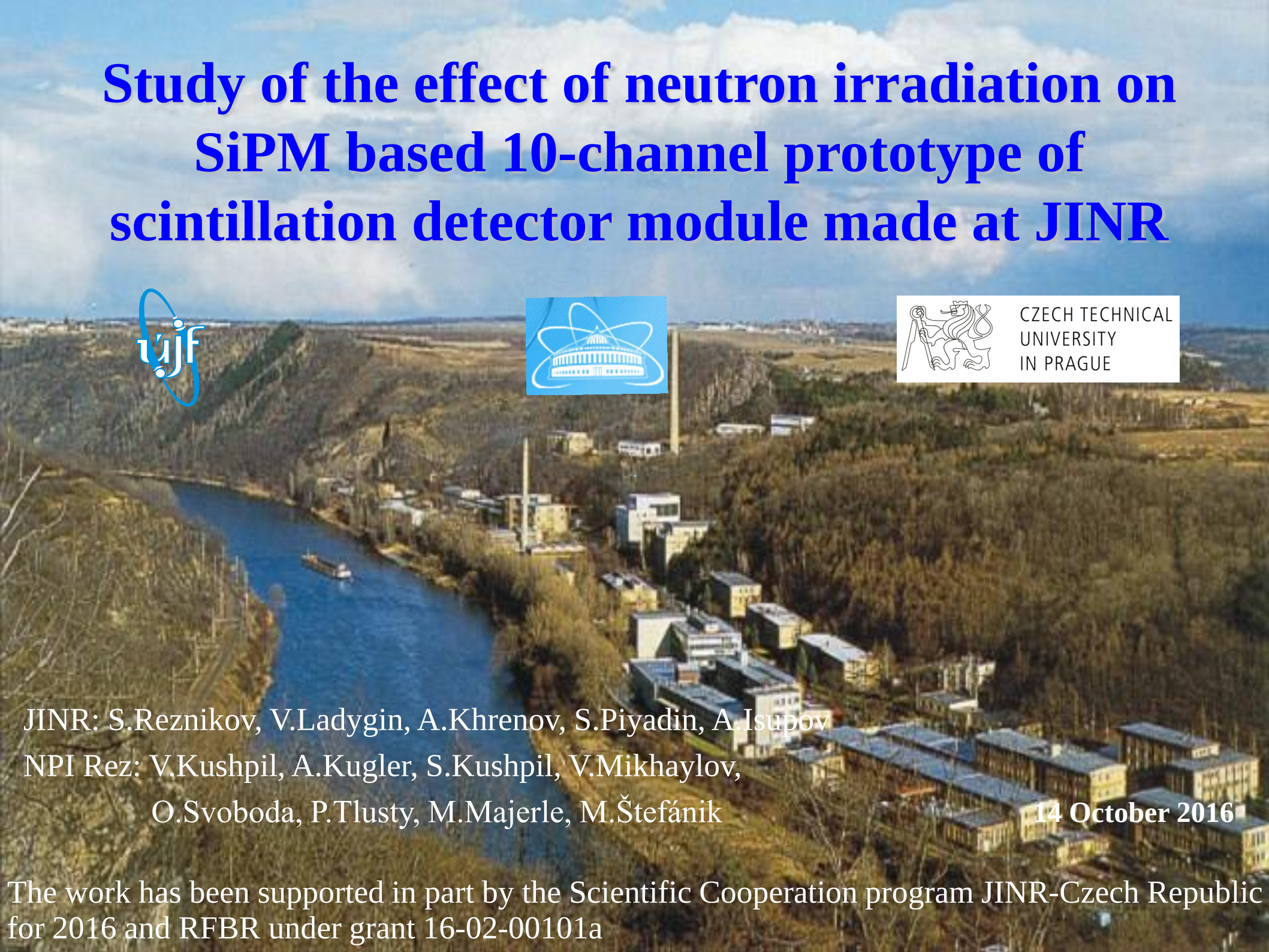
Study of the effect of neutron irradiation on SiPM based 10-channel prototype of scintillation detector module made at JINR



