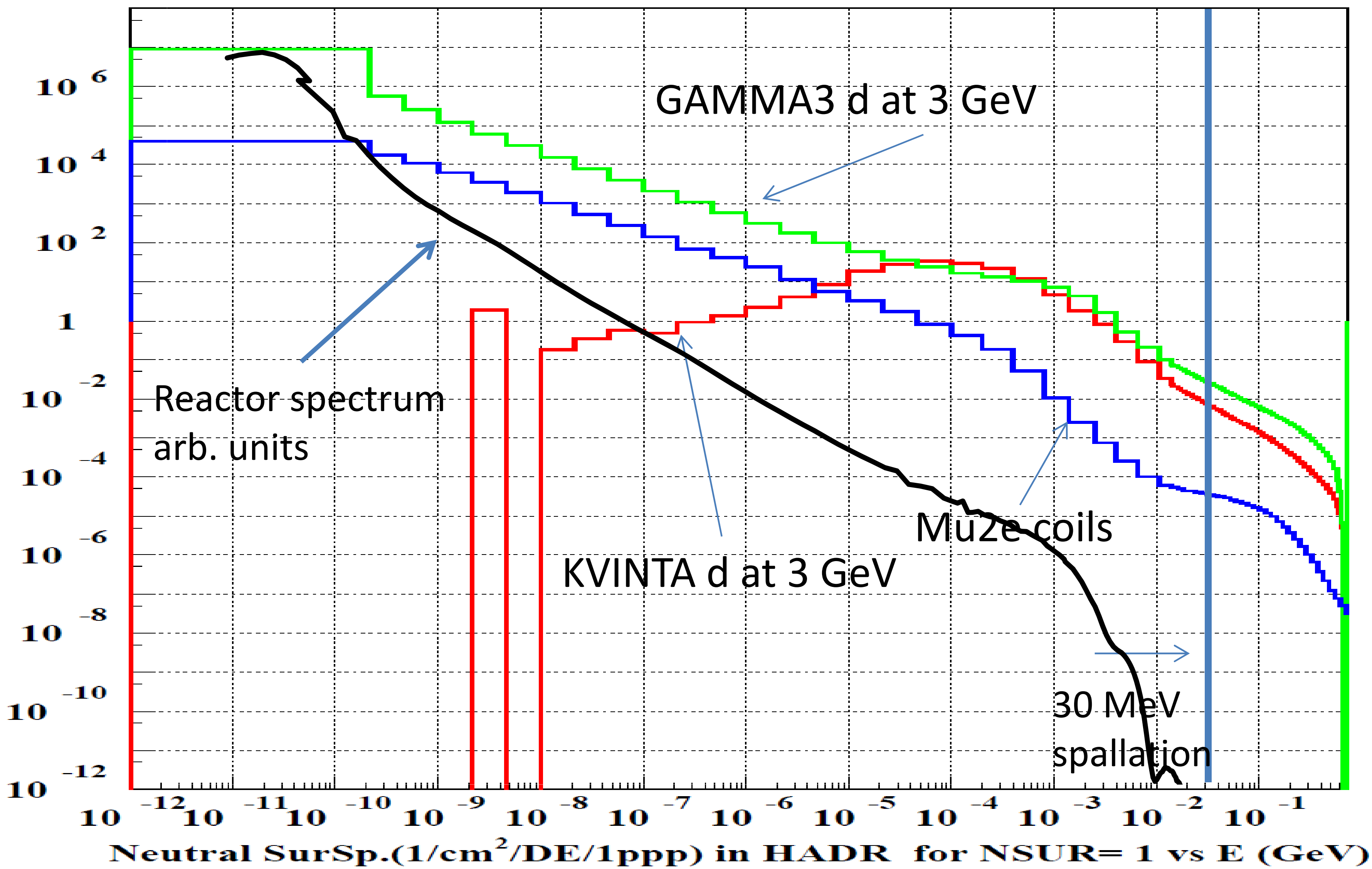
2-nd set of samples has been irradiated at KVINTA (in both runs, spectra were measured after each run), neutron fluence ~ 1-3E7 n/cm^2/s

3-rd set of samples will (hopefully) be irradiated on a Pb-Bi target irradiated by 660 MeV protons at Phasotron accelerator (preliminary a month later)

4-th set of samples will (hopefully) be irradiated at a reactor (0.8 MeV) at ~E17 n/cm^2

