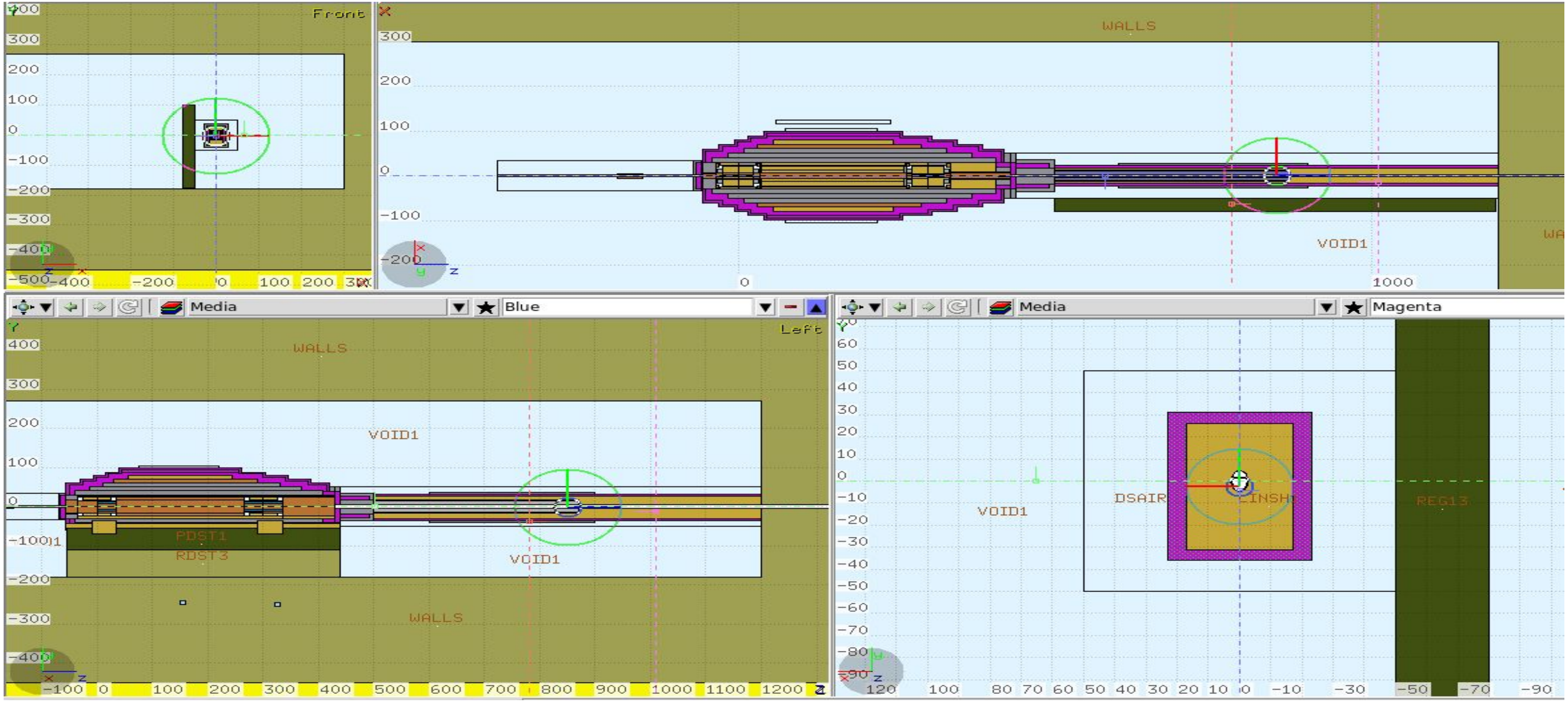
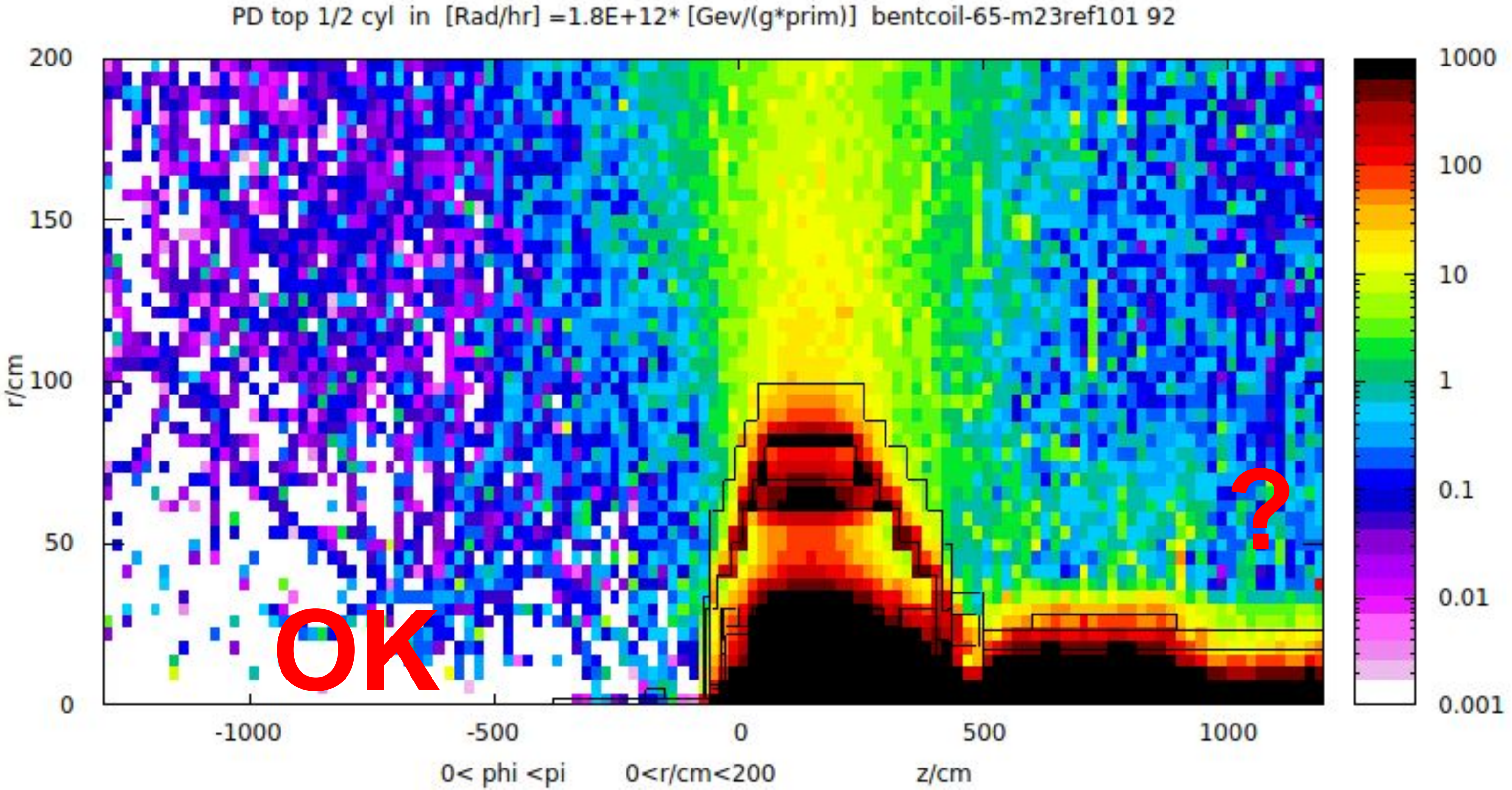
CPS beam line and VBV lifetime; Teflon as a benchmark.