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14 October 2016

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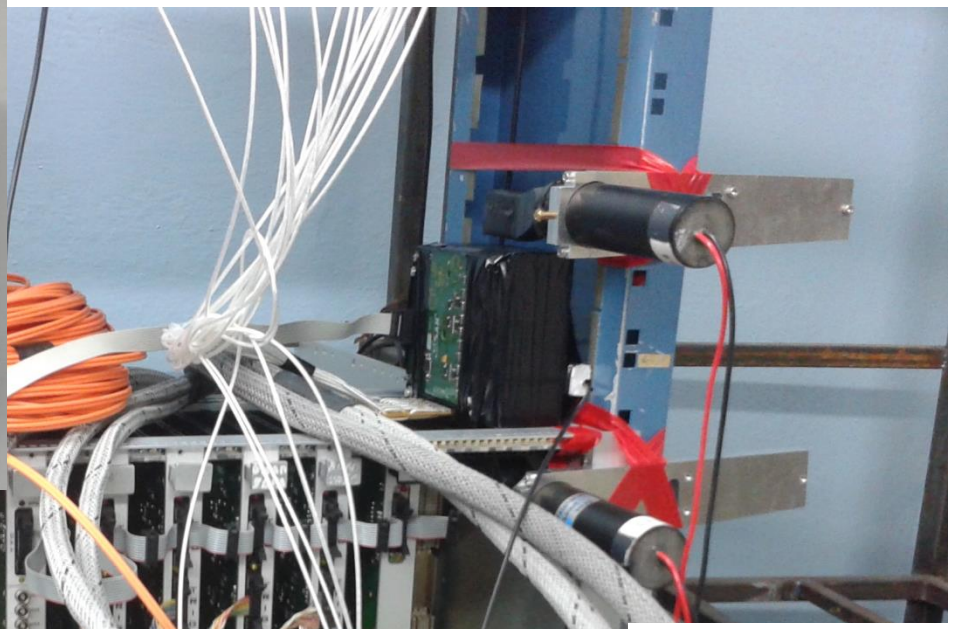
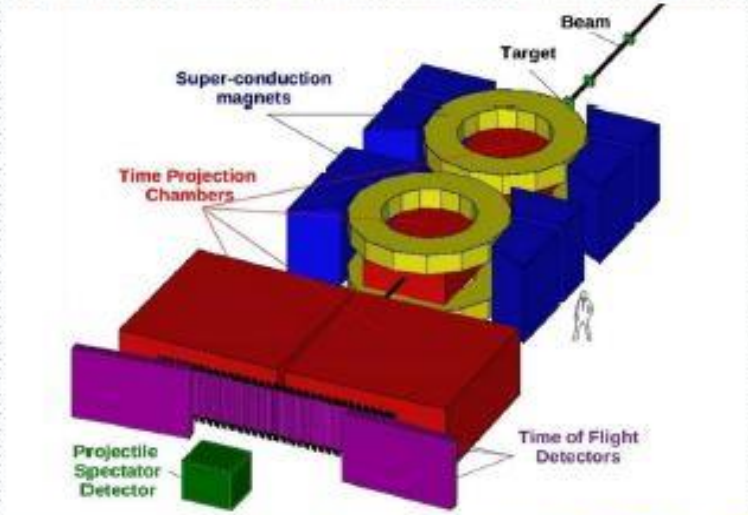
SiPM based 10-channel prototype module