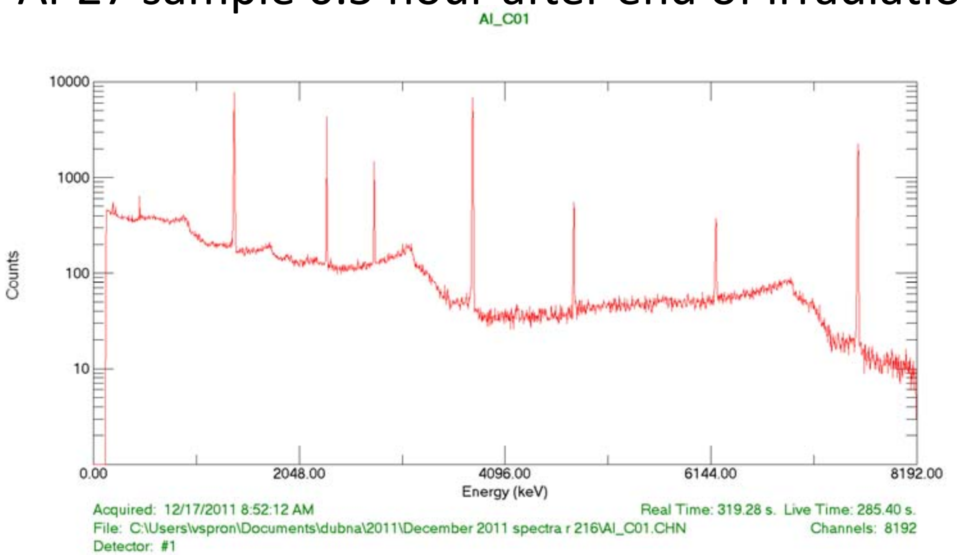
5-th set is a control one (not to be irradiated).

Secondary neutron spectra of Mu2e PS coils, KVINTA and GAMMA3 at 3 GeV, a Reactor

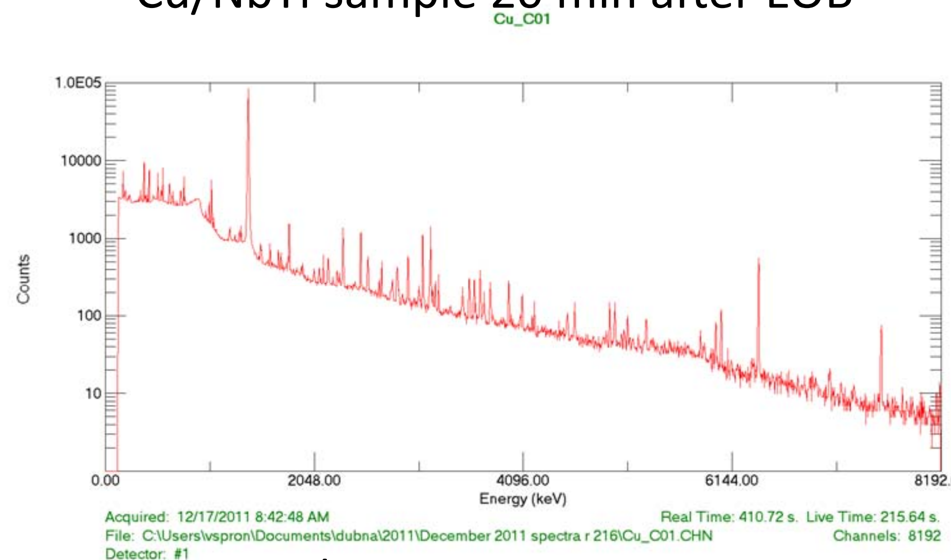


Gamma-spectra of samples after two KVINTA irradiations (0.5+2.0 AGeV)

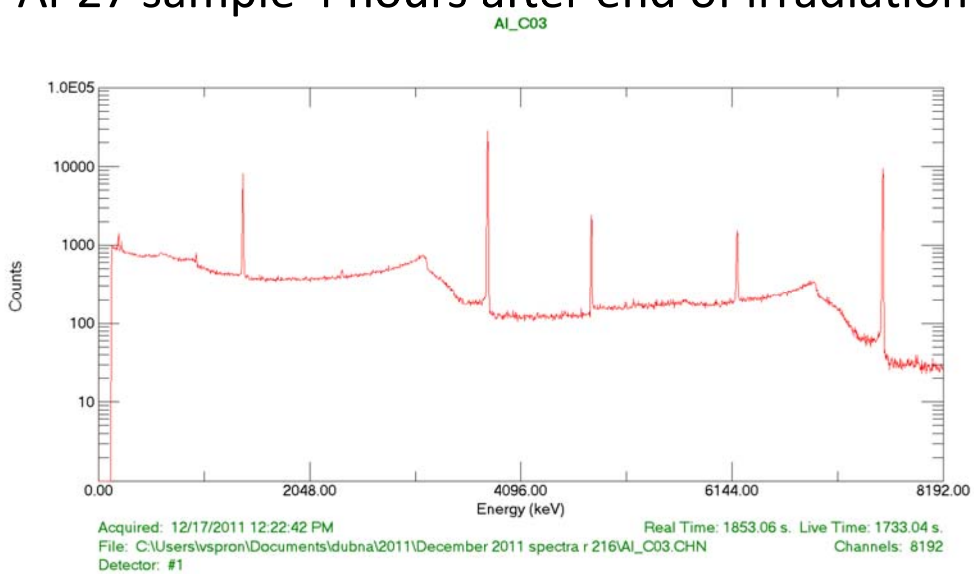
Al-27 sample 0.5 hour after end of irradiation