[baturin@hallal1 ABSTSTref9]$ flair bentcoil-65-m23ref101.flair

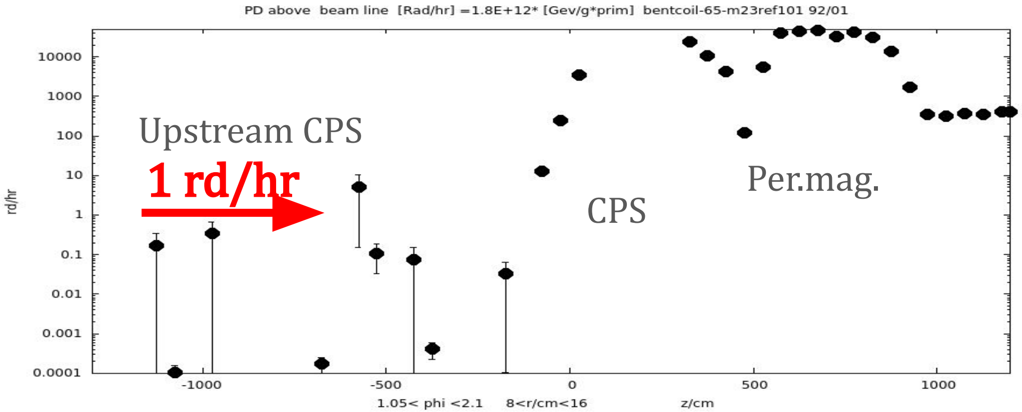


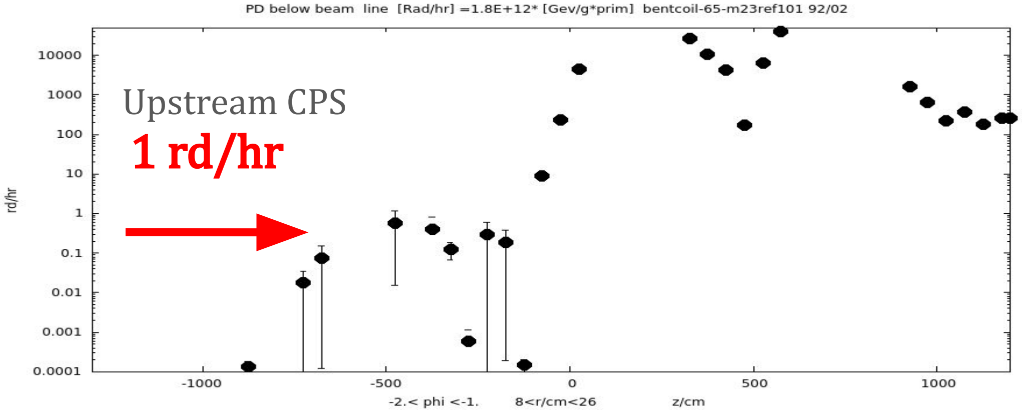
- Assume that critical part of vacuum remote control (VBV) is located at 8<r/cm<16
- What is PD in this area along the beam line? What is neutron flux - to be respon.

Prompt Dose r.vs.z -profile above the beam line (top ½ semi sphere).



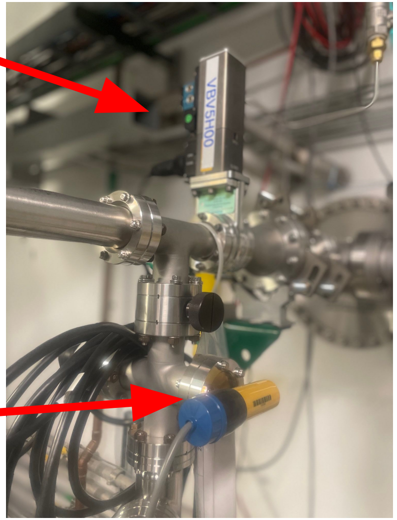
Prompt Dose z-profile on Top and Bottom of the beam line at 8<r/cm<16