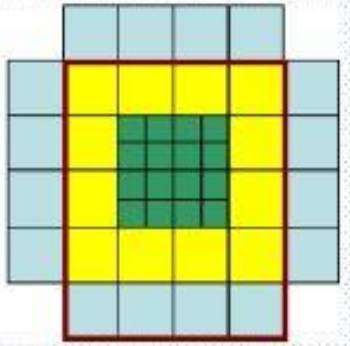


KETEK PM3350

PSD and ZDC

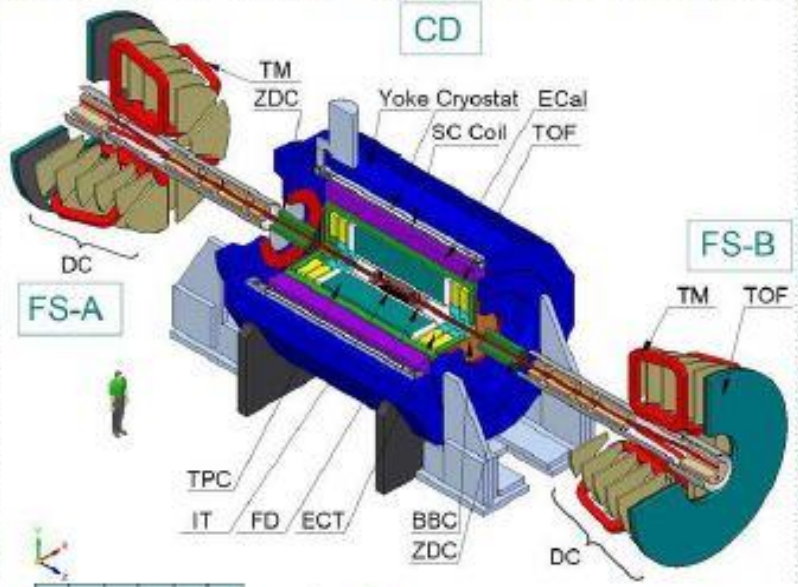
NA61 Projectile Spectator Detector

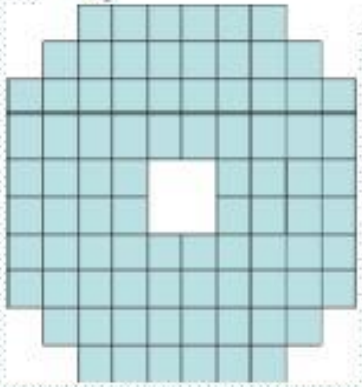


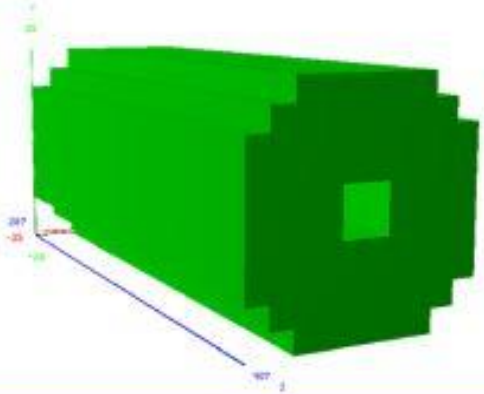


60 sandwiches in one module
16 inner modules of 10 x 10 x 120 cm^3
28 outer modules of 20 x 20 x 120 cm^3
Total weight ~ 17 tons, 17-25 m from target
No beam hole for intensity up to $2x10^5$ ions/sec
NA61 beam energy up to 150 AGeV

