Creation of High Energetic Neutrons and Aging Studies with Muon Detectors

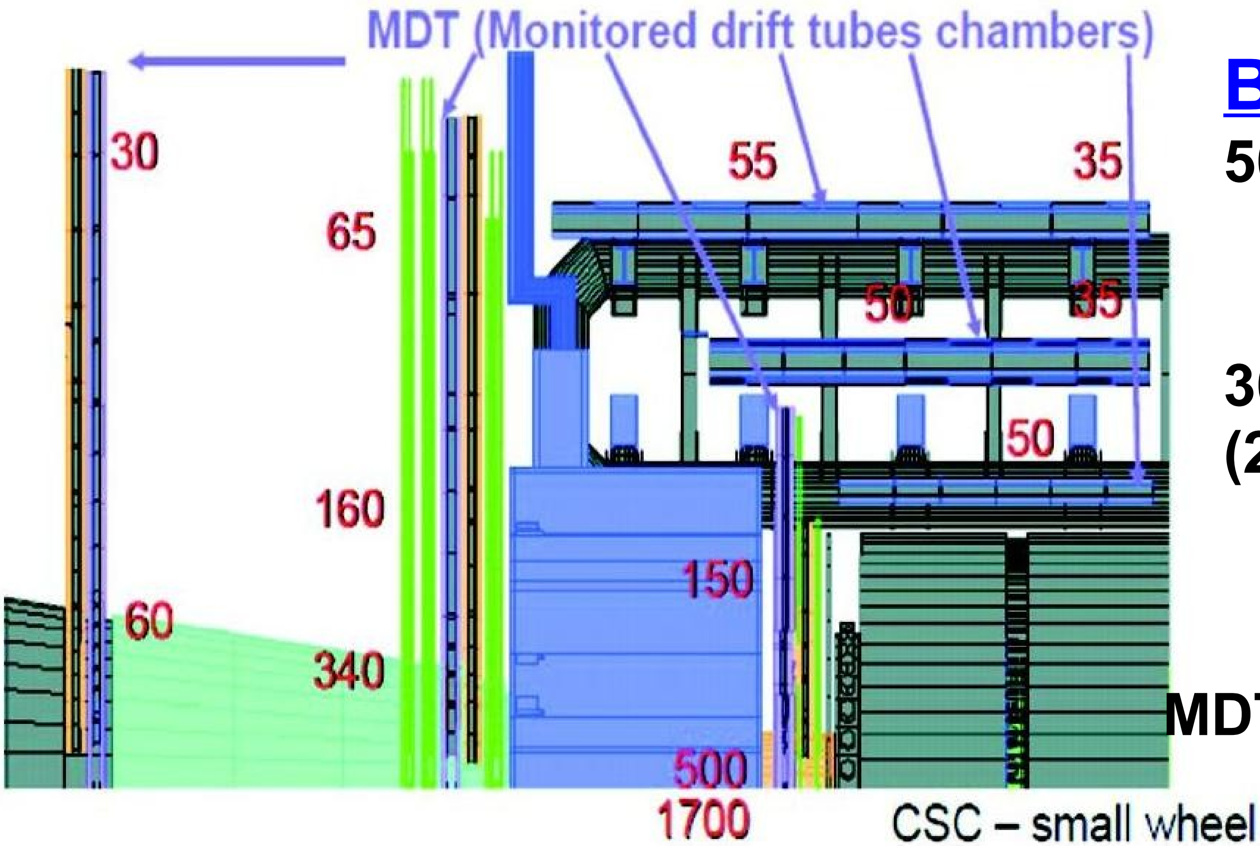
Alexander Ruschke

LS Schaile, LMU München

Outline

1. motivation
2. ion beam preparation + pulse shape discrimination
3. neutron reactions and properties
4. aging studies at MDT tubes
5. summary & outlook

Background Hit Rates of γ's and Neutrons at L = 10^{34} 1/cm^{2}s



<u>**BOS MDT**</u>	<u>**CSC-Detector**</u>
50 Hz/cm^2	**500 - 1700Hz/cm^2**
↓	↓
30kHz/tube (2m*3cm)	**300-1020 kHz/tube (2m*3cm)**

MDT efficiency ε_n(11MeV) = 4 *10^{-4}

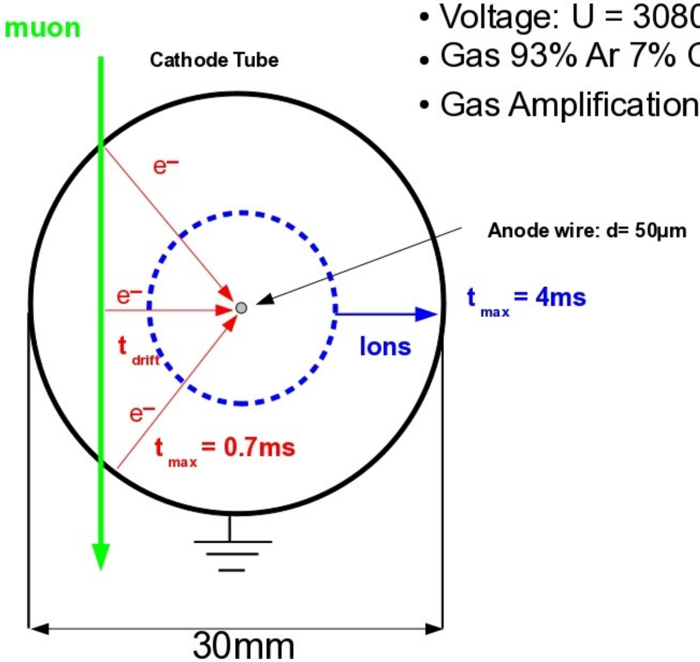
simulation for LHC L =10^{34} 1/cm^2*s design luminosity with safety factor 5

Aim: neutron source with flux density of 5*10^6 Hz/cm^2

Impact of γ Background

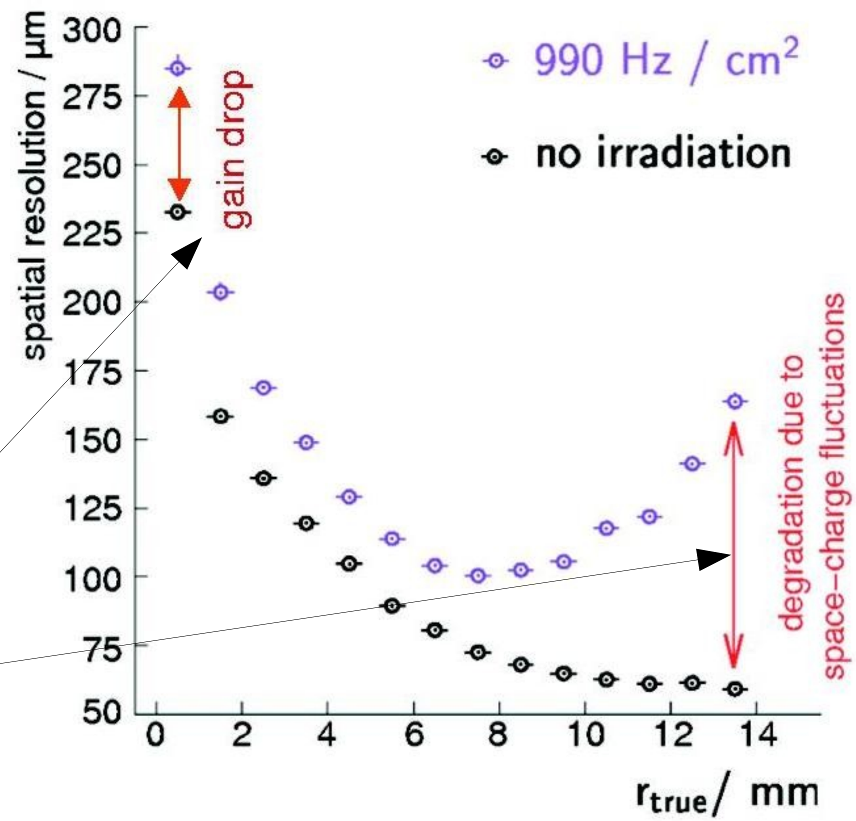
Atlas MDT Drifttube

- Pressure 3 bar
- Voltage: U = 3080V
- Gas 93% Ar 7% CO_2
- Gas Amplification 20000



t_{drift} ➡ r_{drift}
nonlinear ➡ E-field dependent space charge effects

measurement :
100 GeV muons +
^{137}Cs 550 Gbq
(662 keV γ)
X5 2005 at CERN



slow ion-drift 4ms

➡ **space charge effects modify electric field**
non linear r-t relation

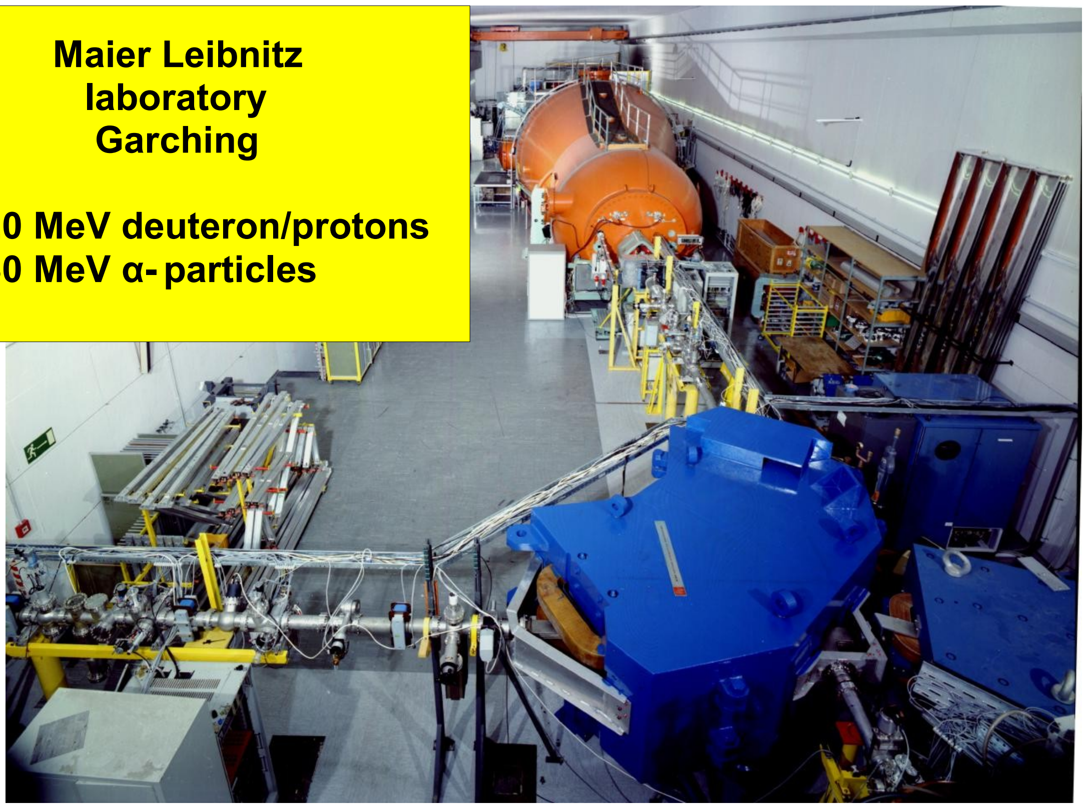
➡ **reduction of gain amplification (gain drop)**
degradation of resolution at large drift radii due to space charge fluctuations