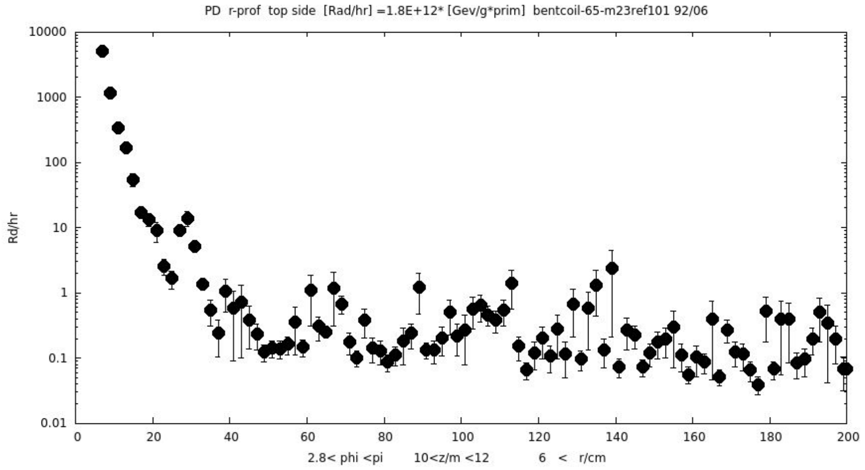
300 rd/hr

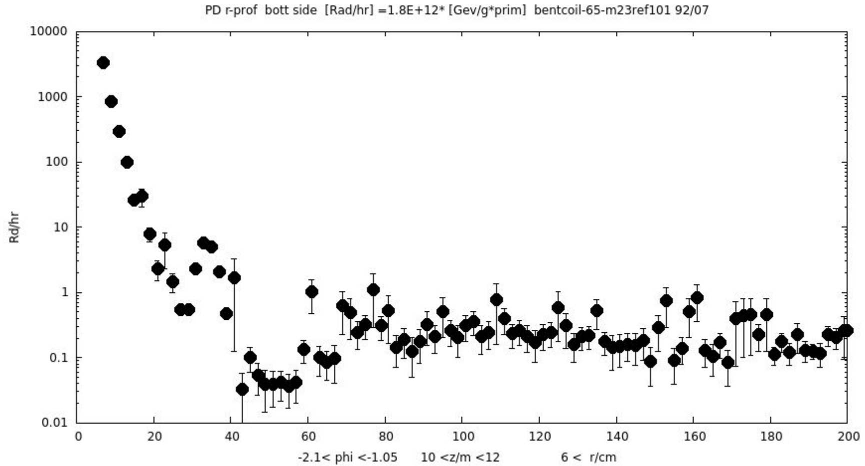
200 rd/hr



- Place upstream CPS with Bypass line?

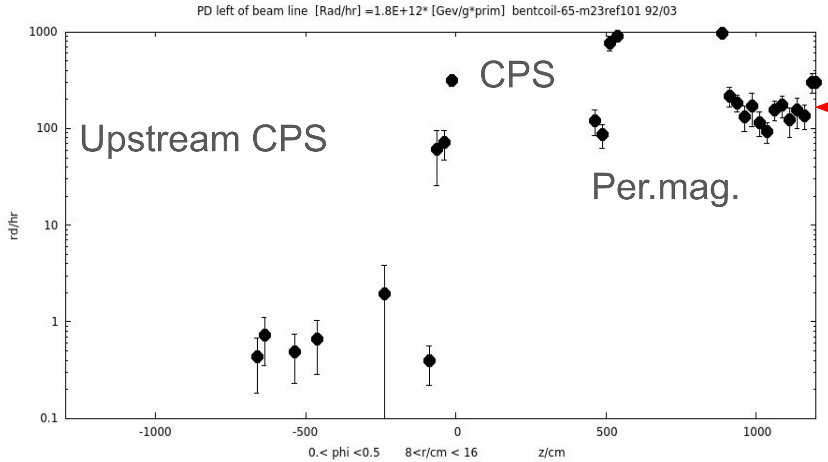
Prompt Dose r-profile on Top and Bottom of the beam line. 10<z/m<12



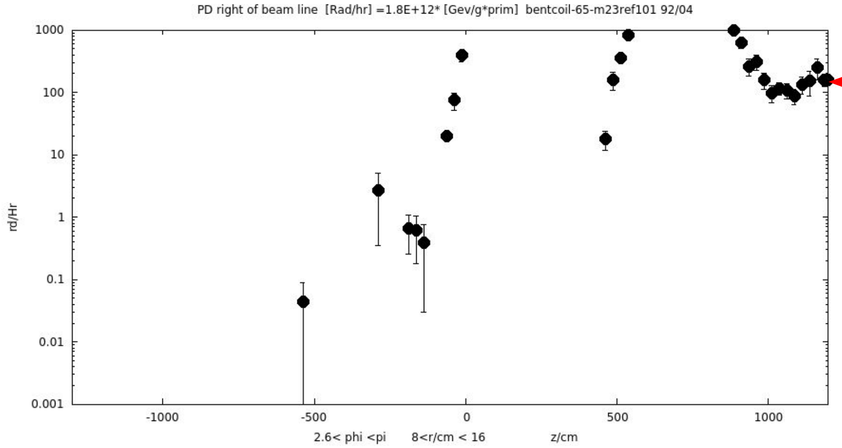


- At r/cm = 8 PD=~1000 rd/hr
- At r/cm= 14 PD=~100-200 rd/hr
- At r/cm= 20 PD=~2 rd/hr
- At r/cm > 30 PD=~10 rd/hr