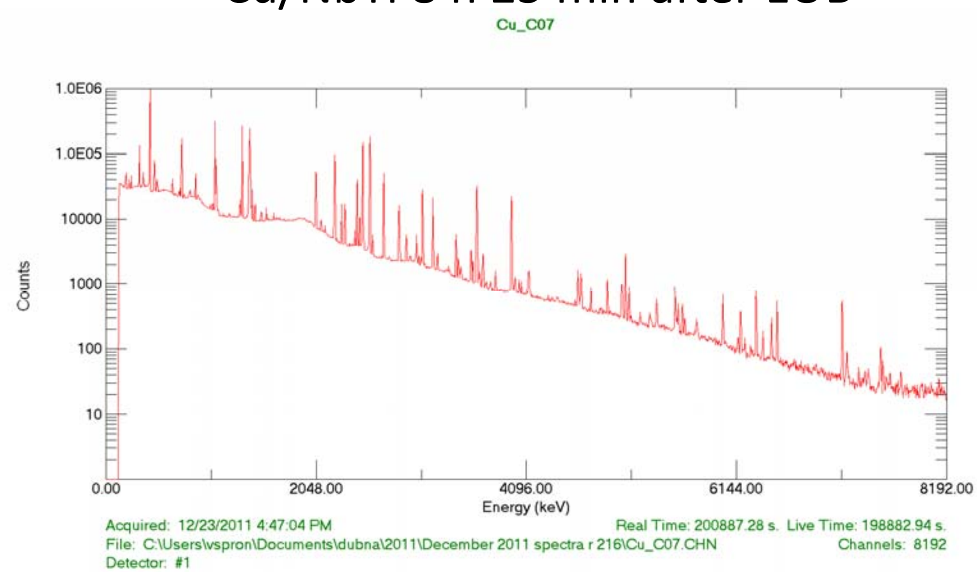
Cu/NbTi sample 20 min after EOB



Al-27 sample 4 hours after end of irradiation

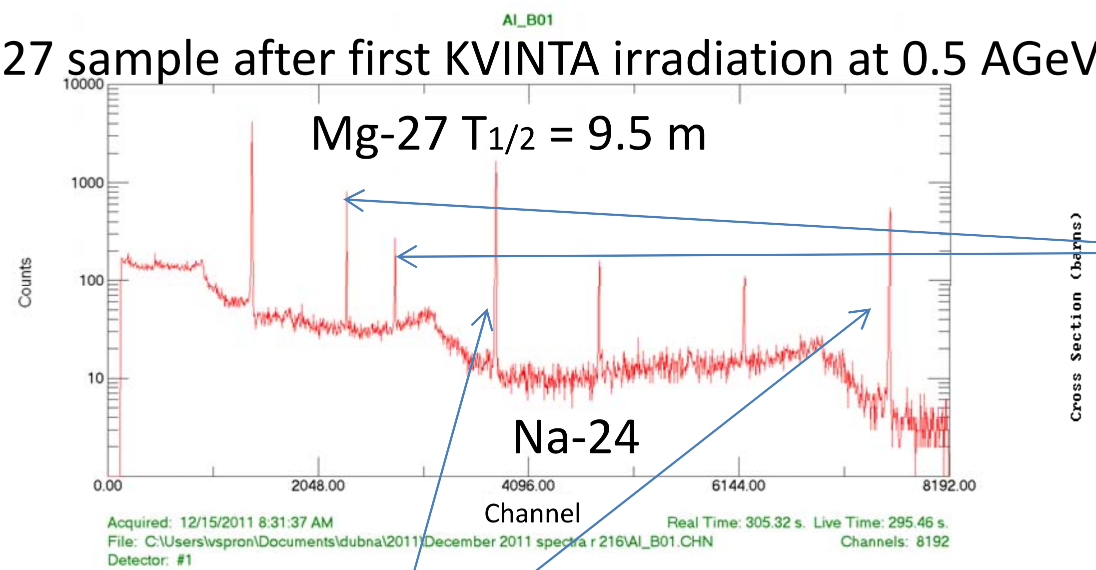