NICA MPD Zero Degree Calorimeter

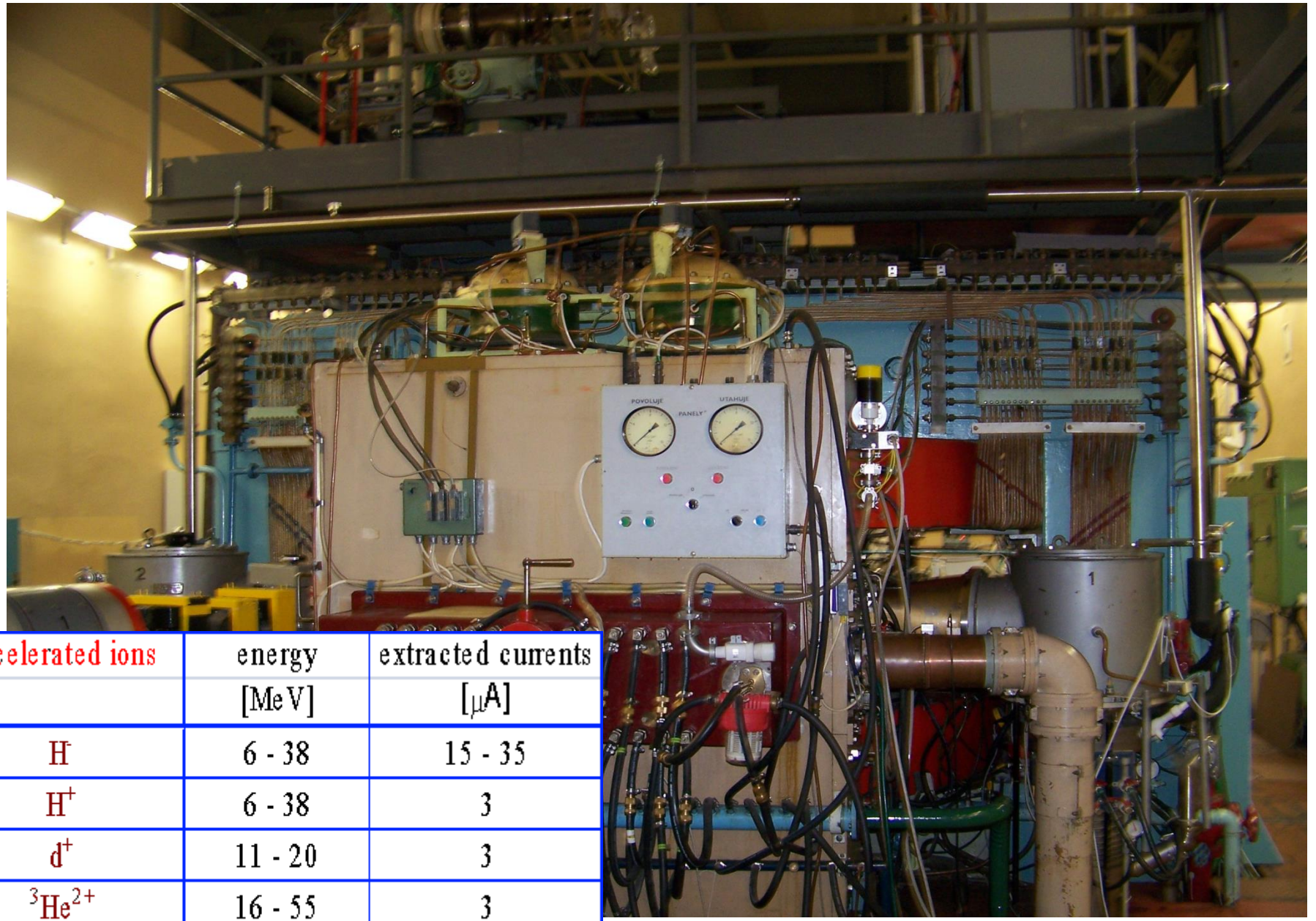






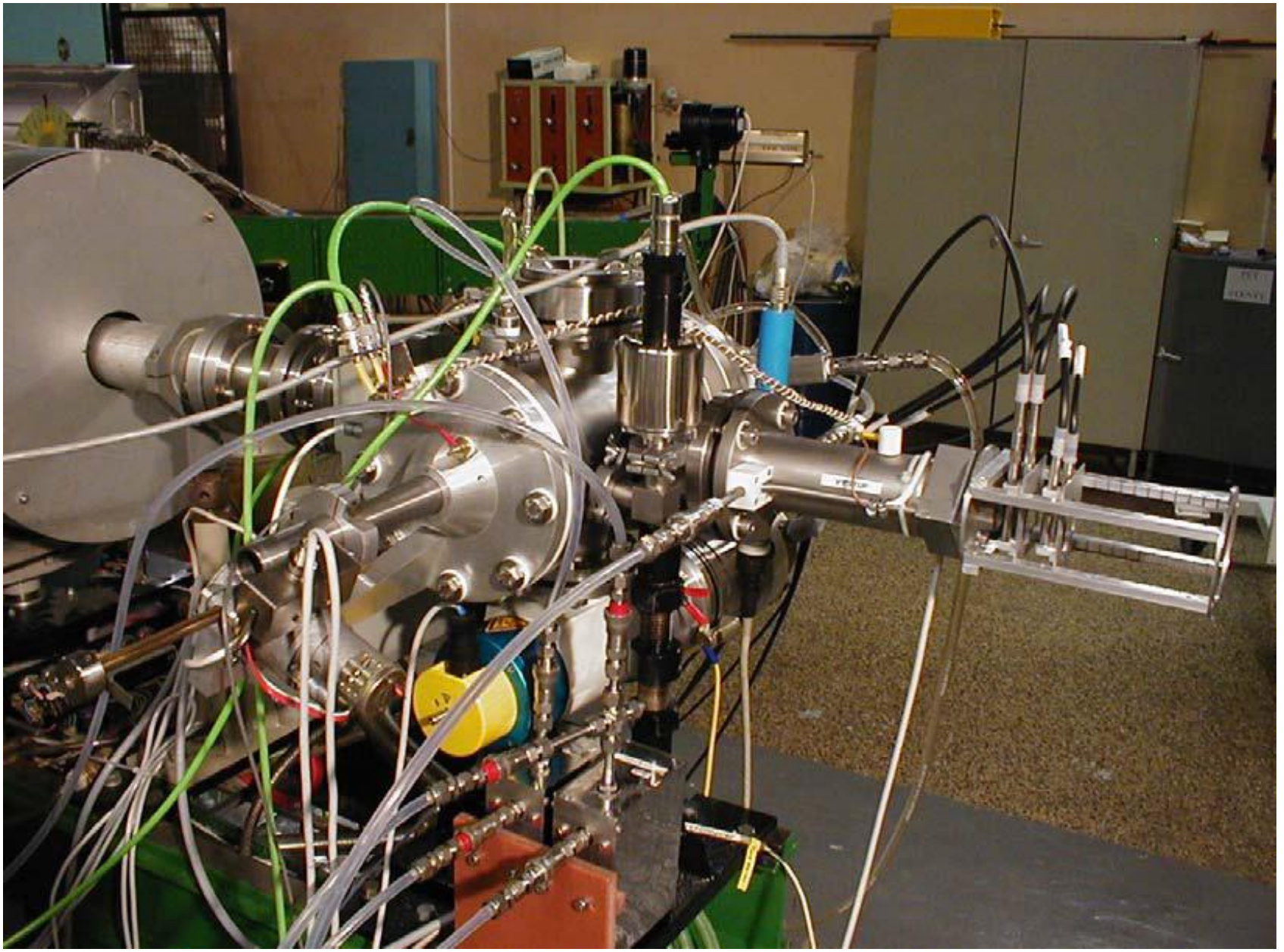
60 sandwiches in one module
16 modules of 5 x 5? x 120 cm^3
Total weight ~ 10 tons, 28 m from collision estimate
Beam hole (10x10 cm) for intensity up to $1x10^9$??? ions/sec
NICA beam energy up to $\sqrt{s_{NN}}$ =11GeV?(~ E_{beam}=63 AGeV)