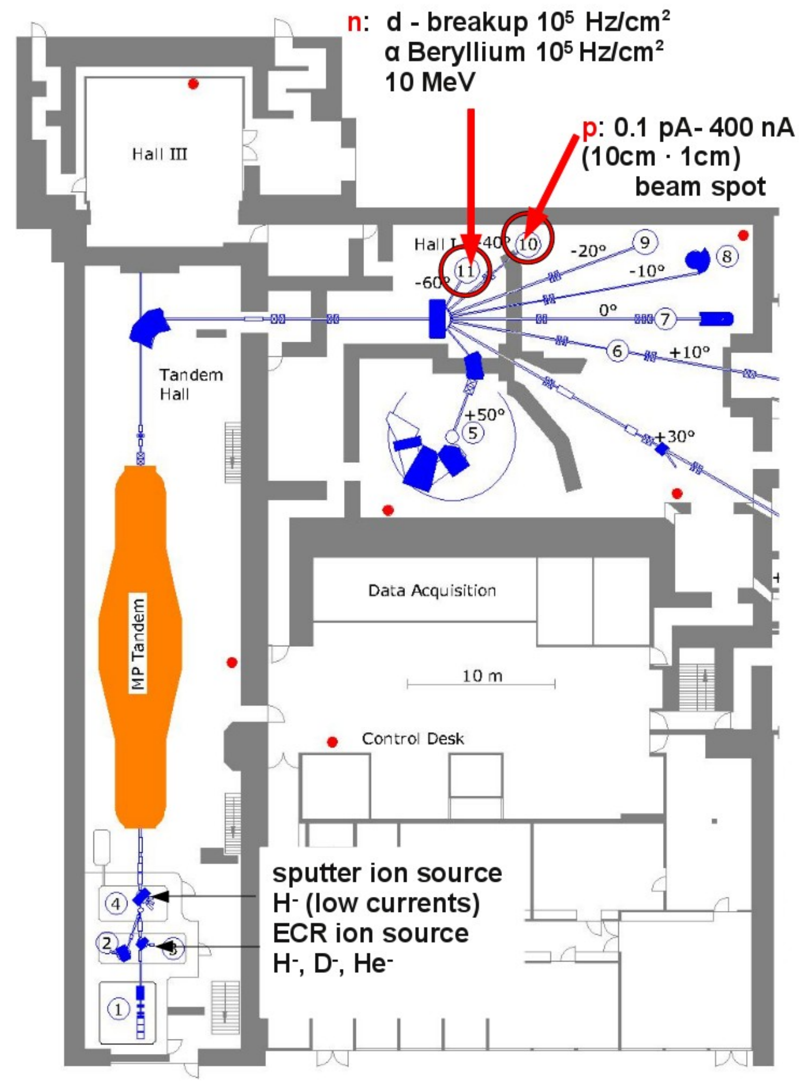
Munich Tandem Laboratory

tandem accelerator
14MV

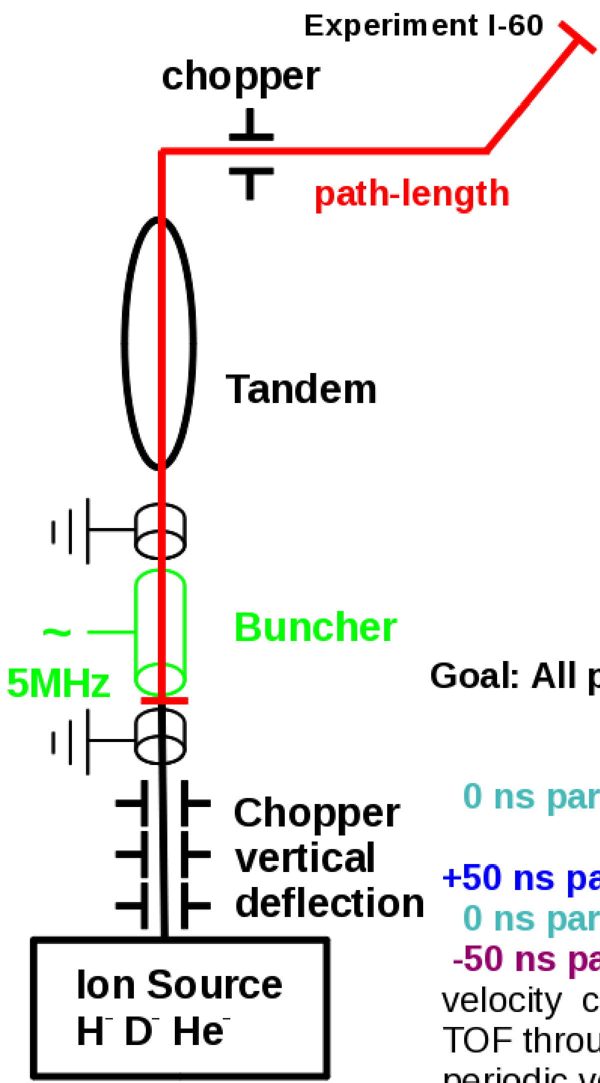
Maier Leibnitz laboratory Garching

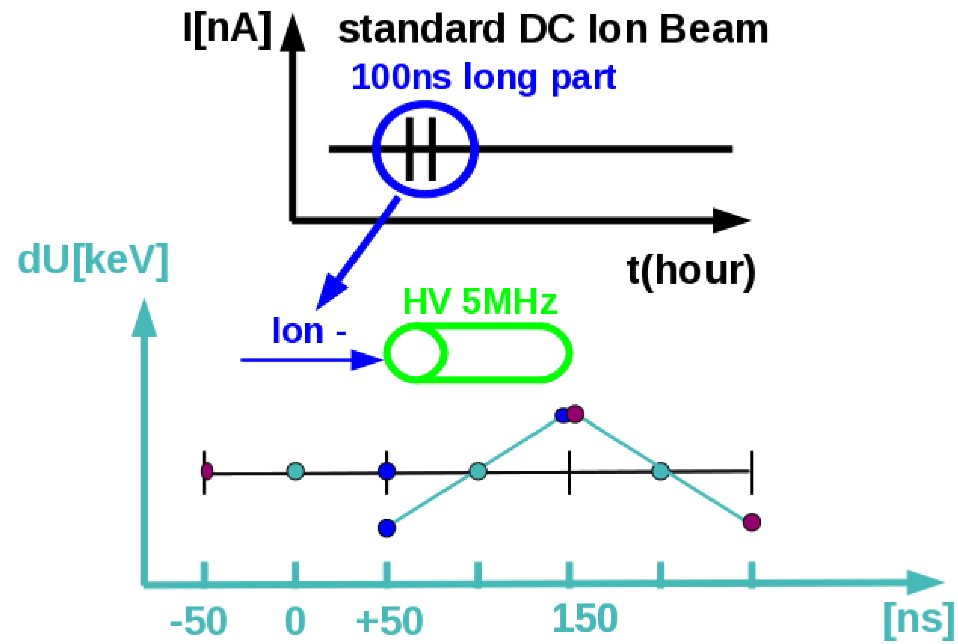
- **20 MeV deuteron/protons**
- **30 MeV α- particles**





Pulsed Beams with Time Structure Time of Flight(TOF)



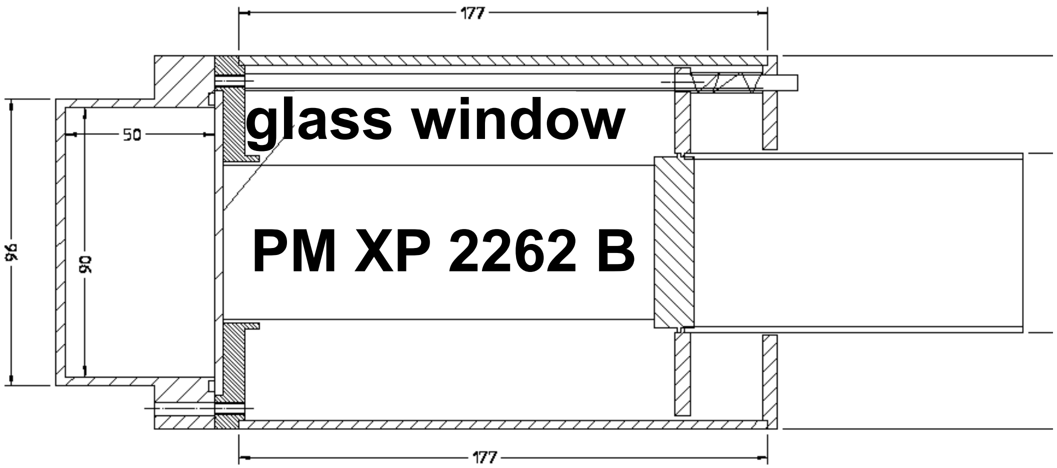


Goal: All particles within 100 ns long period arrive simultaneously at the target (TIME Focus by BUNCHING)

0 ns particle takes time t to arrive at experiment (**t** = **path-length/v**)

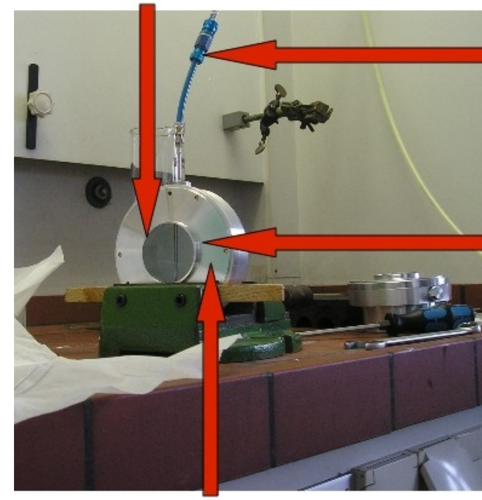
+50 ns particle are decelerated by 2 * dU ~ keV
0 ns particle are unaffected by dU = 0V
-50 ns particle are accelerated by 2 * dU ~ keV
velocity change results in time focus
TOF through tube = 100ns
periodic voltage (5Mhz) with amplitude x keV

Neutron-Detector [PSD]



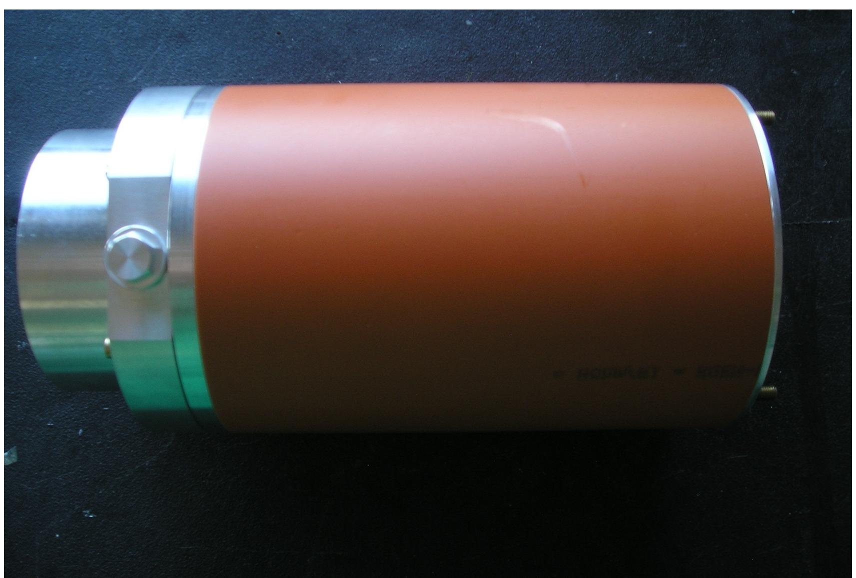
glass plate

bubbling with nitrogen gas



cell contains 370ml of liquid scintillator BC-501-A

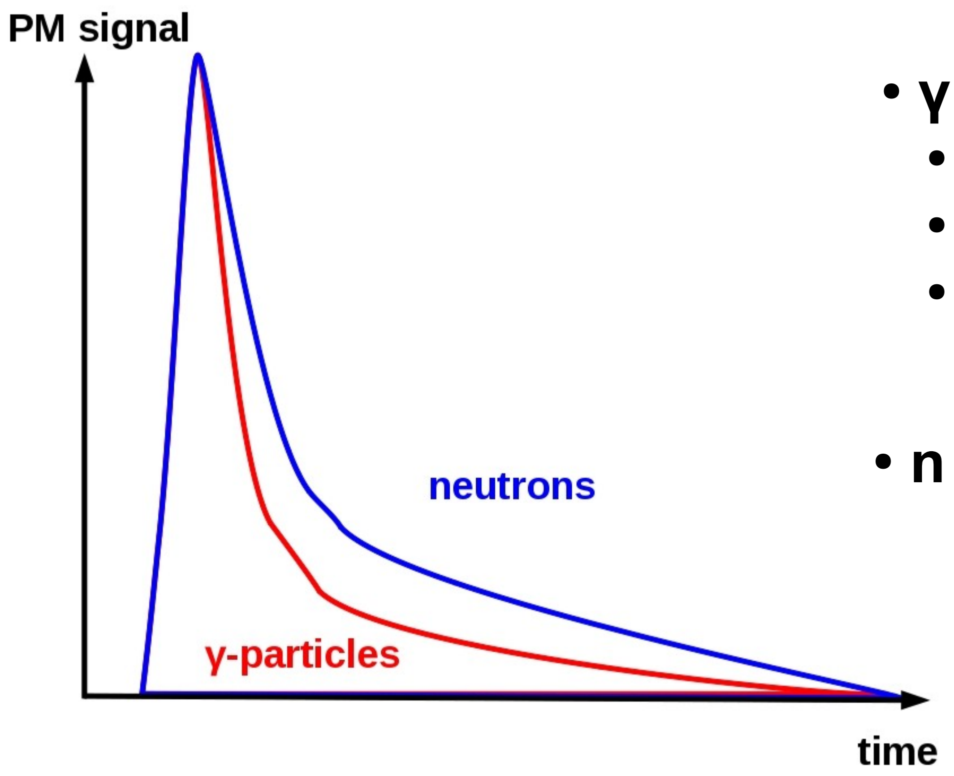
aluminum cell:
- aluminum 3mm thick
- 90mm diameter
- 50mm depth
- white coating of inner walls