PD z-profile Left and Right to the beam line at 8<r/cm<16



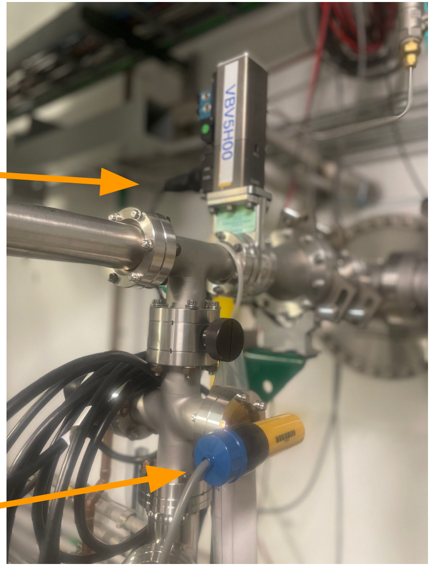
150 rd/hr Left side



150 rd/hr

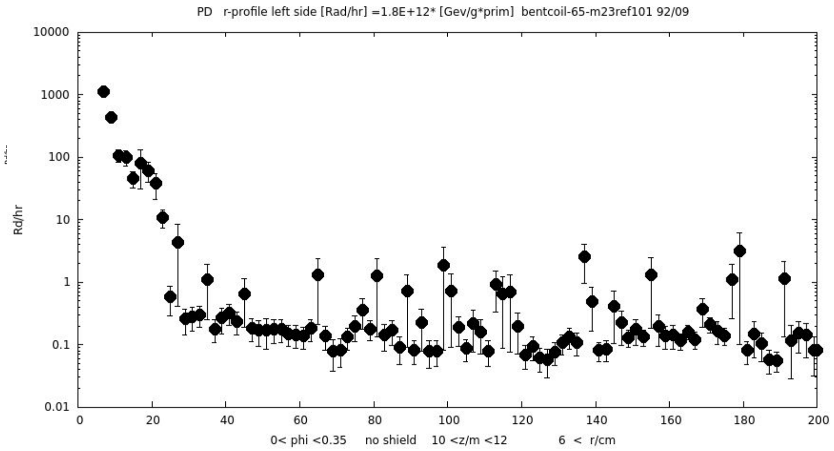
r=8 cm

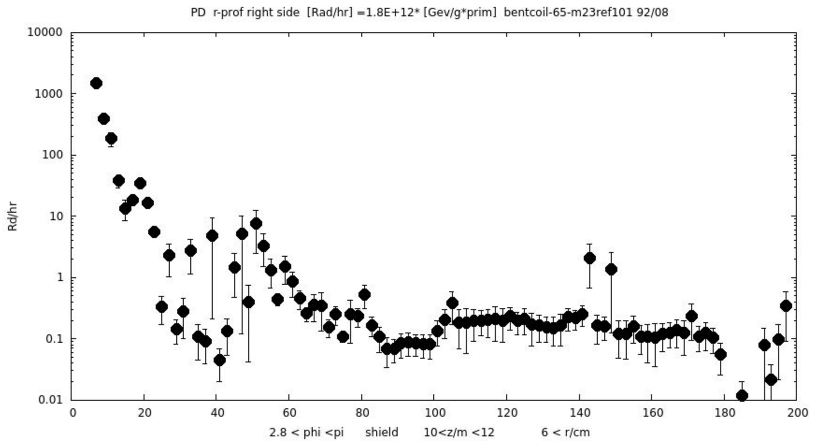
r=16 cm



- Lower than for Top and Bottom due to orientation of permanent magnet.
- Change orientation by 90°?

PD r-profile. Left and Right to the beam line. 10<z/m<12





- At r/cm = 8 **PD=~500 rd/hr !**
- At r/cm =14 PD=~50-100 rd/hr
- At r/cm = 30 PD =~0.1 rd/hr !
- Left=right difference is due to the additional concrete shield at the right side
- Twice lower than for Top and Bottom profiles.

Tensile strength of Teflon (pPTFE 6.4×50.1 mm) vs TID **in Air.**

https://www.sciencedirect.com/science/article/pii/014139109290093K?via%3Dihub

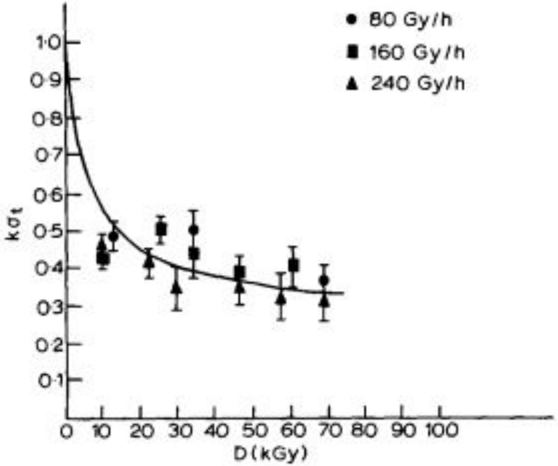


Fig. 3. The dependence of K_{σ_t} on the doses, *D*, for pPTFE irradiated at various dose rates (80 Gy/h, 160 Gy/h, 240 Gy/h).

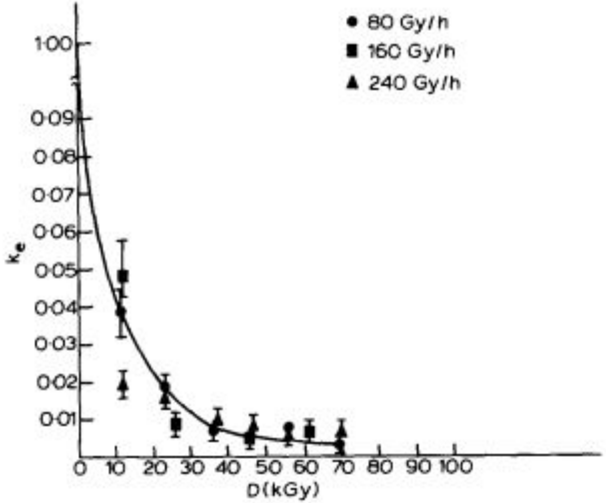


Fig. 6. The dependence of K_e on the dose, *D*, for pPTFE irradiated at various dose rates (80 Gy/h, 160 Gy/h, 240 Gy/h).

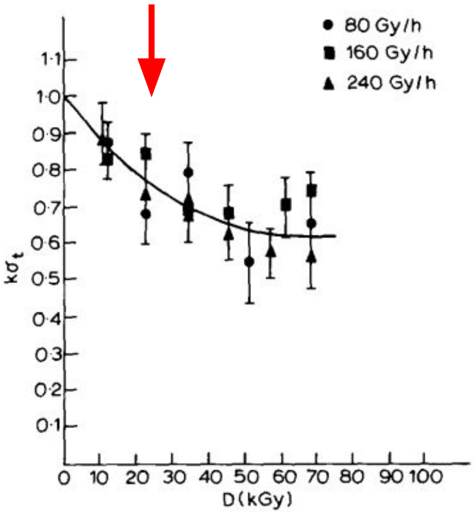
- At 20.E+3 Gy= **2 Mrad** (up to **10 Mrad ?**) pure Teflon sample brakes at ~ 45% of nominal load, elongates by ~2%.
- At 100 rad/hr (of γ) Teflon LT = 2.E+4 hrs = 2.3 years. May be 3 times longer - 7 years!

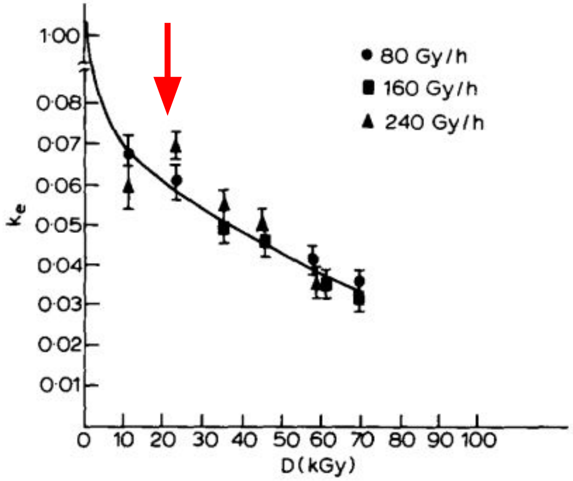
Tensile strength of Teflon (cPTFE 6.4×50.1 mm) vs TID **in Air.**

https://www.sciencedirect.com/science/article/pii/014139109290093K?via%3Dihub

https://www.osti.gov/servlets/purl/1671997

M. I. Chipară





Ratio of "tensile strength" of irradiated and unirradiated samples of cPTFE (Carbon filled)) vs TID/kGy .

Ratio of the "elongation at break" for irradiated to that of unirradiated cPTFE vs TID/kGy.

- At 20.E+3 Gy= **2 Mrad** Teflon+C sample Brakes at ~ 80% of nominal load, while elongates by ~6%.
- At 100 rad/hr (of γ) Teflon LT = 2.E+4 hrs = 2.3 years.