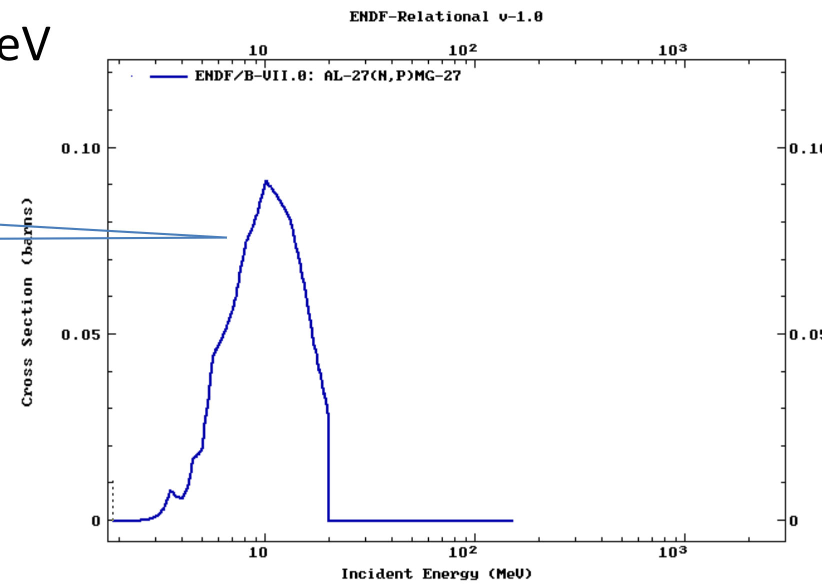
Cu/NbTi 8 h 25 min after EOB

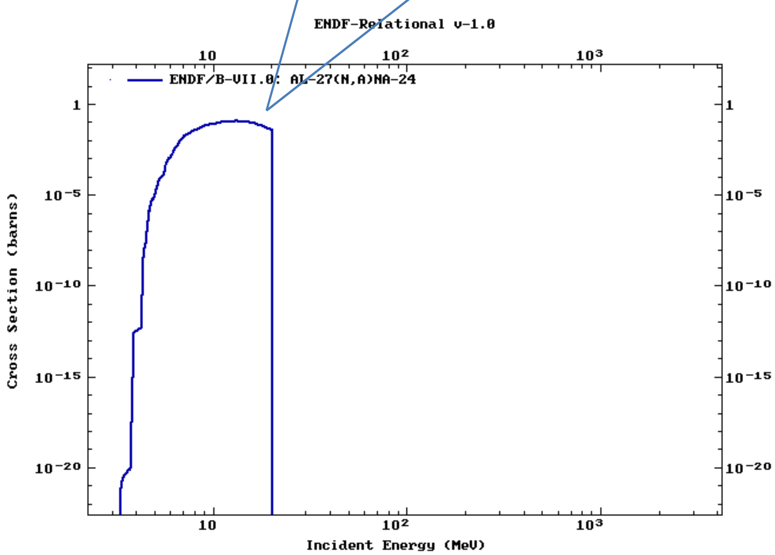


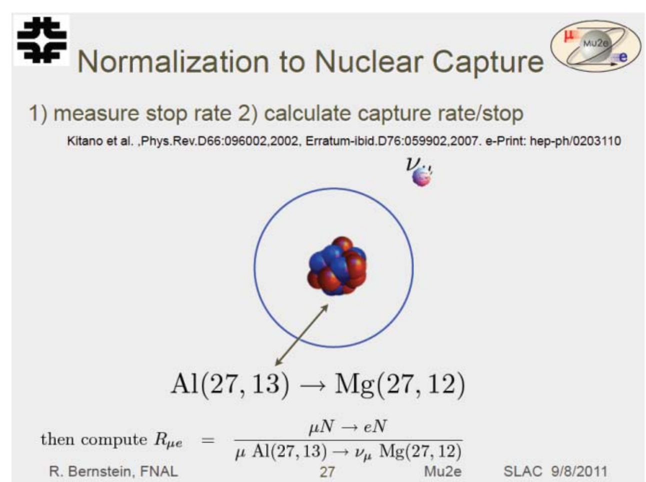
Gamma-rays from Mg-27 decay. One more background.