- **2 " photo multiplier tube XP 2262 B**
- **liquid scintillator BC-501A**
- **7 detectors were built and are functional**
- **data acquisition with QDC (charge to digital converter)**

Neutron Identification

pulse shape discrimination [PSD] in liquid scintillator (CH_x)



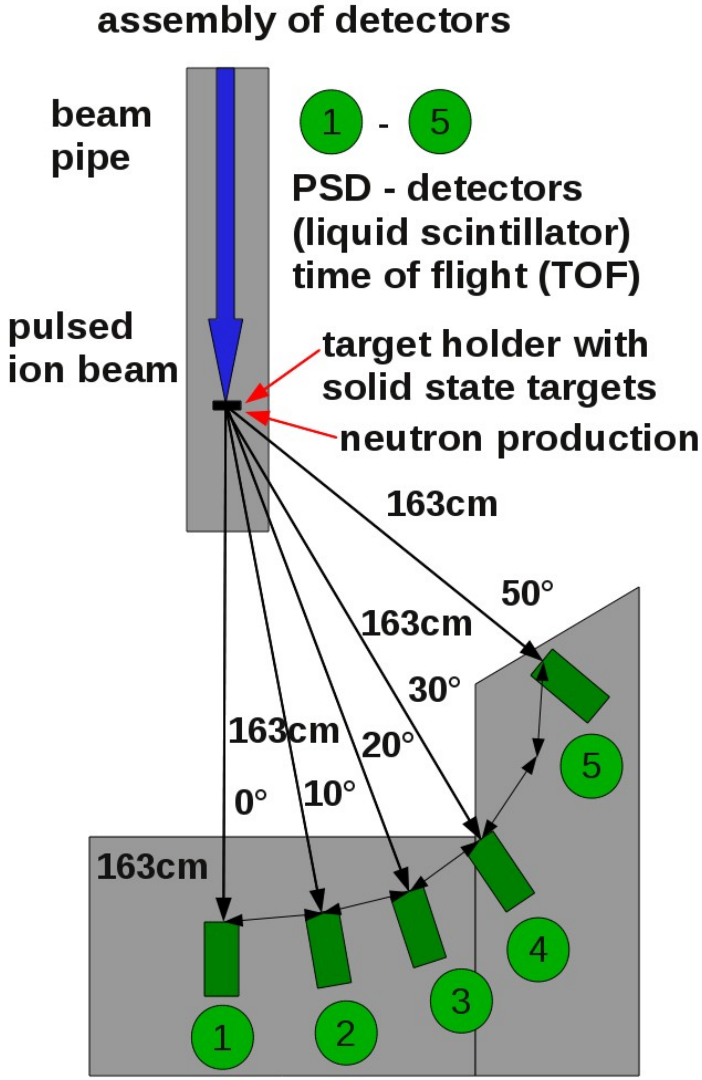
- **γ - signal interaction via:**
  - **photo effect**
  - **compton effect**
  - **pair production**

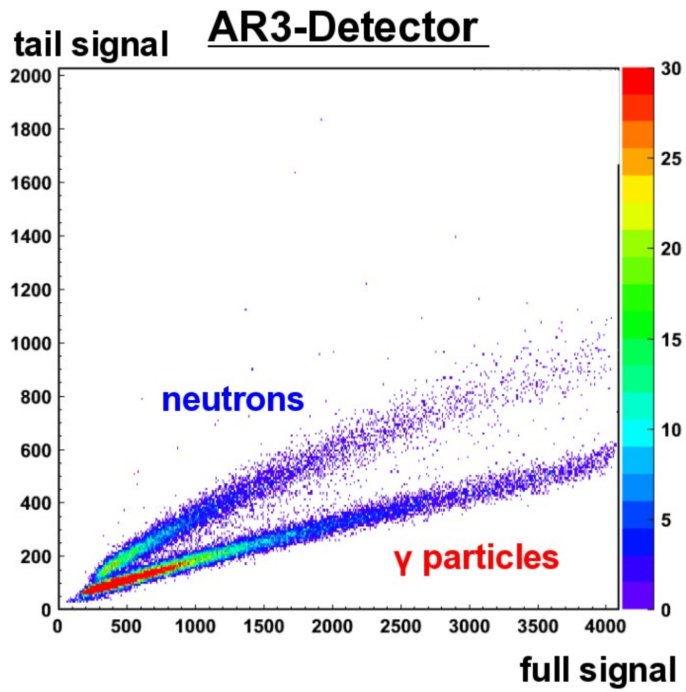
  } **light production by electrons**

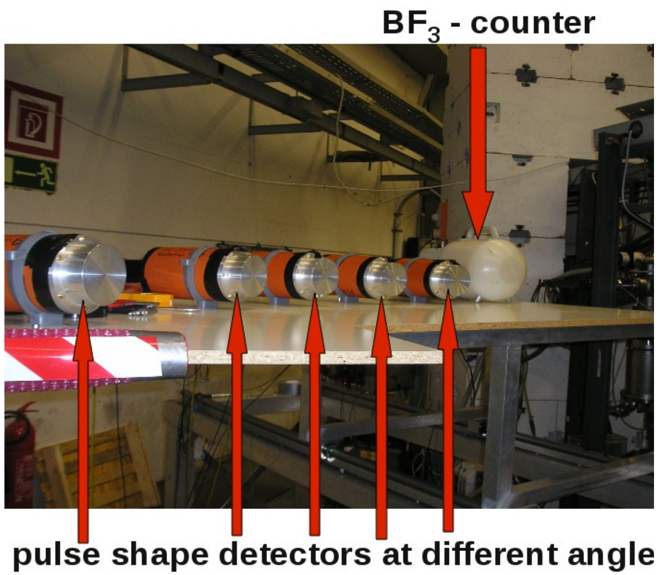
- **n - signal is created by proton- ion recoil:**

→ **longer tail signal**

Production and Characterization of High Energetic Neutrons







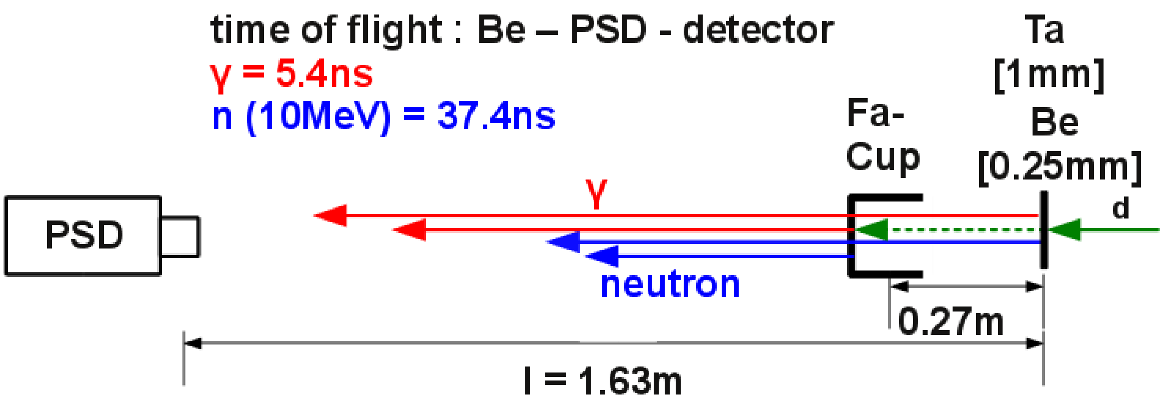
- solid state target: • d + Be, • α + Be } n + x
- pulse shape discrimination (PSD)
- time of flight method (TOF)

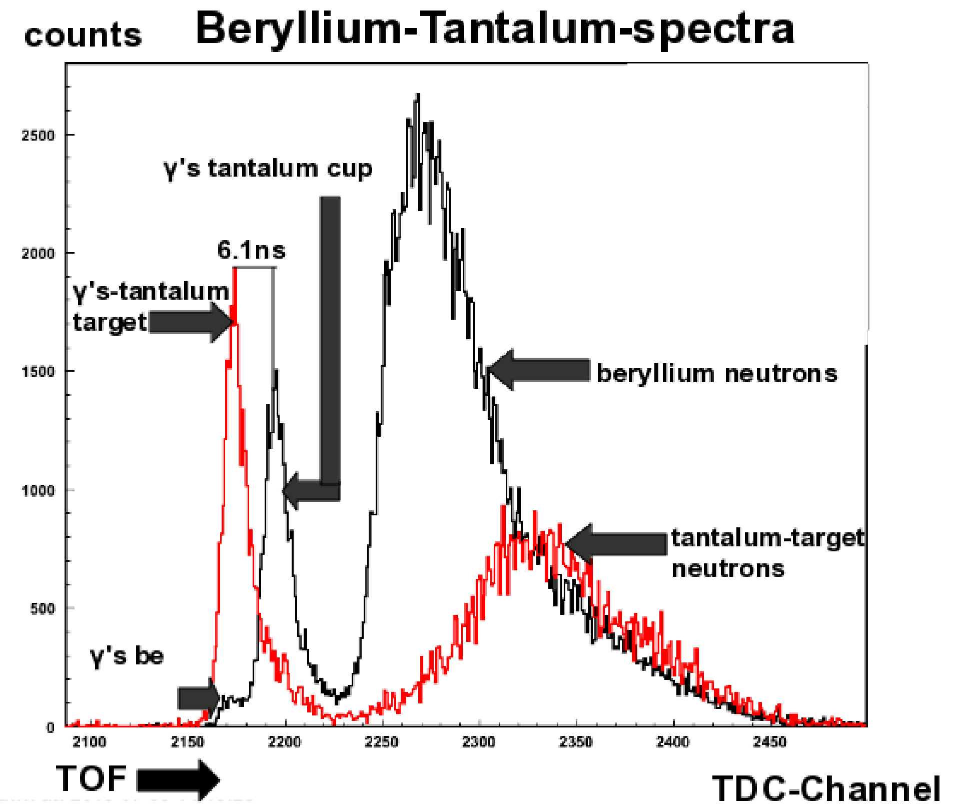
d-Breakup on Nuclear Potential

- **motivation**:
  - **low binding energy 2.2 MeV**
  - **20 MeV deuteron on target**

- **n-energy-determination:**
  - **pulsed ion beam**
  - **time of flight method (TOF)**