Compilation of Radiation Damage Test Data

https://cds.cern.ch/record/357576/files/CERN-98-01.pdf

Table 2a

General classification of rigid thermoplastics with respect to their radiation resistance

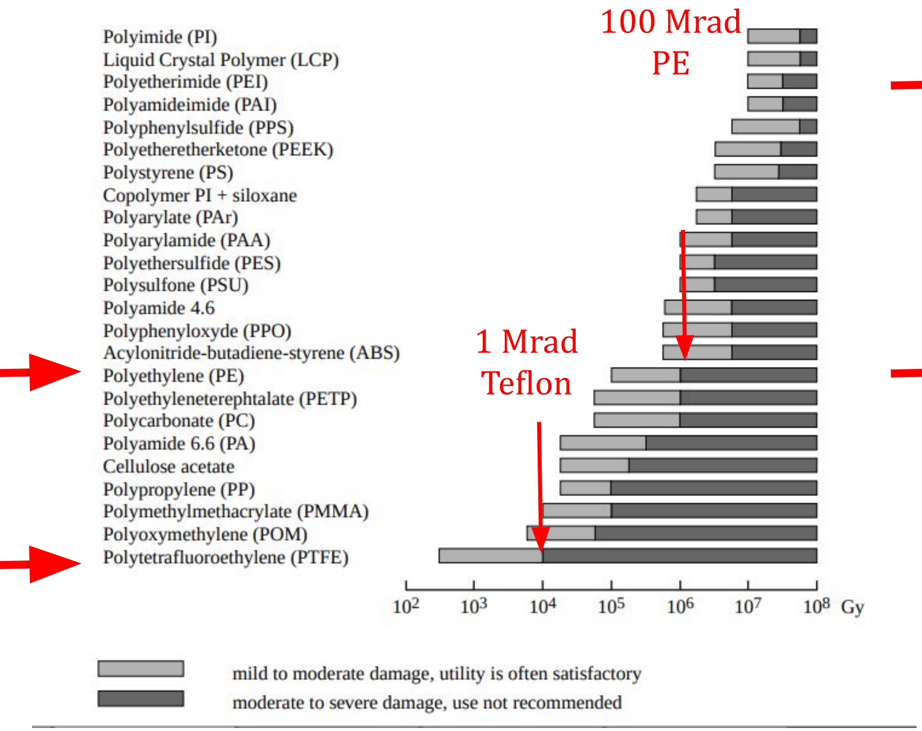
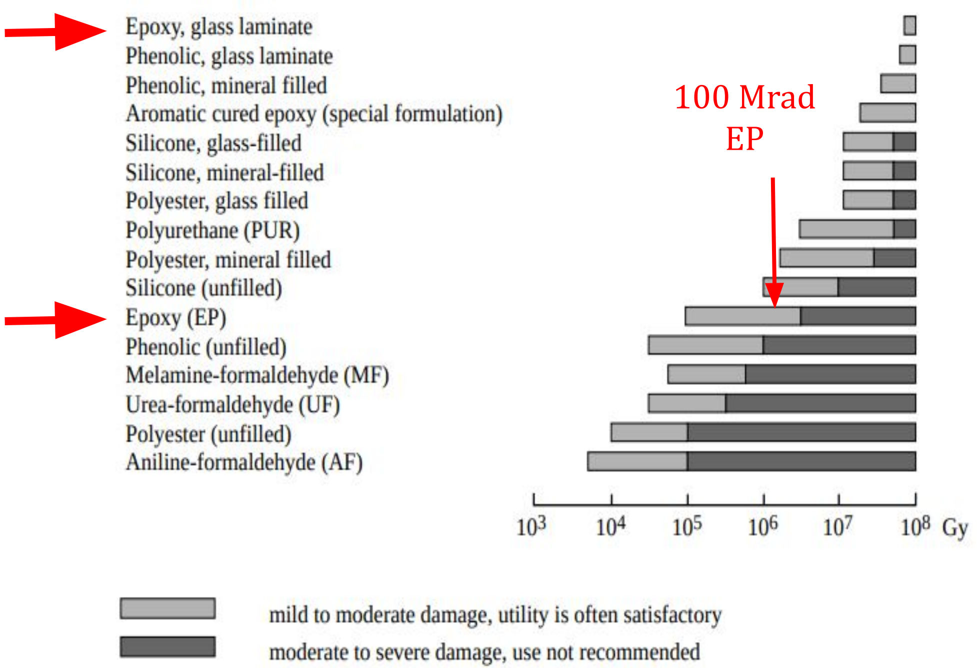


Table 2b

General classification of thermoset resins and composites with respect to their radiation resistence



Irradiation performance of PolyTetraFluoroEthylene (PTFE, Teflon, $0.6^2 \times 10$ cm^3) in a mixed fast neutron and gamma radiation field.

Otto K. Harling *, Gordon E. Kohse, Kent J. Riley
MIT Nuclear Reactor Laboratory, 138 Albany Street, Cambridge, MA 02139, USA
Received 17 December 2001; accepted 1 April 2002