Al-27 sample after first KVINTA irradiation at 0.5 AGeV

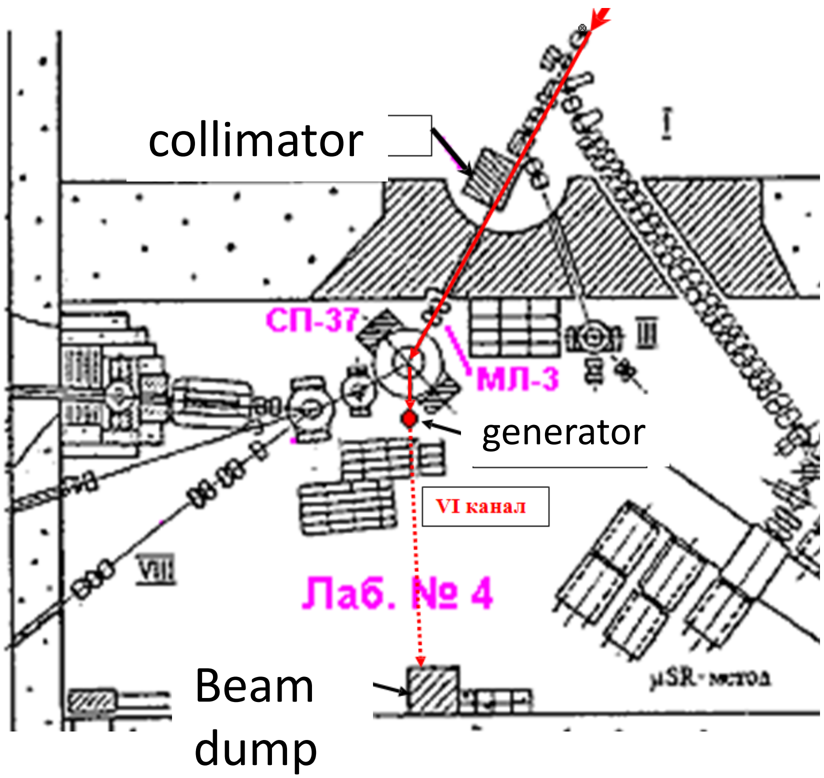


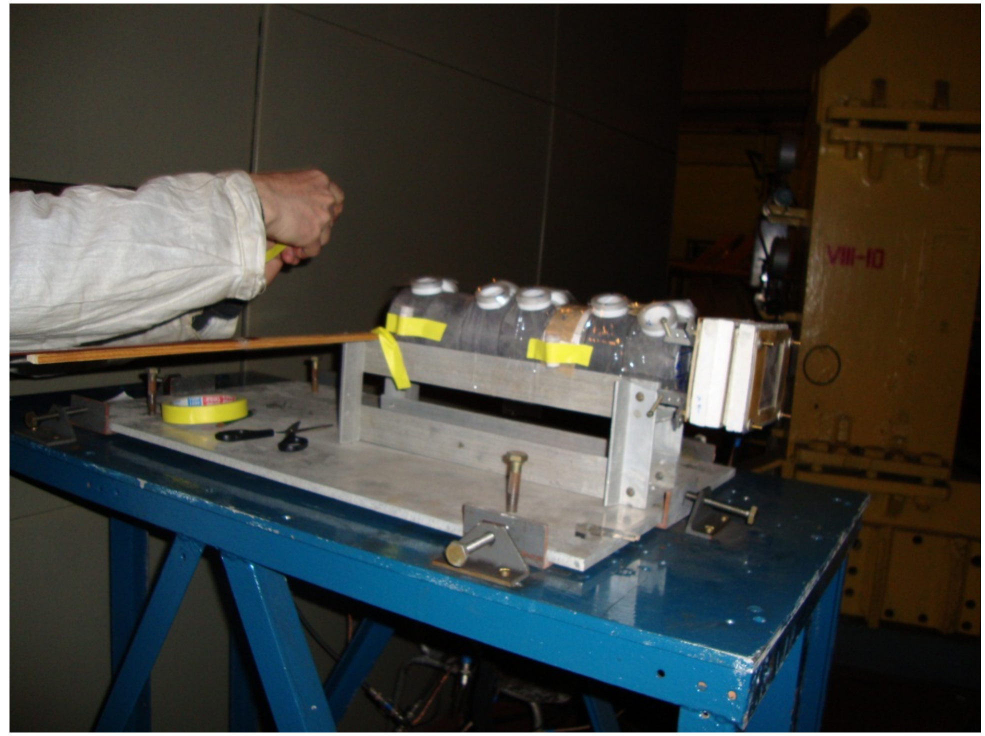






Target “GENERATOR” at Phasotron





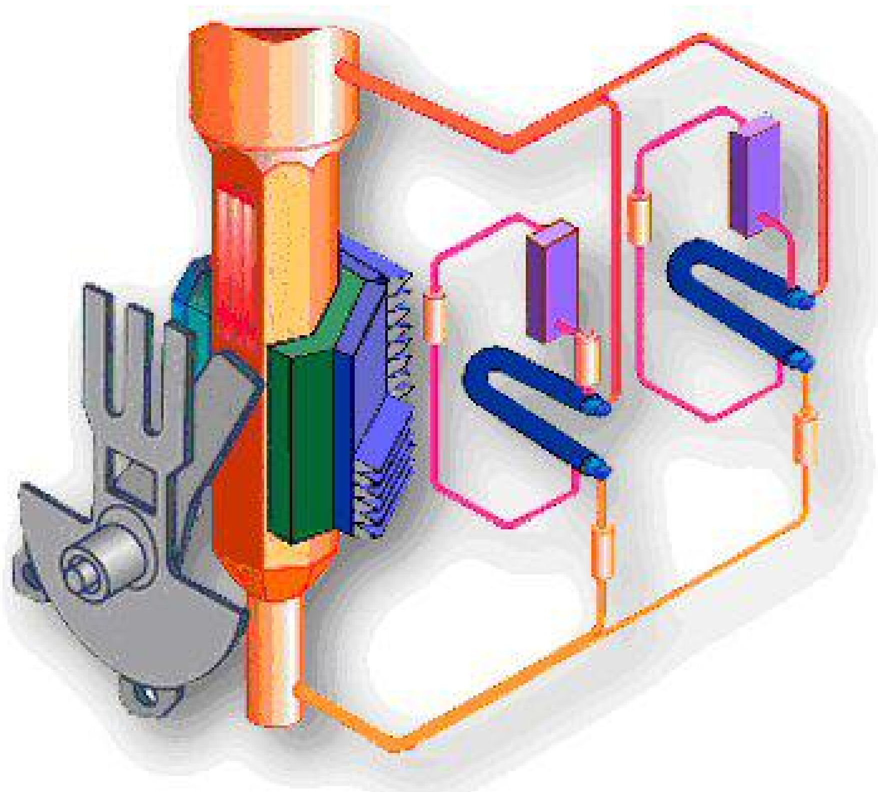
Accelerator: Tp=660 MeV, Ip=~2 μA, extracted beam 10 ns bunches, 70 ms interval