→ **many neutrons with E ≤ 20MeV**





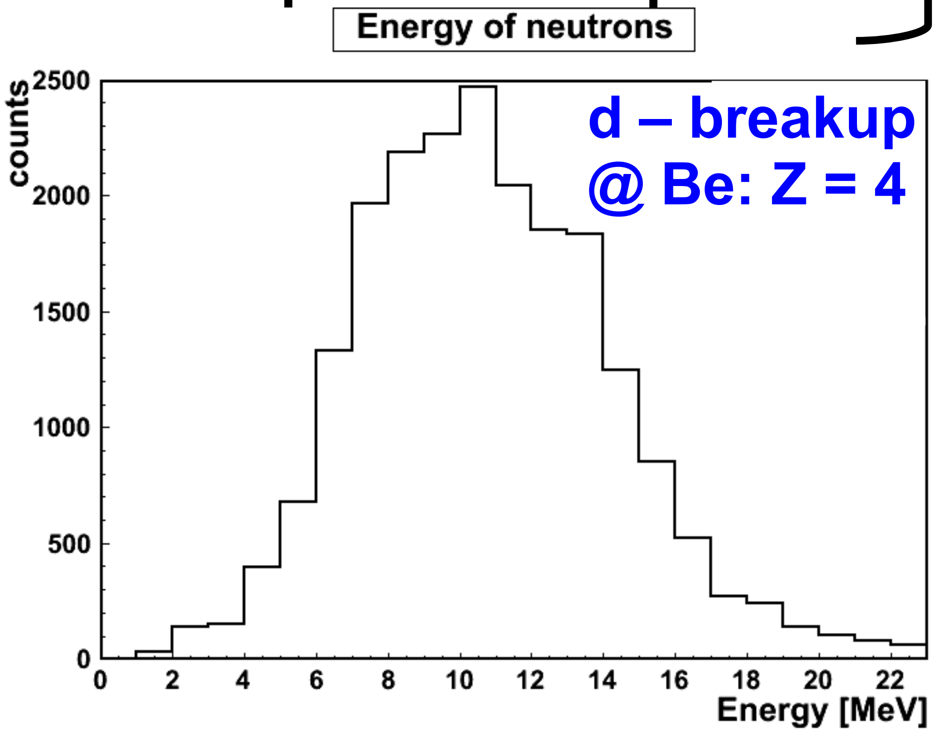
different measurement times (red and black)

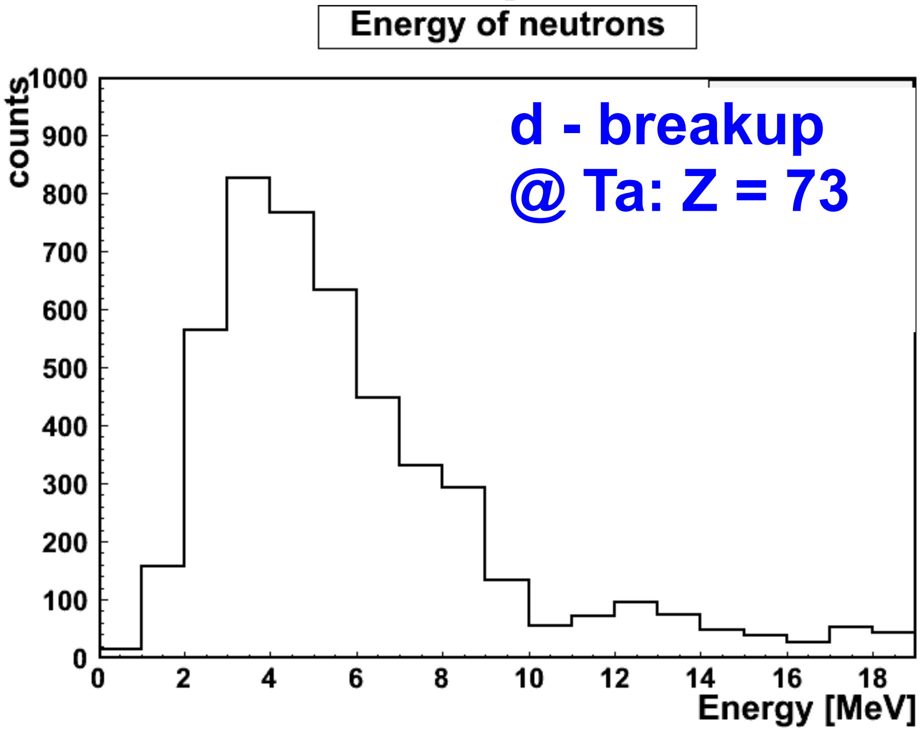
Neutron Energy @ d-Breakup

- **time of flight information** ➡ $E_n = \frac{1}{2} \cdot m \cdot v_n^2 = \frac{1}{2} \cdot m \cdot \left(\frac{l}{t_{TOF\ (n)}}\right)^2$

- **20 MeV deuteron ion beam**
- **d - breakup on nuclear potential**

$$E_n = \frac{1}{2} \cdot \left(E_d - \frac{(Z \cdot e^2)}{R_B} - 2.2\ MeV\right)$$



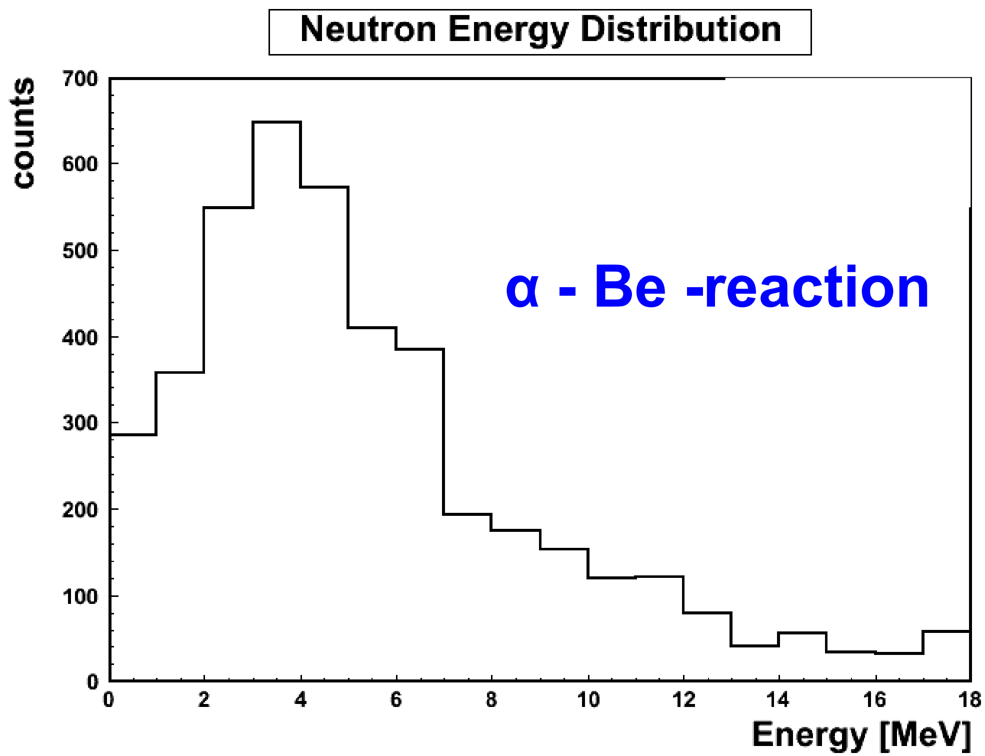


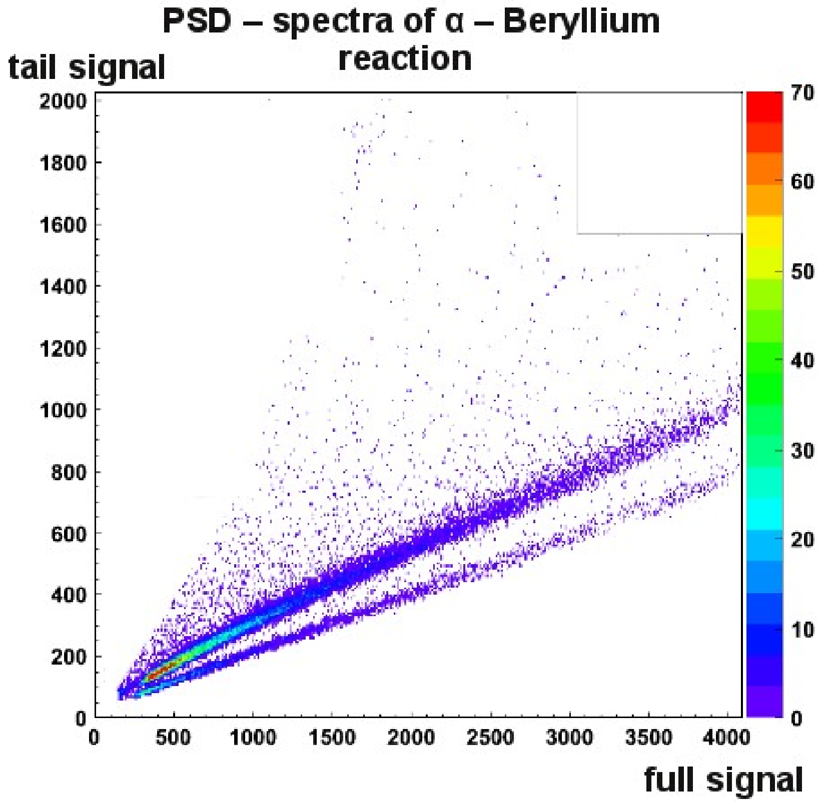
- **neutrons from d- breakup at beryllium Z = 4**
- **most probable value 10.7 MeV**
- **FWHM 4 MeV**

- **neutrons from d-breakup at tantalum Z = 73**
- **most probable value 4 MeV**
- **FWHM 2 MeV**
- **in accord with Bleul NIM B 261(2007)974-979**

Neutron Energy @ α - Be - Reaction

motivation:
- $\alpha + {}^{9}_{4}Be$ ➡ ${}^{12}_{6}C + n + 5.709$ MeV (exotherm)
- Q-value + 30 MeV α - particle ➡ 35 MeV neutrons…?
- α- Be reaction with low γ yield