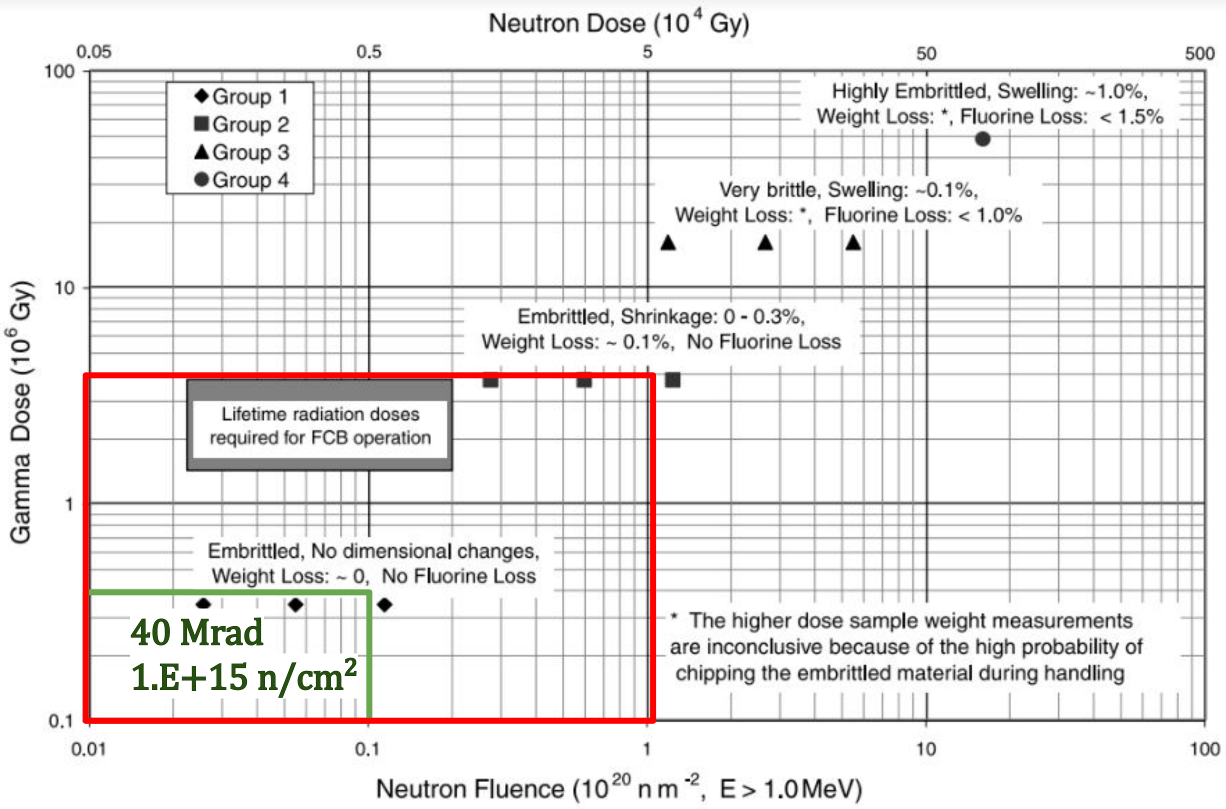


Fig. 1. Summary of the PTFE irradiation tests.

Teflon tests were done in Air atmosphere!

- **Critical Prompt Dose ~10-40 Mrad**
- **Critical neutron flux ~1.E+15 n/cm^**

CERN compilation of radiation damage data (1980)

HEATING ELEMENT

BASE MATERIAL: Teflon

TYPE: –

SUPPLIER: –

IDENTIFICATION: 291–1980

DESCRIPTION OF MATERIAL:
Flexible heating element of total width 68 mm consisting of a carbonized tissue (woven fibres) of width 38 mm embedded in an insulating coating of Teflon

APPLICATION AT CERN:
Heating element for vacuum chamber bakeout at the Intersecting Storage Rings and at the Super Proton Synchrotron LSS4 and LSS5

IRRADIATION CONDITIONS:
Type: Reactor ASTRA, switched-off reactor position 35 in air, dose rate 10 Gy/s
Doses: 1×10^5, 1×10^6 Gy

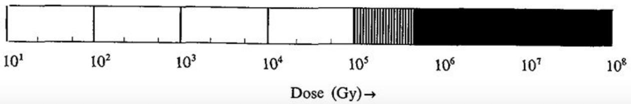
METHODS OF TESTING:

RESULTS:
Teflon matrix was severely damaged at 1×10^6 Gy. After some handling to test flexibility, the electrical resistance was greater than $2 \times 10^6\ \Omega$. At the lower dose of 1×10^5 Gy, however, the Teflon did not break, and the electrical resistance was $6.6 \times 10^3\ \Omega$ at a length of 15 cm.

Remarks:

REFERENCES:

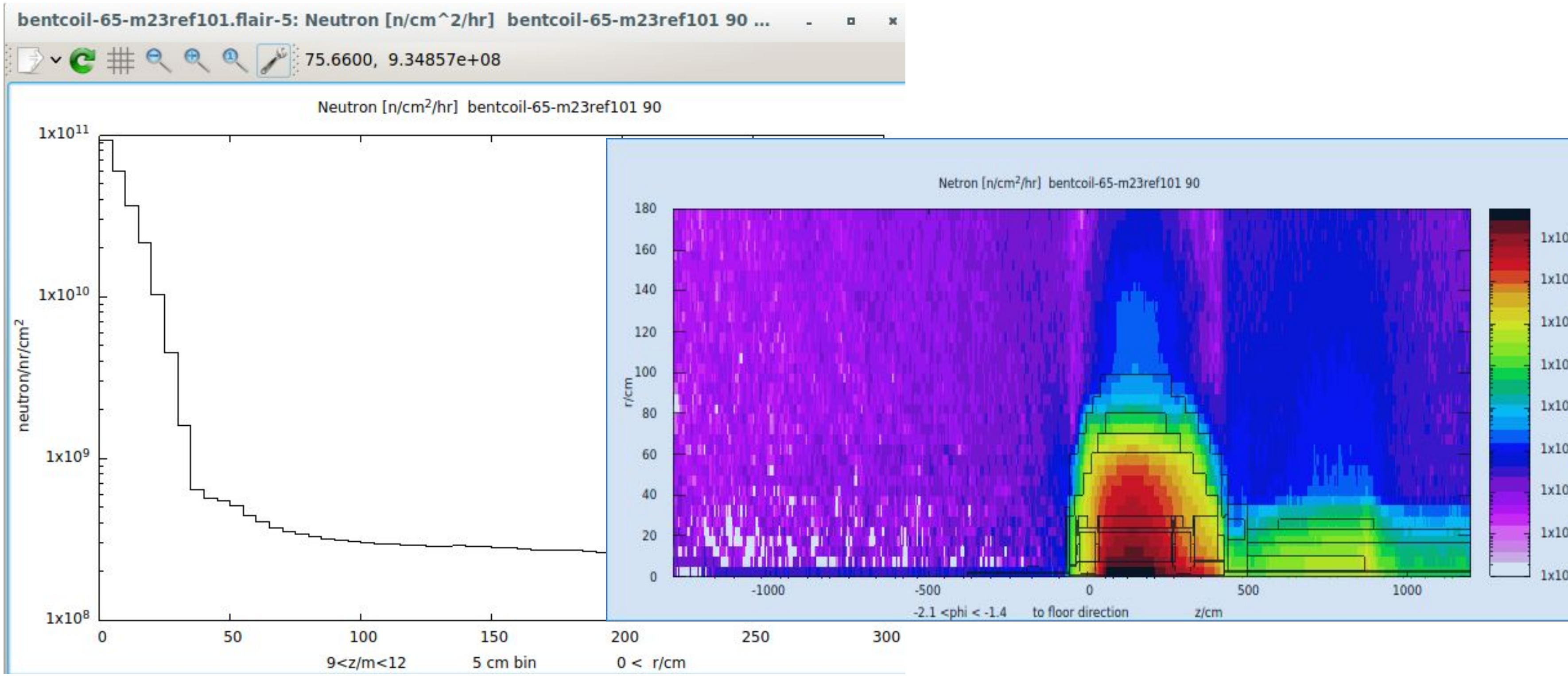
APPRECIATION: **** USE IN HIGH LEVEL RADIATION AREAS NOT RECOMMENDED ****
See Appendix 7



Teflon in a heating element. Test in Air!