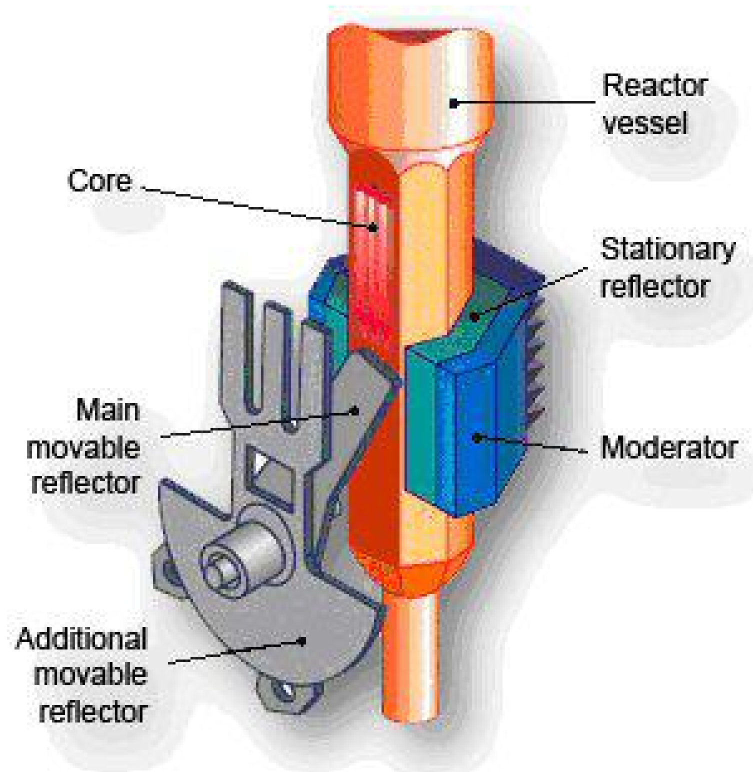
Pb and Pb-Bi targets, l = 33 cm, D = 8 cm, beam spot ~ 2-3 cm

Actual intensity: 1.5E11 p/s, duration of irradiations – several hours

Neutron flux on surface: 7E8 n/cm^2/s

Pulsed Fast Reactor IBR-2





Pulse frequency 5 Hz, heat carrier – liquid Na, PuO_2 fuel (82.5 kg)
Peak power in pulse 1500 MW, thermal power 2 MW,
Neutron flux from the moderator surface: average: 1E13 n/cm^2/s
maximum in pulse: 1E16 n/cm^2/s

En > 100 keV

Potential Fermilab Irradiation Facilities

- Meson Test Beam Primary Line (protons)
- Muon Test Area (MTA) (protons)
- Neutron Therapy Facility (NTF) (neutrons)
- ES&H Instrumentation Group (gamma, neutrons)
- MI Collimator

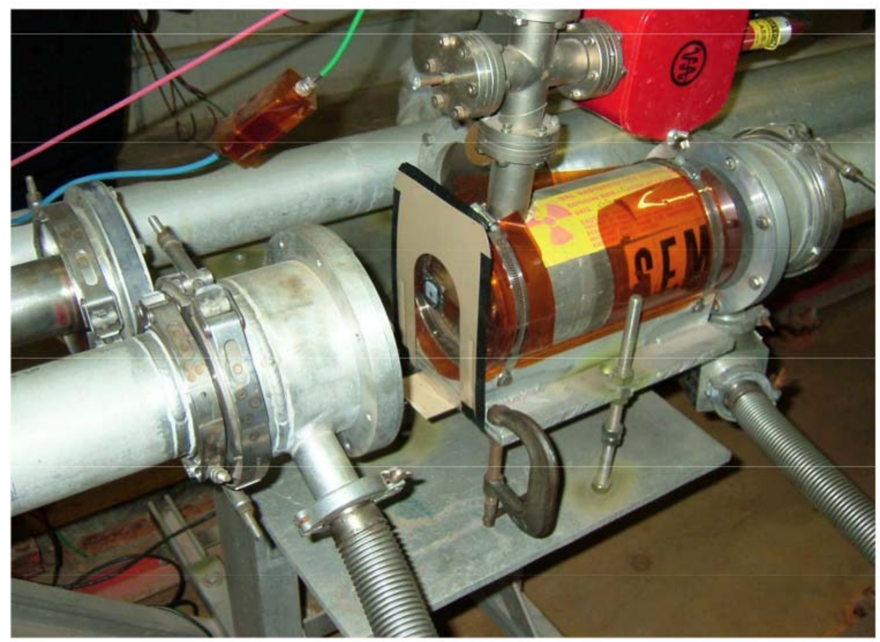
See talk of Eric Ramberg

Meson Test Beam Primary Line

- Fermilab Test Beam Facility is at the end of MTest beamline
- 120 GeV primary protons
- Flux 1.5E11 protons/spill, 1 spill/minute 4 sec long, 12 hours/day
- Beam spot size 1 cm^2
- Gap M01 in beampipe before