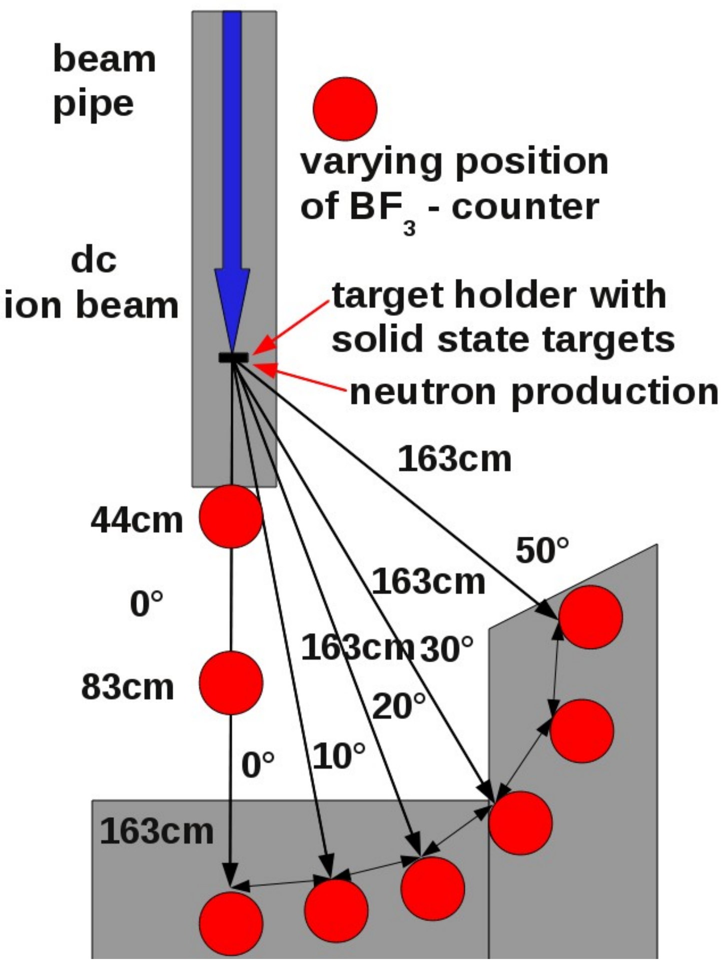


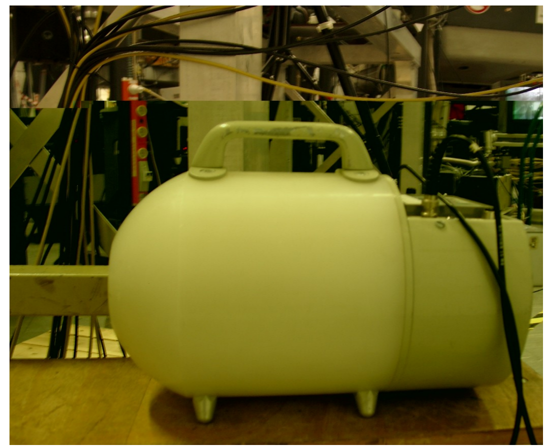


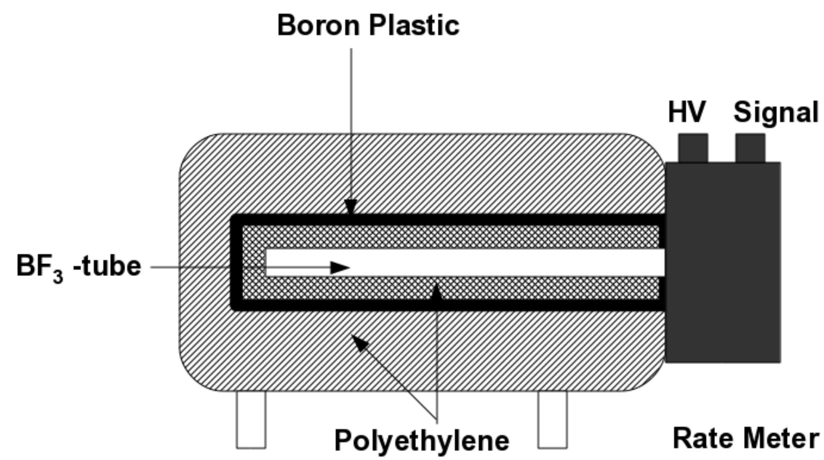
- most probable value 4.7 MeV
- FWHM 2 MeV
- result: ➡ - no direct reaction
  - creation of compound nuclei
- few γ - particle

Neutron Flux Density

assembly of detectors







- BF_3 - detector at different angles (0º – 50º)
- BF_3 - detector is insensitive for γ - particle
- determination of neutron flux density by

$$\Delta\phi_0 = \frac{N}{t\cdot\kappa}$$

$$[\Delta\phi] = [\frac{1}{cm^2\cdot s}]$$

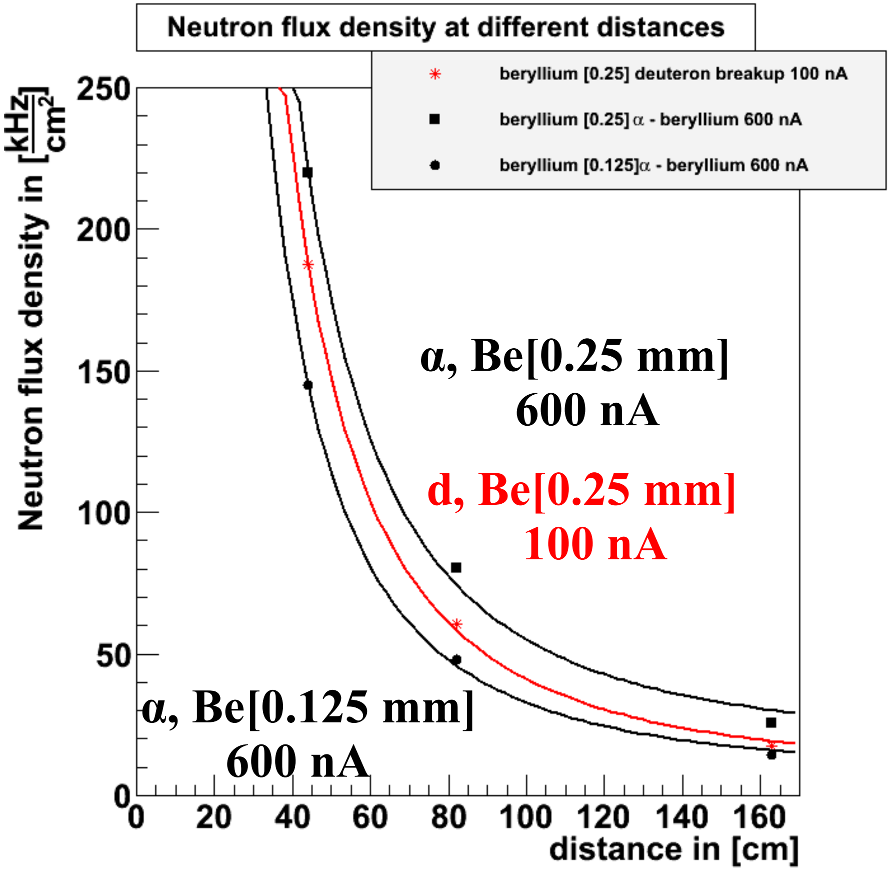
$$\kappa = \text{efficiency of detector} \qquad \kappa = 0.4 \; \frac{cps}{n/cm^2\cdot s}$$

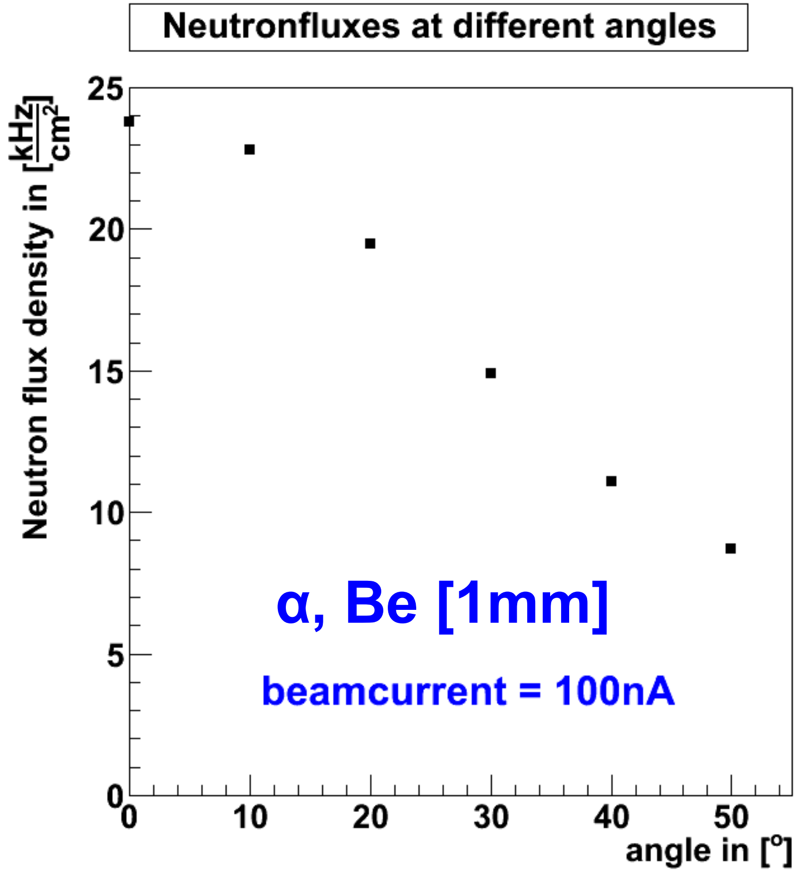
$$\Delta\phi_0 = \text{neutron flux density}$$

$$N = \text{counted neutrons by } BF_3 \text{ counter}$$

$$t = \text{time}$$

Distance & Angle Dependence

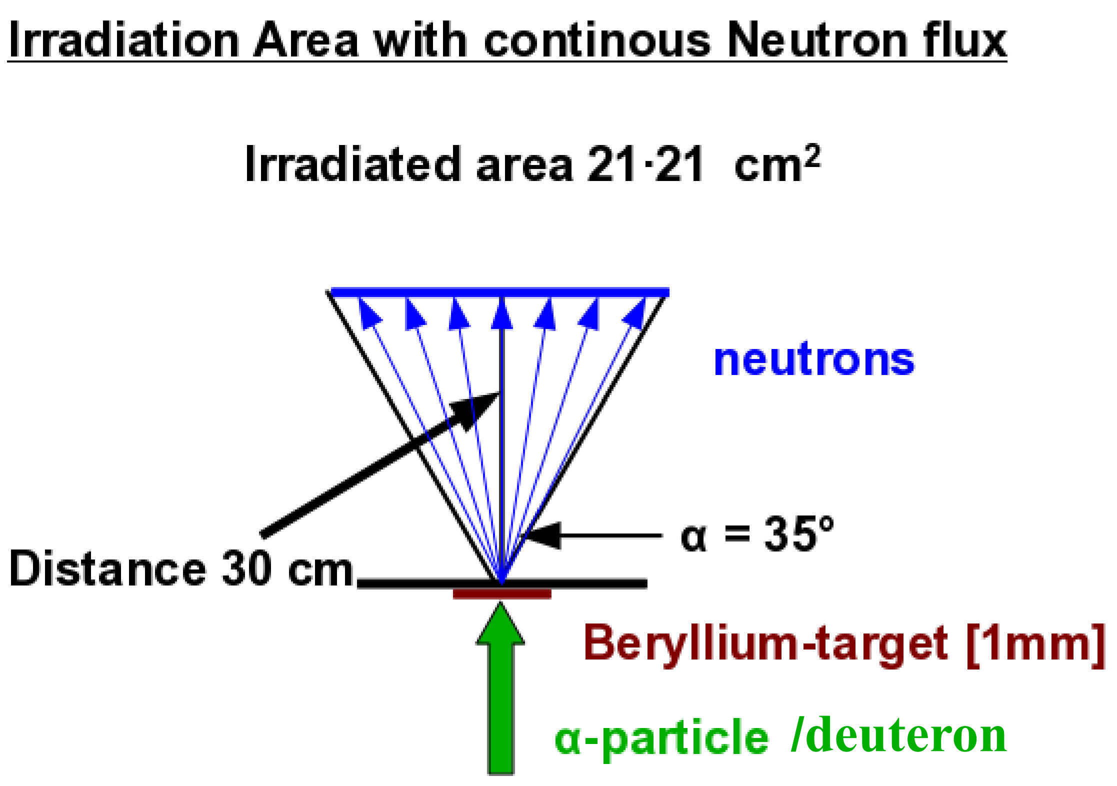




- intensity scales with $\frac{1}{r^2}$
- intensity α – Be scales with target thickness
- intensity d – Be higher yield