- Teflon **<u>does not break</u>** at 1.E+5 Gy = **10 Mrad** !

Teflon LT and Neutron flux r-profile near exit form Tagger Hall (9<z/m <12)



- At 10<r/cm<15 neutron flux ~**0.4 E+11 n/cm^2/hr;** maximum **PD=500 rad/hr**
- Neutron-induces Teflon LT >20000 hrs= ~**2 year** (critical flux =1.E+15 n/cm^2)
- Photon - induced Teflon LT >10 Mrad/500rad/hr = 20000 hrs=~**2 years** (critical PD =10 Mrad)

ELECTRONICS COMPONENTS

BASE MATERIAL: Various

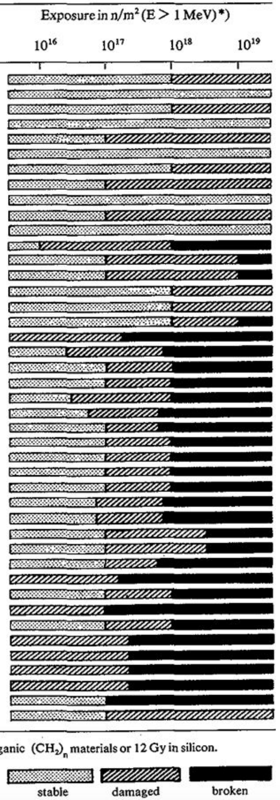
TYPE: See table below

SUPPLIER: Various

IDENTIFICATION: 133–1974

CERN compilation of radiation damage data (1980)

Designation		Type
Resistor:	carbon	1 kΩ, 5%
	metal film	1 kΩ, 1%
	wire wound	100 Ω, 5%
	potmeter "cermet"	1 kΩ, 78P
Capacitor:	ceramic	20 nF, 30 V
	mica	22 pF, 300 V
	polyester	15 nF, 125 V
	polycarbonate	15 nF, 250 V
	MKL	0.22 μF, 100 V
	electrolytic Al	200 μF, 10 V
	tantalum	15 μF, 20 V
Diode:	rectifier, Si	10D6
	general-purpose, Si	1N914
	general-purpose, Si	BAY72
	hot carrier, Si	HP2900
	Zener, Si	ZF6,8
	tunnel, Ge	1N3717
Transistor:	NPN, Si	2N918
	PNP, Si, rad. resist.	2N5332
	PNP, Si, rad. resist.	MM4261H
	FET, Si, N-channel	2N3819
	FET, Si, P-channel	2N3820
	MOSFET, P-channel	3N165
	MOSFET, N-channel	BSV81
Integrated:	TTL gate	SN7400N
	TTL flip-flop	SN7473N
	TTL counter	SN7493N
	TTL one-shot	SN74121N
	TTL gate	MC3000P
	TTL flip-flop	MC3055P
	amplifier, rad. res.	RSN55900
	amplifier, rad. res.	RSN55910
	op. ampli. rad. res.	RSN52709
	op. ampli. rad. res.	μA744
	op. ampli. FET input	μA740
	op. ampli. gen. purpose	MC1741
	comparator	SN72710
	op. ampli.	T1303
	op. ampli.	T1319
	op. ampli. FET input	T1420
Discrete:	op. ampli.	T1024
	DAC, 10 bits	T4022
Rectifier:	selenium	B250C75



*) Conversion factor 10^{17} n/m² (E > 1 MeV) ≈ 410 Gy in organic $(CH_2)_n$ materials or 12 Gy in silicon.

Stable operation of electronic components

Integrated

TTL logics, amplifiers, General purp. Si 1.E+13 n/cm^2. (200/2000/20000 hrs)

Diodes

General purpose Si 1.E+13 n/cm^2. (200/2000/20000 hrs)

Ht Carrier, Zener 1.E+14 n/cm^2. (200/20000/20000 hrs)

Resistors

Carbon and wire 1.E+14 n/cm^2. (2000/20000 hrs)

Metal Film unlimited

Capacitor

Ceramic 1.E+13 n/cm^2 (200/2000/20000 hrs)

Polyester 1.E+14 n/cm^2 (2000/20000 hrs)

Mica, MKL, Tantalum unlimited

All **brakes typically at 10 times higher** neutron flux.

AT 10<r/cm<15 neutron flux ~0.5 E+11 n/cm^2/hr.