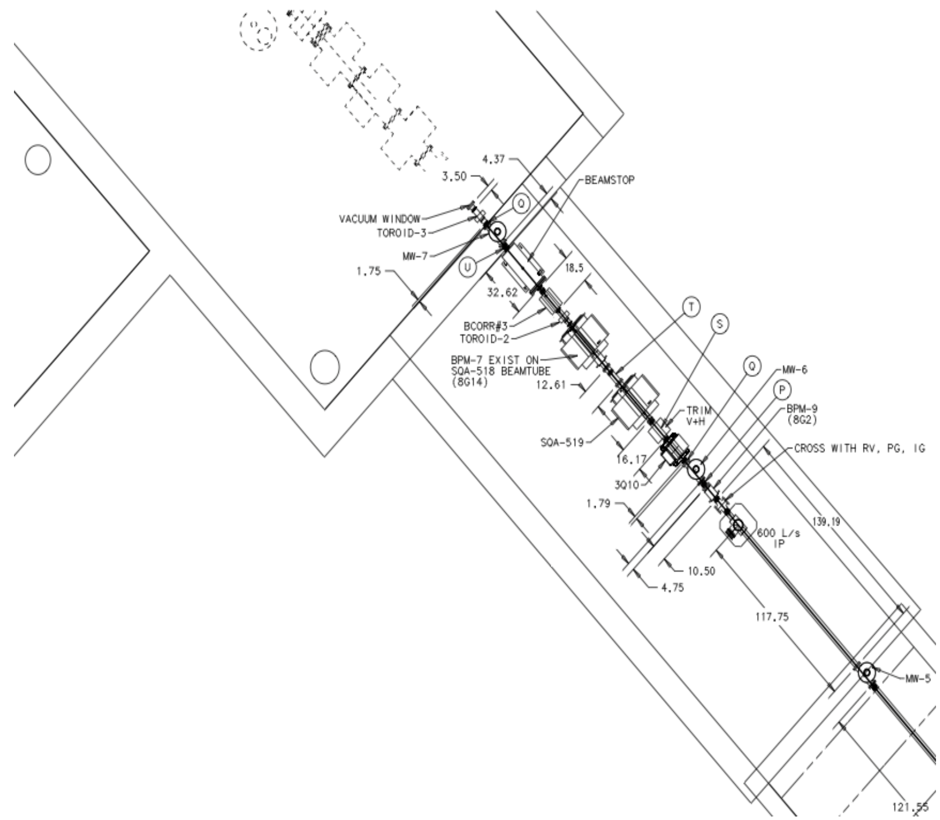
it hits the first attenuator

- Gap is 15 cm long
- SEM flux monitor upstream
- MOU submitting necessary



Muon Test Area (MTA)

- At the end of Linac
- Area not yet approved to take primary Linac beam
- Approved for 100% and 0% transmission experiments
- Up to 5E12 protons/60us bursts
- One burst per minute
- When the beamstop is closed
  – 5E13 protons/minute



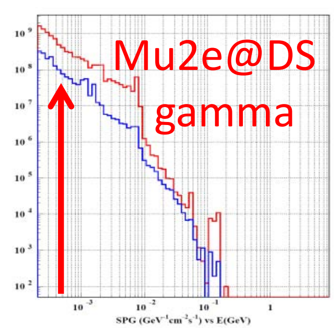
- Radiation safety guidelines are not explicit about thin foils
- Probably MOU is needed

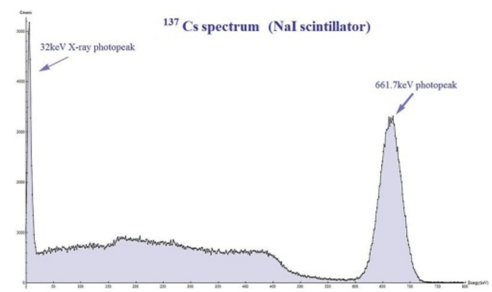
Neutron Therapy Facility (NTF)