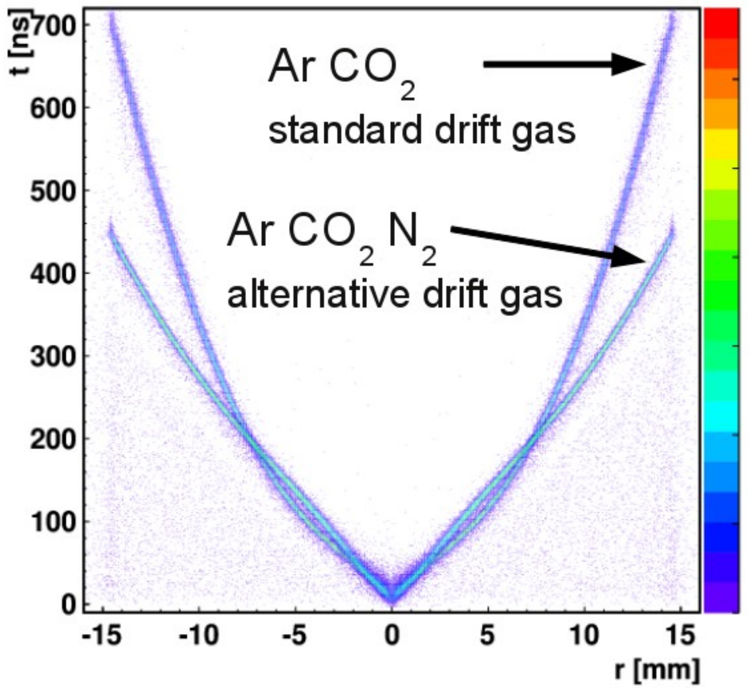
- angle dependence: ± 30º flux density decreases by a factor of 2, irradiation of a large area is possible, with neutron fluxes density up to $5 \circ 10^6$ Hz/cm2

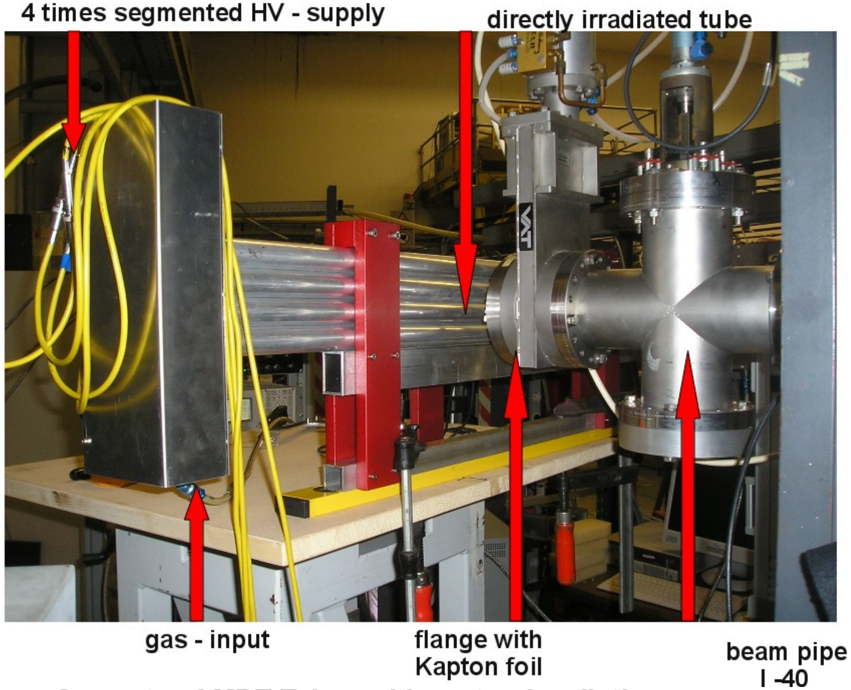
Neutron Irradiation of New Detectors

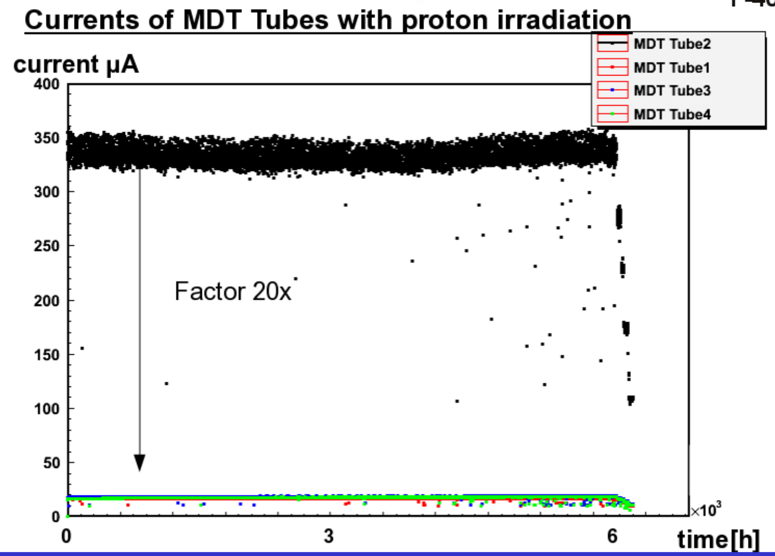


- test of micromega detectors (J.Bortfeldt)
- test of 15 mm MDT tubes

Aging Study of Alternative Drift Gas



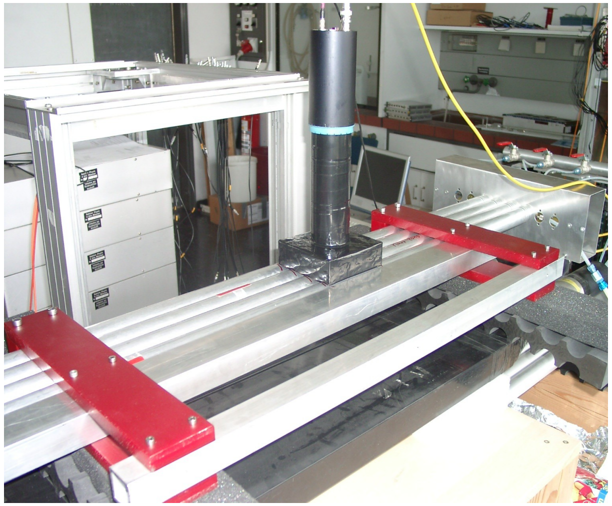


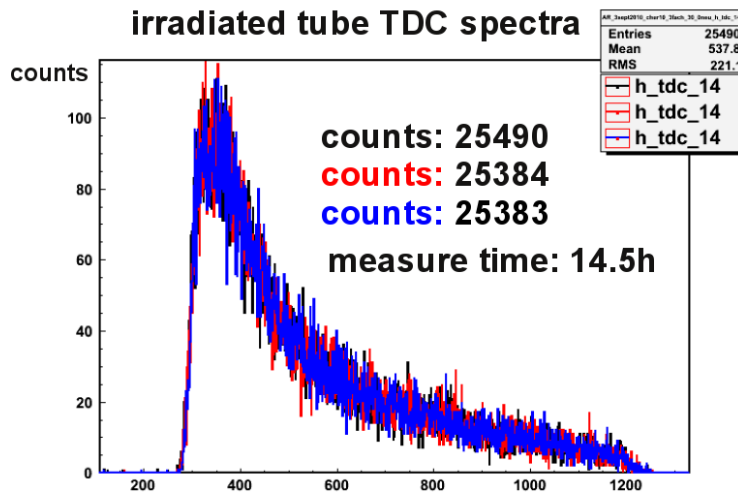


- Ar CO_2 N_2 96:3:1% promising drift gas
- almost linear, 35% faster than Ar CO_2

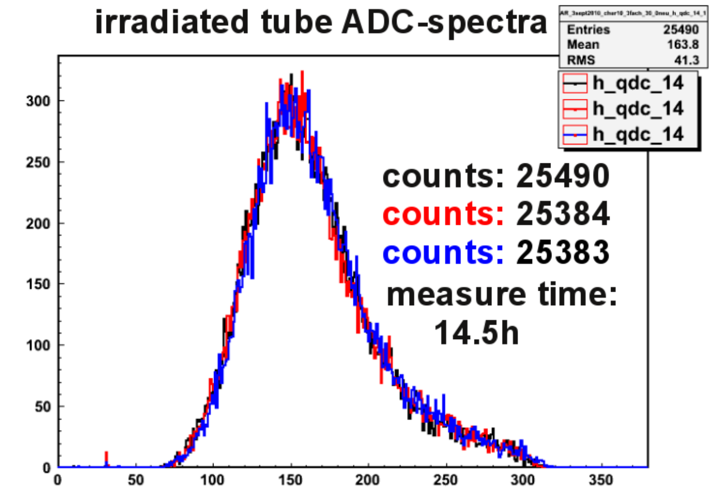
- 20 MeV protons, 105 nA dc for 6 hours
- beam spot : 7cm ◦ 1cm at 8 Hz (wobbler)
- tube current 340 µA @ 3080 V ⟶
  1 C / cm ≈ QC 1 lifetime of ATLAS

Analysis after Irradiation





black: Ar CO_2 93% : 7 % irradiated
red: Ar CO_2 N_2 96% : 3% : 1% irradiated
blue: Ar CO_2 93% : 7 % not irradiated



black: Ar CO_2 93% : 7 % irradiated
red: Ar CO_2 N_2 96% : 3% : 1% irradiated
blue: Ar CO_2 93% : 7 % not irradiated

control measurement in laboratory using cosmic muons with standard drift gas Ar CO_2 93:7%:

- **TDC spectra identical**
- **ADC spectra identical**
- **number of counts identical**
- **same measurement time**

NO AGING OBSERVED

same result comparing not irradiated tube

Summary & Outlook

2 reactions to produce MeV neutrons

- **d + Be 10 MeV (1-20MeV) 50 ◦ 10^5 Hz/cm^2**
- **α + Be 4 MeV (broad) 5 ◦ 10^5 Hz/cm^2 (few γ- particle)**

LHC limits can be achieved

20 MeV protons for aging studies and high rate studies
beam spots of 1 mm^2 – 8 ◦ 1 cm^2 available

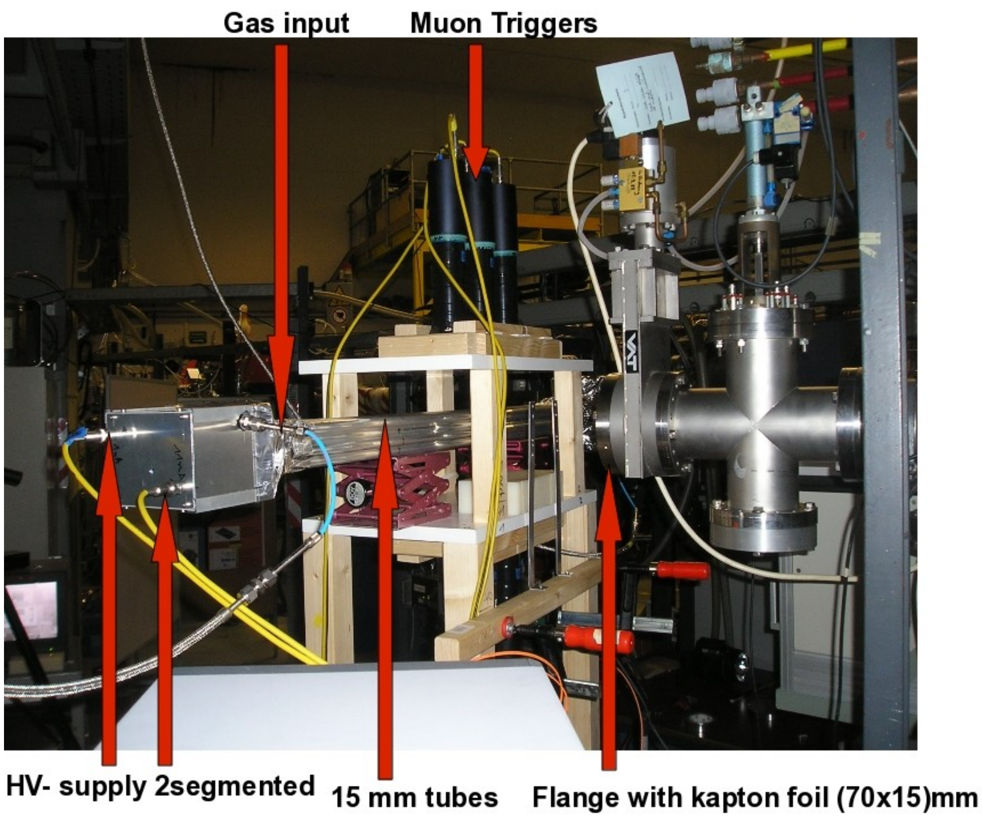
- **optical beam control: quartz glass**
- **p-beam intensities between fA – µA**