Cyclotron U120M

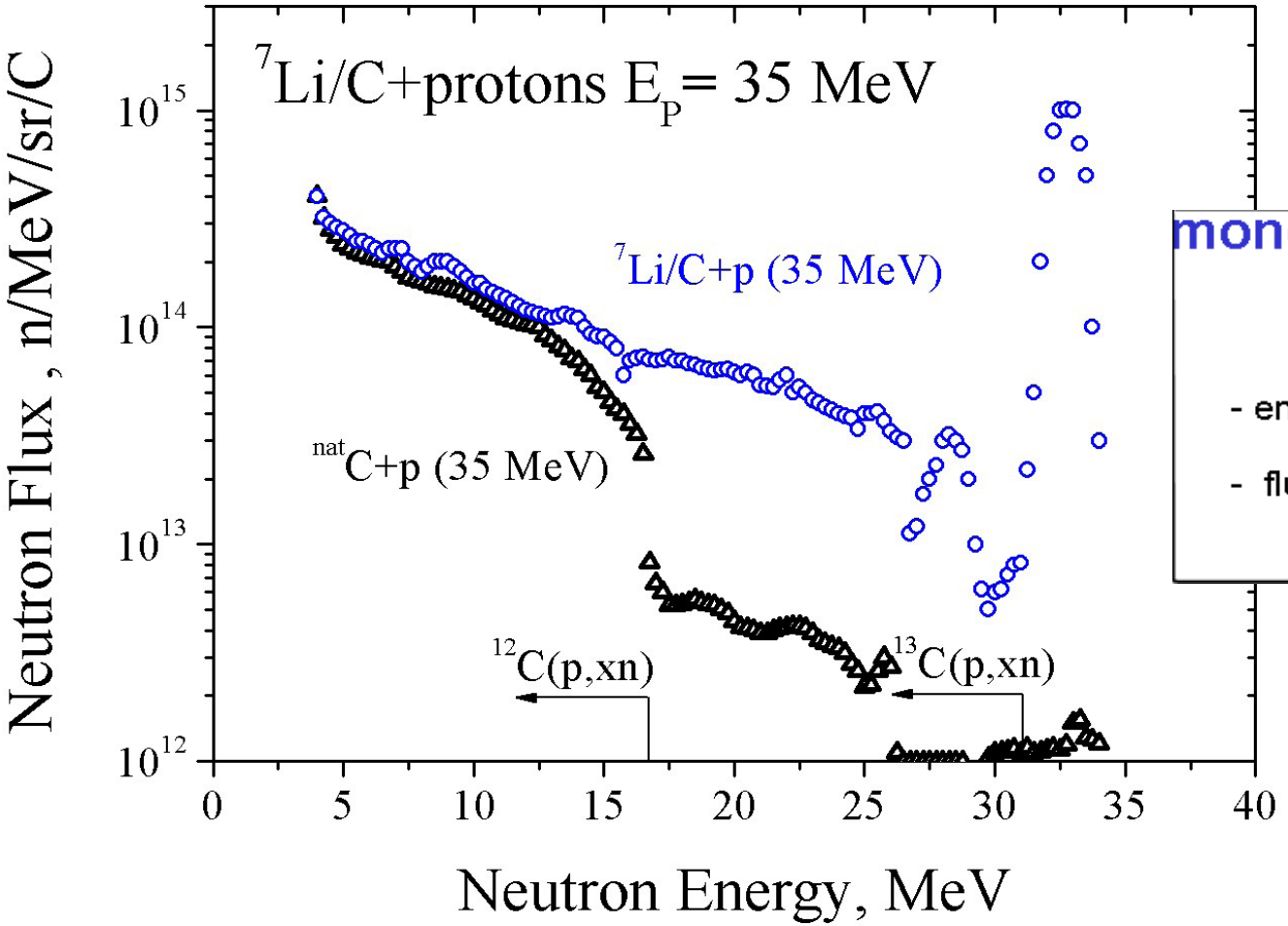


accelerated ions	energy [MeV]	extracted currents [μA]
H^-	6 - 38	15 - 35
H^+	6 - 38	3
d^+	11 - 20	3
$^3He^{2+}$	16 - 55	3
$^4He^{2+}$	22 - 40	3

Cyclotron U120M (fast neutrons)



Cyclotron U120M (p + D_2O)