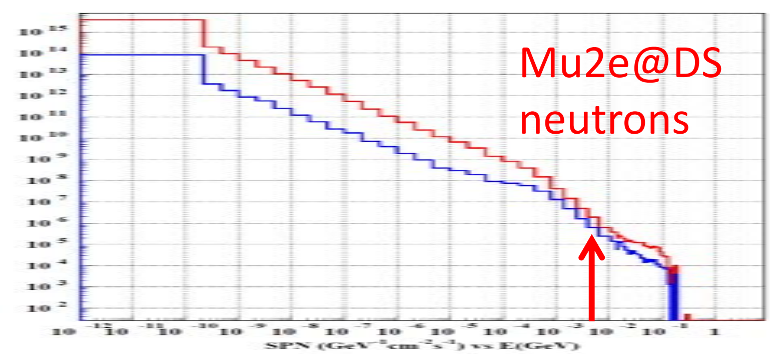
- In the middle of the Linac
- Linac pulses at 66 MeV
- Be or gold target
- Fast neutrons (average En=10 MeV)
- 1E6 neutrons per pulse with 10 Hz
- Irradiations last minutes
- Has been used for experimental tests
- Limited access points
- Long term irradiations are not typically supported

ES&H Instrumentation Group

- Facility for calibration of radiation monitors
- Has 3 rooms where detectors can be placed next to the source or several meters away
- Cs-137 (200 Ci), 3E6 phot/cm^2/s at 30 cm (7 Gy/hr) (up to 1.4E5 /cm^2/s Mu2e @DS)
- 241Am+Be neutron source (En=4.5 MeV) 6E7 n/s -> 5500 n/cm^2/s at 30 cm from source Mu2e@DS 105000 n/cm^2/s
- Closer source-to-sample distances are allowed





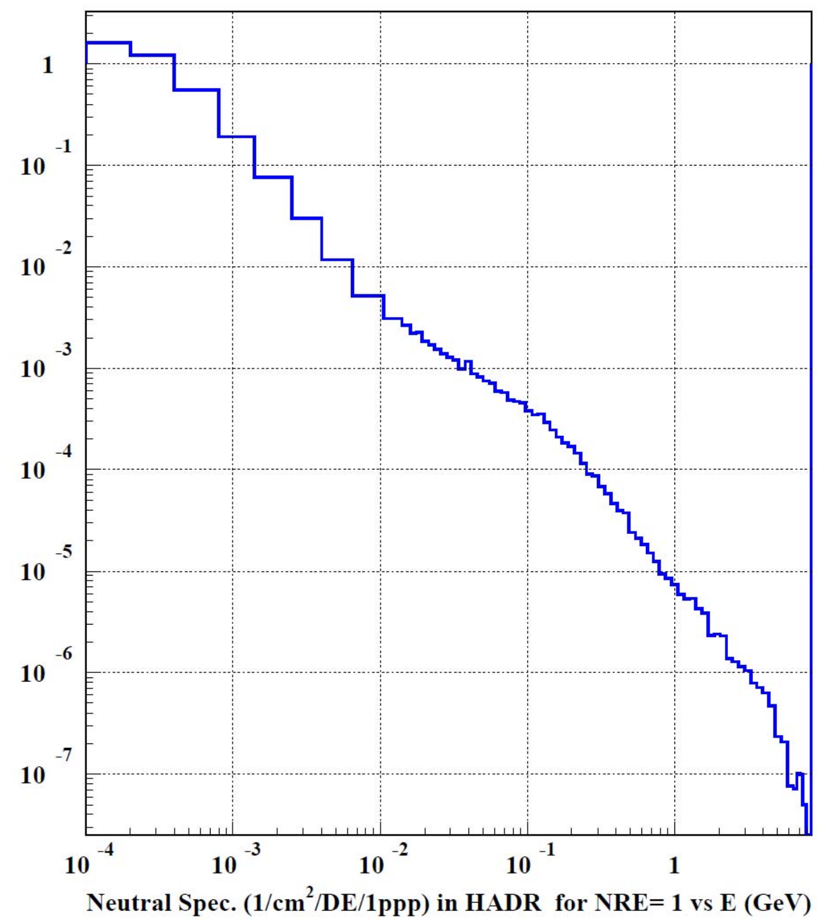


MI Collimator

shielded

unshielded

~1.2E12 protons on collimator



8.8E7-2.2E7 n/cm^2/s

B.C.Brown for details of irradiation

Summary

JINR

Facility	Particle	Energy	Fluence	Beam size
GAMMA-3	Neutron	Spallation, < ~1 GeV	~6E8/ minute	1 cm^2
KVINTA	Neutron	Spallation, < ~1 GeV	~6E8 /minute	1 cm^2
GENERATOR	Neutron	Spallation, < 0.6 GeV	~4E10 /minute	1 cm^2
IBR-2	Neutron	>100 keV	~6E14/minute	1 cm^2

Fermilab

Facility	Particle	Energy	Fluence	Beam size
MTest in (M01)	Proton	120 GeV	9×10^{12} / hour	~ 1 cm^2
Muon Test Area	Proton	400 MeV	$< 3 \times 10^{14}$/hour	~ 1 cm^2
Neutron Therapy	Neutron	~10 MeV	~6×10^{8}/minute	~$(10\ cm)^2$
ES&H Instrumentation	Gamma	0.6 MeV	$< 2.7 \times 10^{16}$/hour	4π
	Neutron	~5 MeV	~2×10^{11}/hour	4π
MI Collimator	Neutron	spallation	~5.3E9/minute	~ 1 cm^2