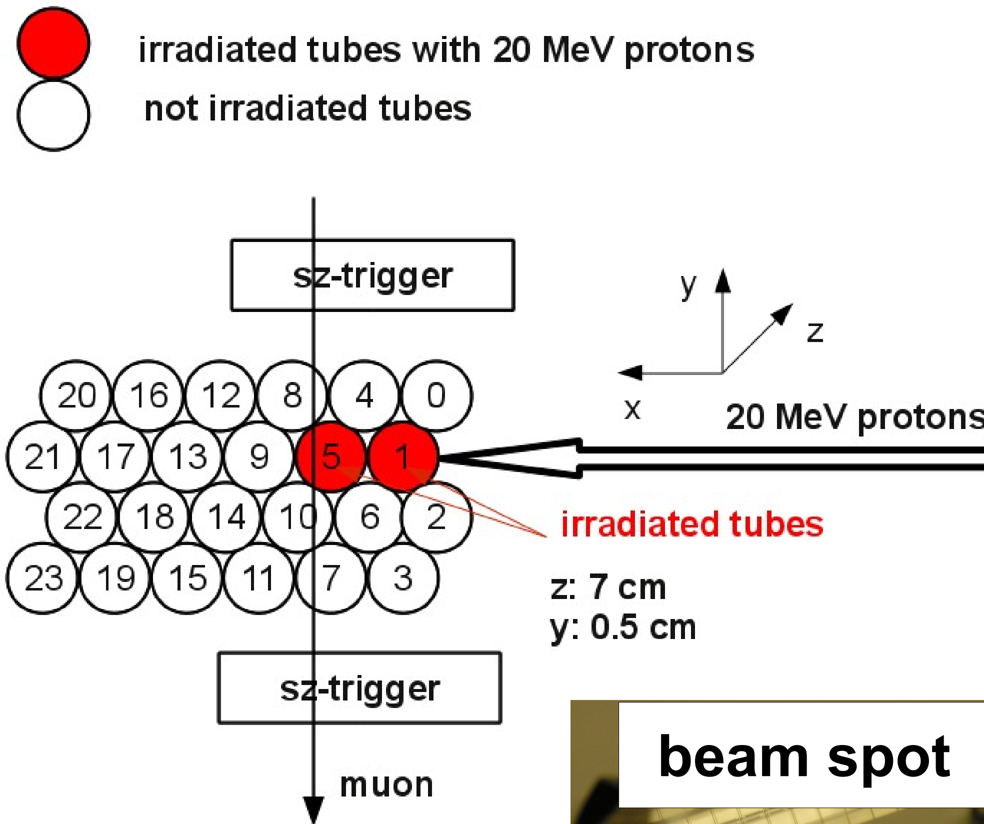
- **aging study of linear and fast drift gas Ar CO_2 N_2**

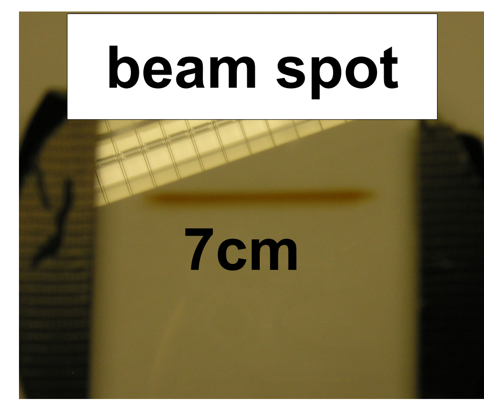
NO aging observed

- **more experiments with developed and further improved setup**

High Rate Capability of d = 15 mm Drift Tubes



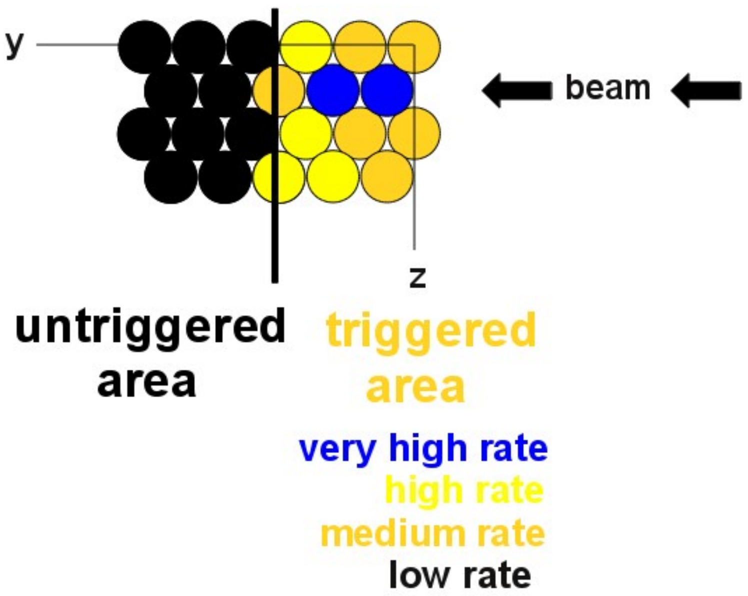




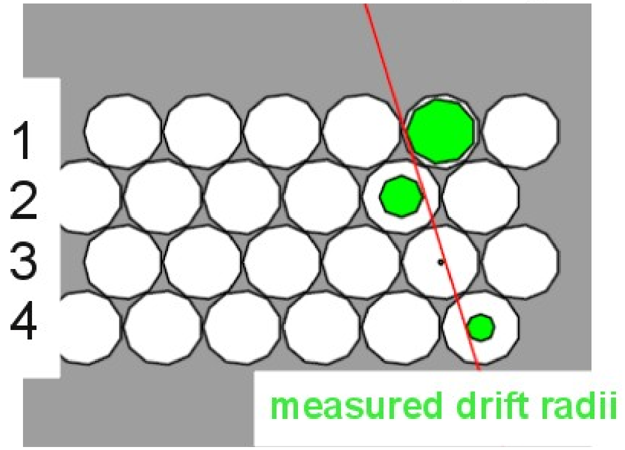
- **production of 400 keV signals in MDT - drift tubes with well focused proton beam and high rates**
- **beam spot = 7 cm ◦ 5 mm at 200 Hz (z ◦ y) (wobbler)**
- **position control: scintillation light in quartz**

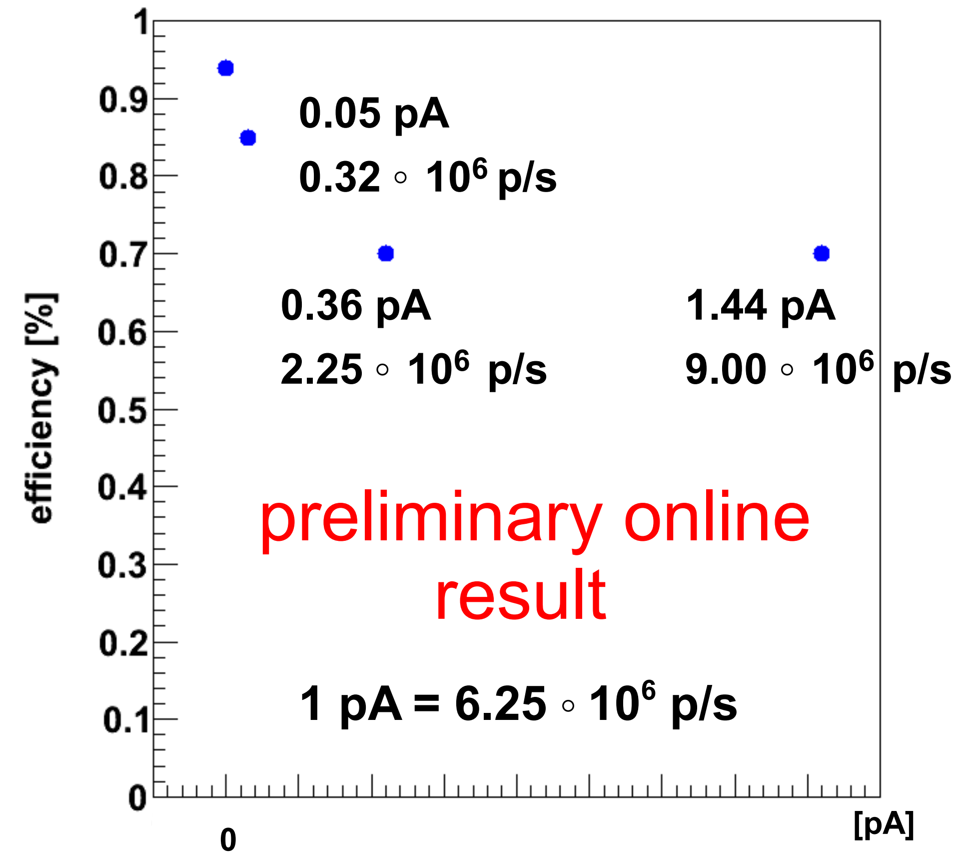
Proton Irradiation of 15mm Tubes

hit distribution



online event display

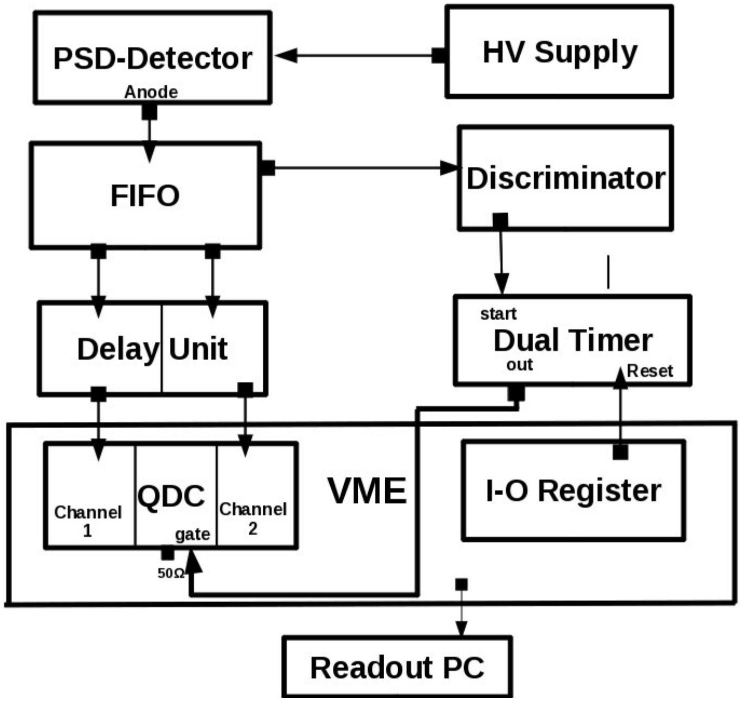




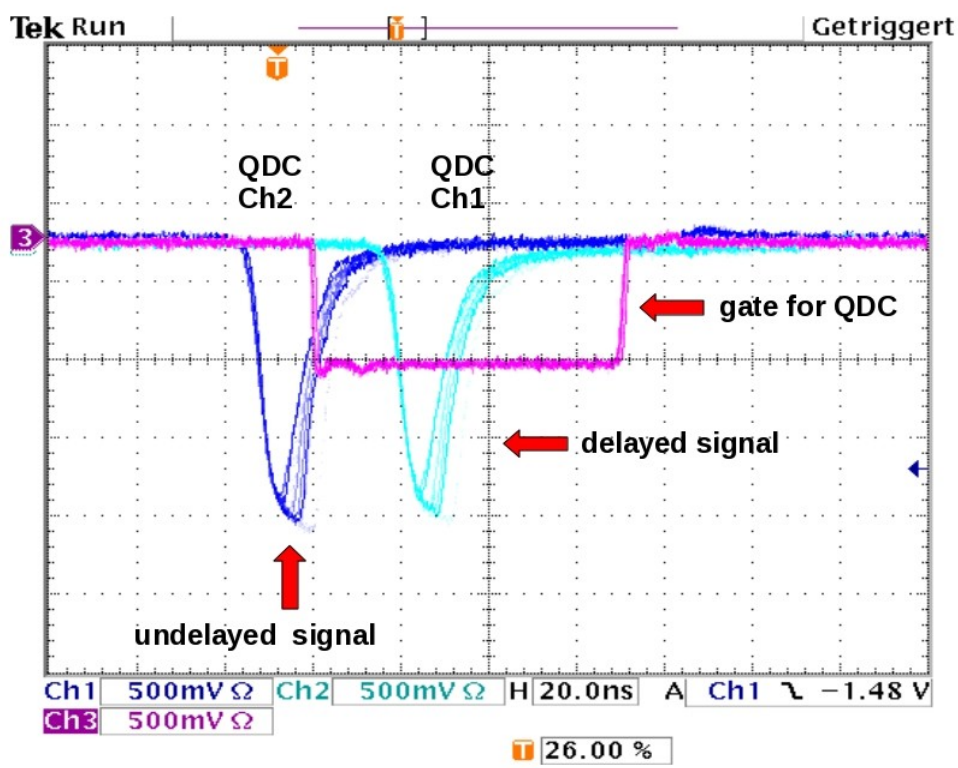
- efficiency determination
- fit muon track to drift radii in layer 1, 3 and 4
- compare predicted radius in layer 2