At 25<r/cm<30 -//- ~0.5 E+10 n/cm^2/hr

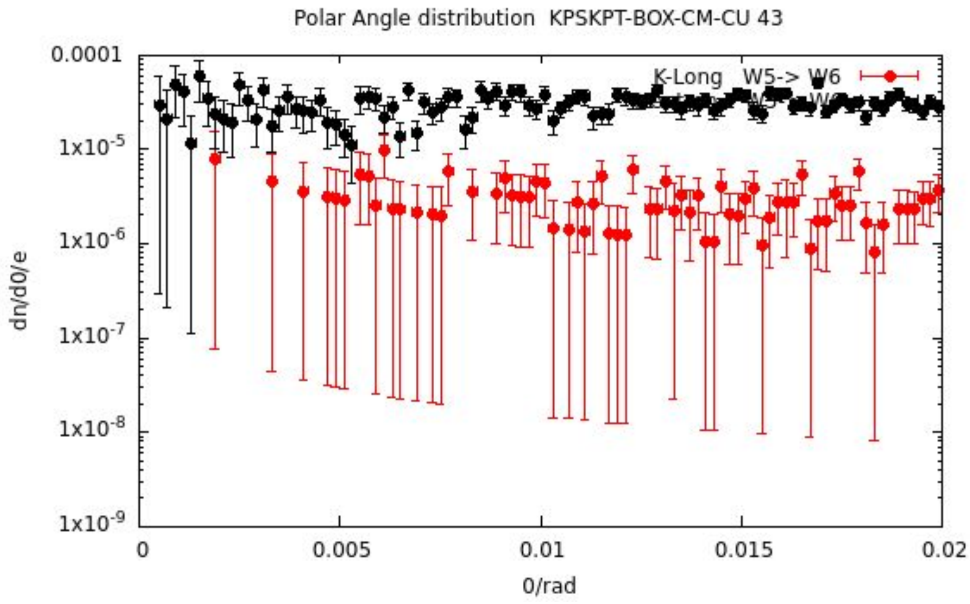
At 50<r/cm -//- ~0.5 E+09 n/cm^2/hr

CONCLUSION

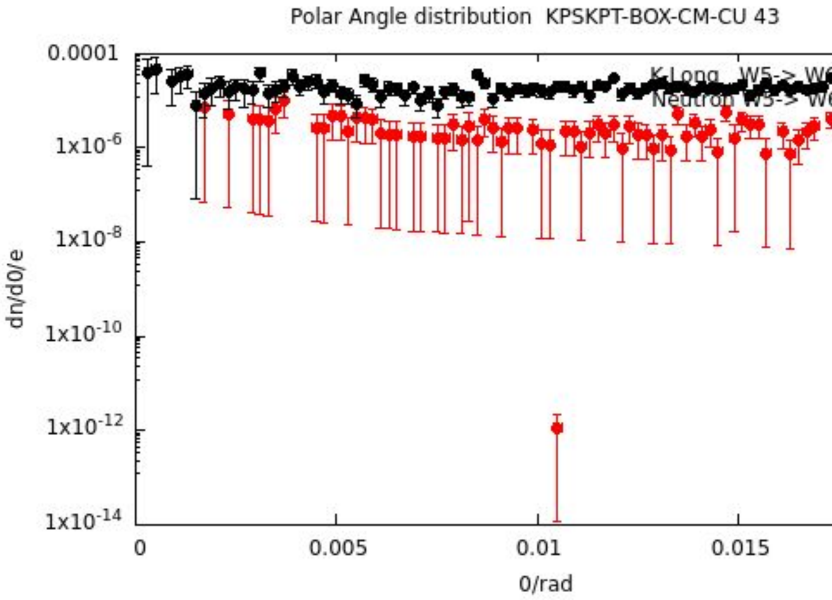
Teflon at r = 8 cm ; worst case scenario.

- **VBV cable** at the exit from Tagger Hall (10<z/m<12) **is exposed to ~ 500 rad/hr** (at r =8 cm).
- From **CERN** database, and Slide-8, we read for the **Teflon** TID = **2 Mrad** (up to 40 Mrad). Therefore,
- Under **photons** **Teflon LT = 0.5 years** (up to 10) of continuous operation (~170 days = 4.E+3 hrs ; SHV conn.).
- Under **neutrons** Teflon **LT = 2 years**
- **Epoxy** and **Polyethylene LT = 50 years** (20000 days =**~4.E+5 hrs**, PCBs and cable insulation).
- At the **<u>upstream</u>** <u>side</u> of the beam line all **LTs are ~ 100 times longer.**
- Is it possible to **avoid** placing **vacuum equipment downstream** the CPS using bypass line?
- Engineering solution to avoid vibration and mechanical load on SHV connectors.

- From **exponential r-profiles** => at r =~ 15 cm LTs are ~ **10 times longer**.
  at r =~ 30 cm — ~**100 times longer**

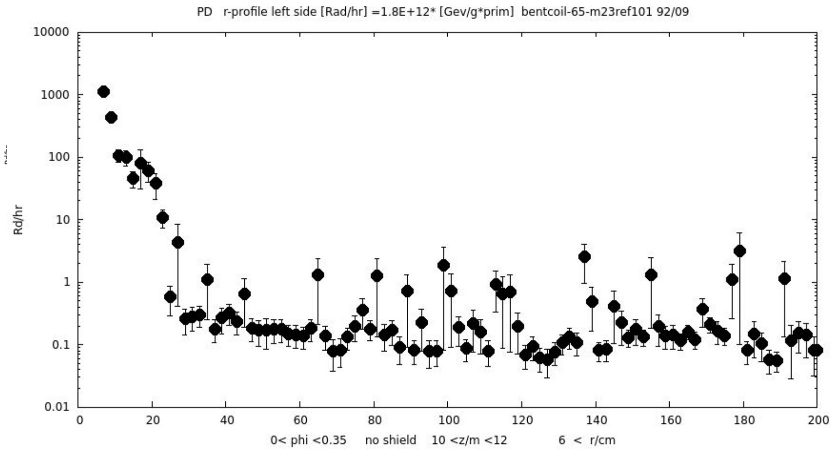


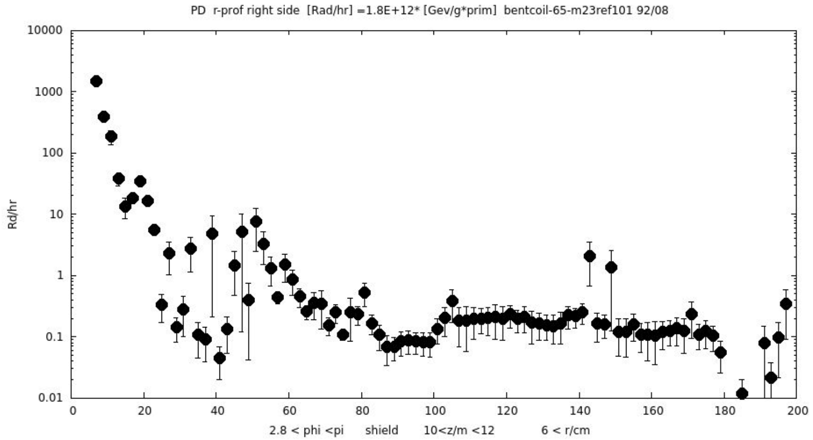
Polar Angle distribution KPSKPT-BOX-CM-CU 43
K-Long W5-> W6
0.0001
1x10-5
1x10-6
1x10-7
1x10-8
1x10-9
0
0.005
0.01
0.015
0.02
dn/d0/e
0/rad



Polar Angle distribution KPSKPT-BOX-CM-CU 43
0.0001
1x10-6
1x10-8
1x10-10
1x10-12
1x10-14
0
0.005
0.01
0.015
dn/d0/e
0/rad

PD r-profile. Left and Right to the beam line. 10<z/m<12





- At r/cm = 8 PD=~500 rd/hr !
- At r/cm =14 PD=~50-100 rd/hr
- At r/cm = 30 PD =~0.1 rd/hr !
- Left=right difference is due to the additional concrete shield at the right side
- At r=14 twice lower than for Top and Bottom profiles.