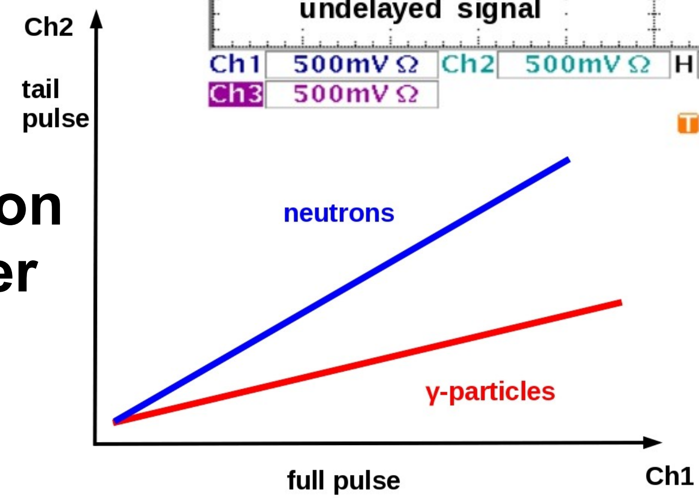
PSD [Electronic]

Schematic diagram of PSD-Electronic



Oscilloscope picture of PSD

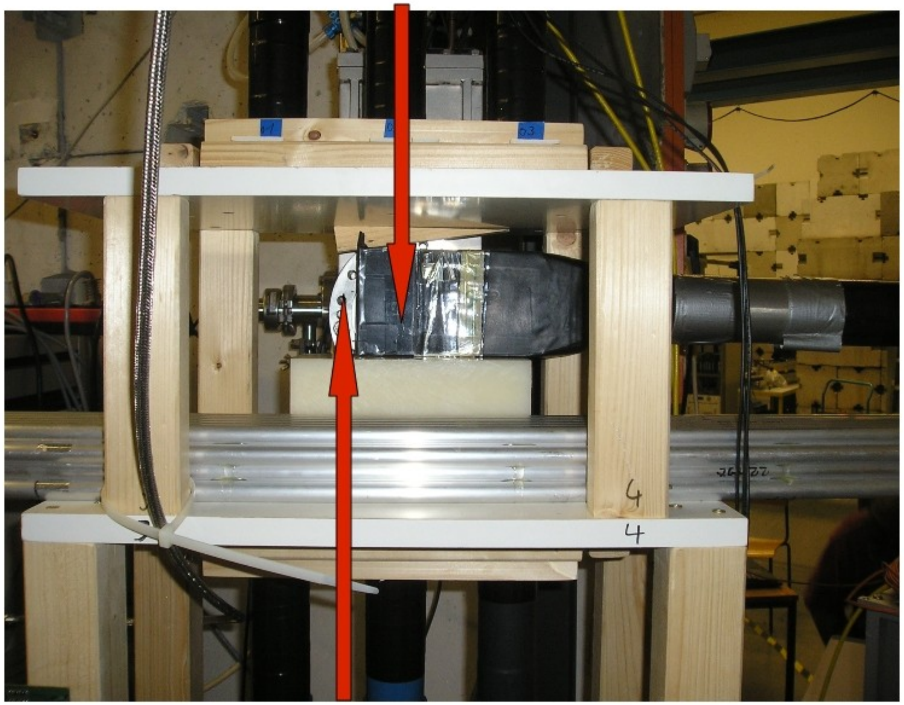




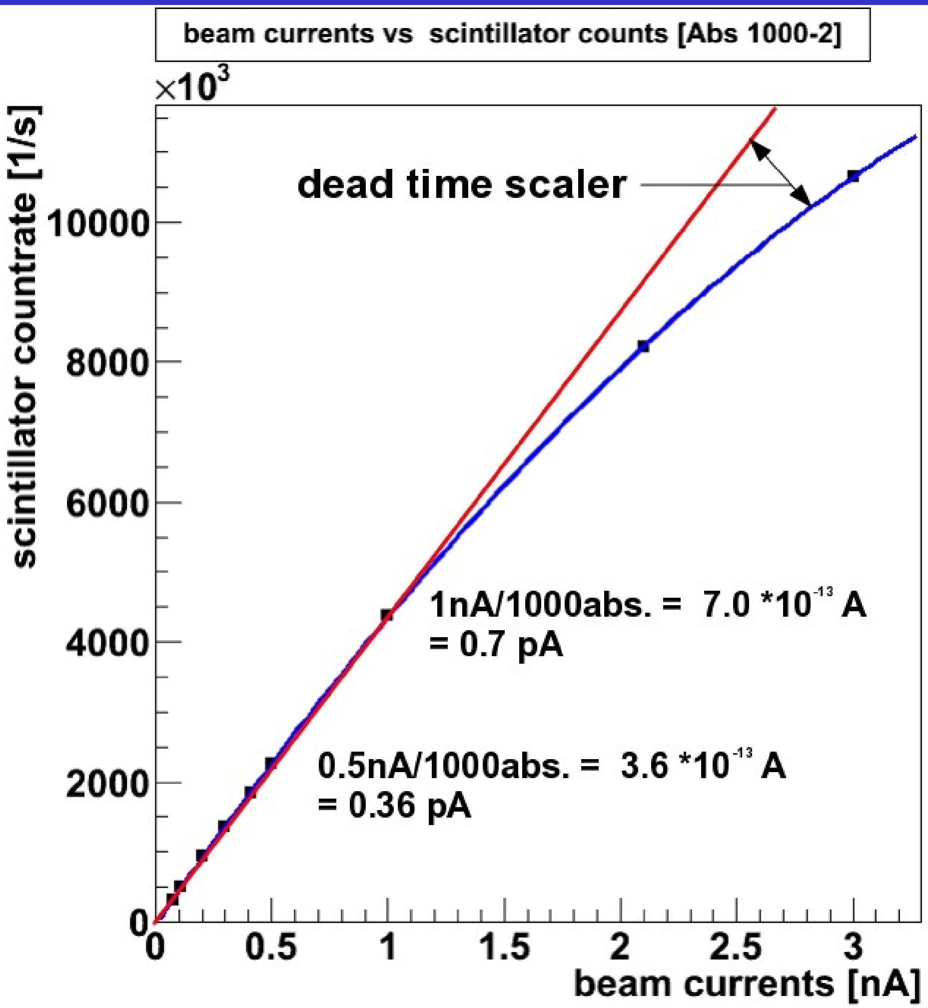
PSD = pulse shape discrimination
QDC = charge to digital converter
FIFO = fan in fan out
I-O = input -output register

Determination of Beam Currents

Scintillator paddle for beam current determination



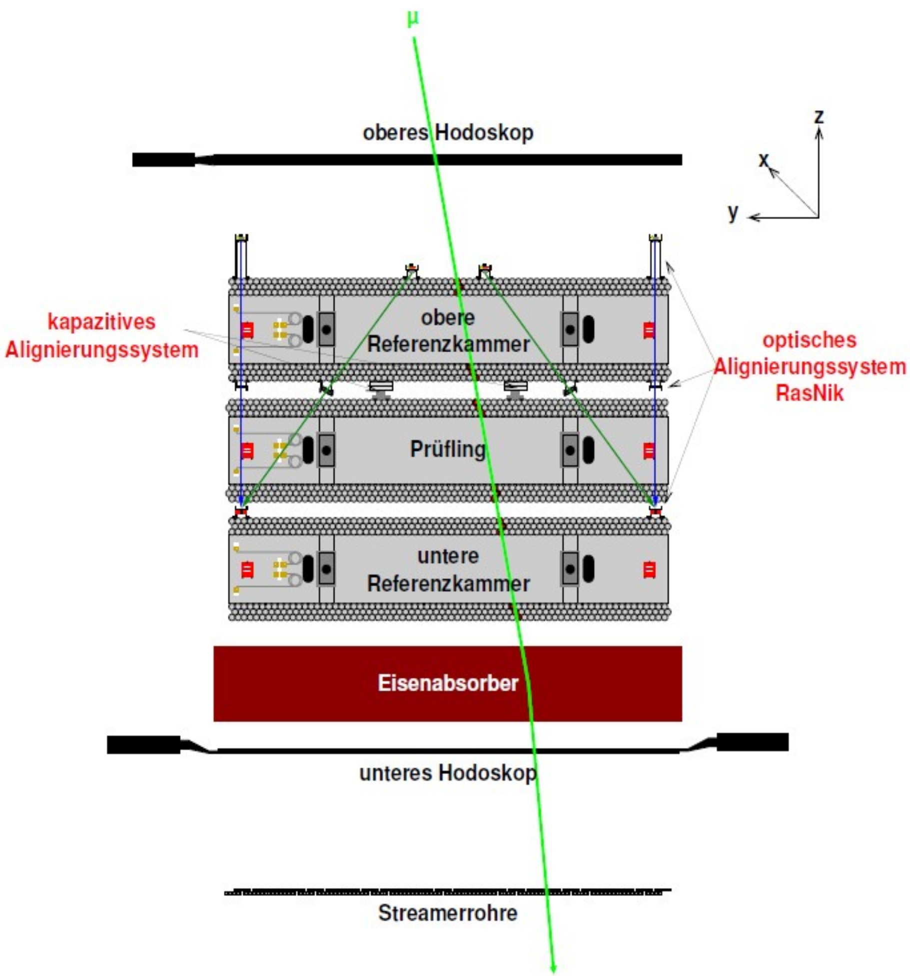
Flange with Kapton foil



- adjustment of pA currents possible with absorbers
  → irradiation of 15 mm tubes with different currents in the range of pA

- Divergence of blue curve because of dead time of scaler

Cosmic Ray Facility and SiPM's



Summary & Outlook

2 reactions to produce MeV neutrons

- d + Be 10 MeV (1-20MeV) $50 \circ 10^5$ Hz/cm^2
- α + Be 4 MeV (broad) $5 \circ 10^5$ Hz/cm^2 (few γ- particle)

LHC limits can be achieved

20 MeV protons for aging studies and high rate studies beam spots of 1 mm^2 – $8 \circ 1$ cm^2 available

- optical beam control: quartz glass
- p-beam intensities between pA – μA
- space charge effects in 15 mm drift tubes high rates in chambers O (10^7Hz)
- aging study of linear and fast drift gas Ar CO_2 N_2

NO aging observed

- more experiments with developed and further improved setup

Outline

1. motivation
2. ion beam preparation + pulse shape discrimination
3. neutron reactions and properties
4. aging studies at MDT tubes
5. high rate irradiation of [15 mm] tube chamber
6. silicon photo-multipliers
7. summary & outlook

Neutron Energy @ α - Be - Reaction

motivation: $\alpha + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + n + 5.709$ **MeV (exotherm)**

Idea: Q-Value 5.709 MeV + 30 MeV α- particle ➡ 35 MeV neutrons...?

2 dim. PSD-TDC-Diagramm