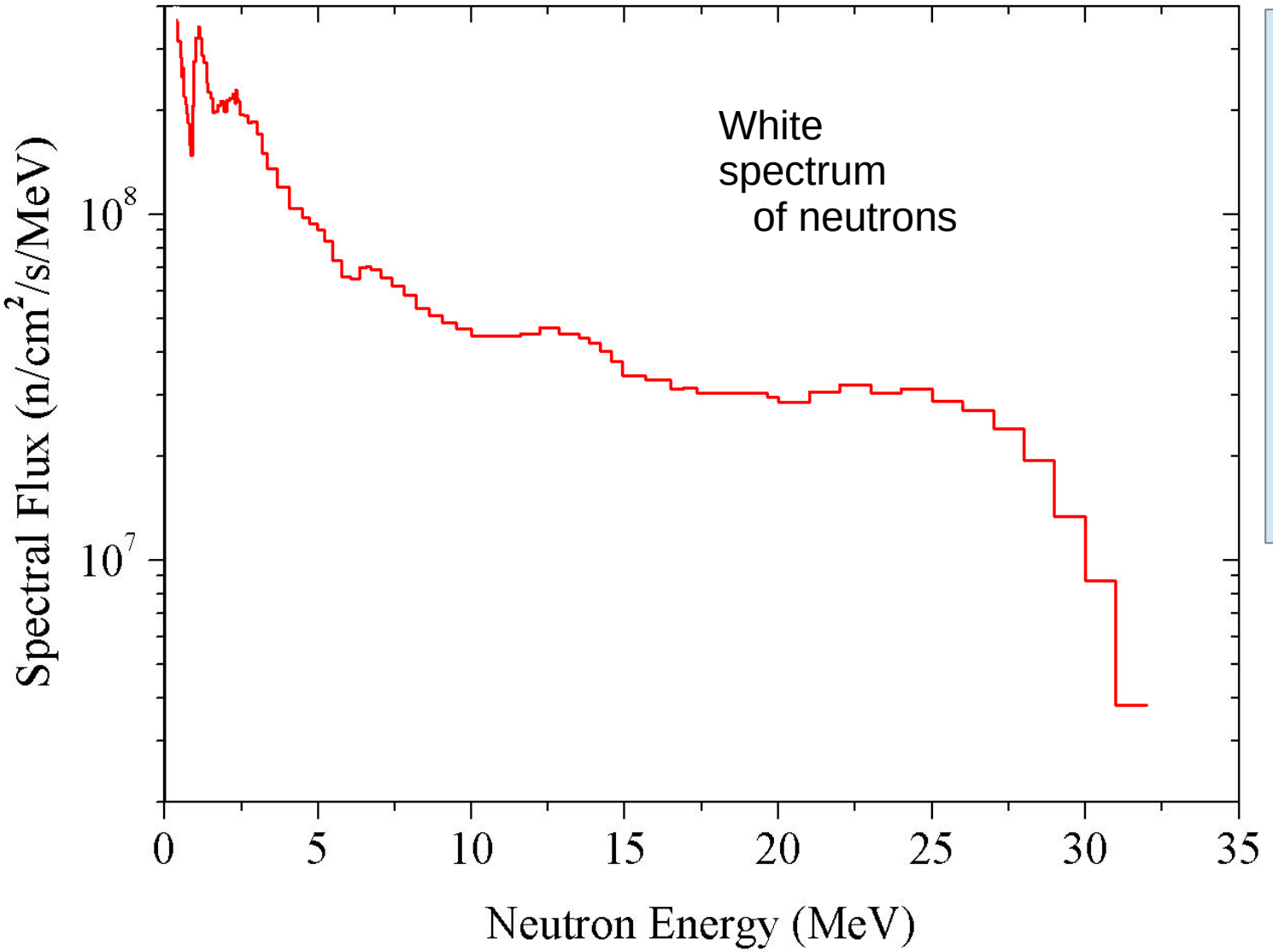
mono-energetic 20-37 MeV

Source reaction p+7Li

- energy range **20 - 37 MeV**
- flux density

3 10^9 n/cm^2/s

Cyclotron U120M(p + Be)



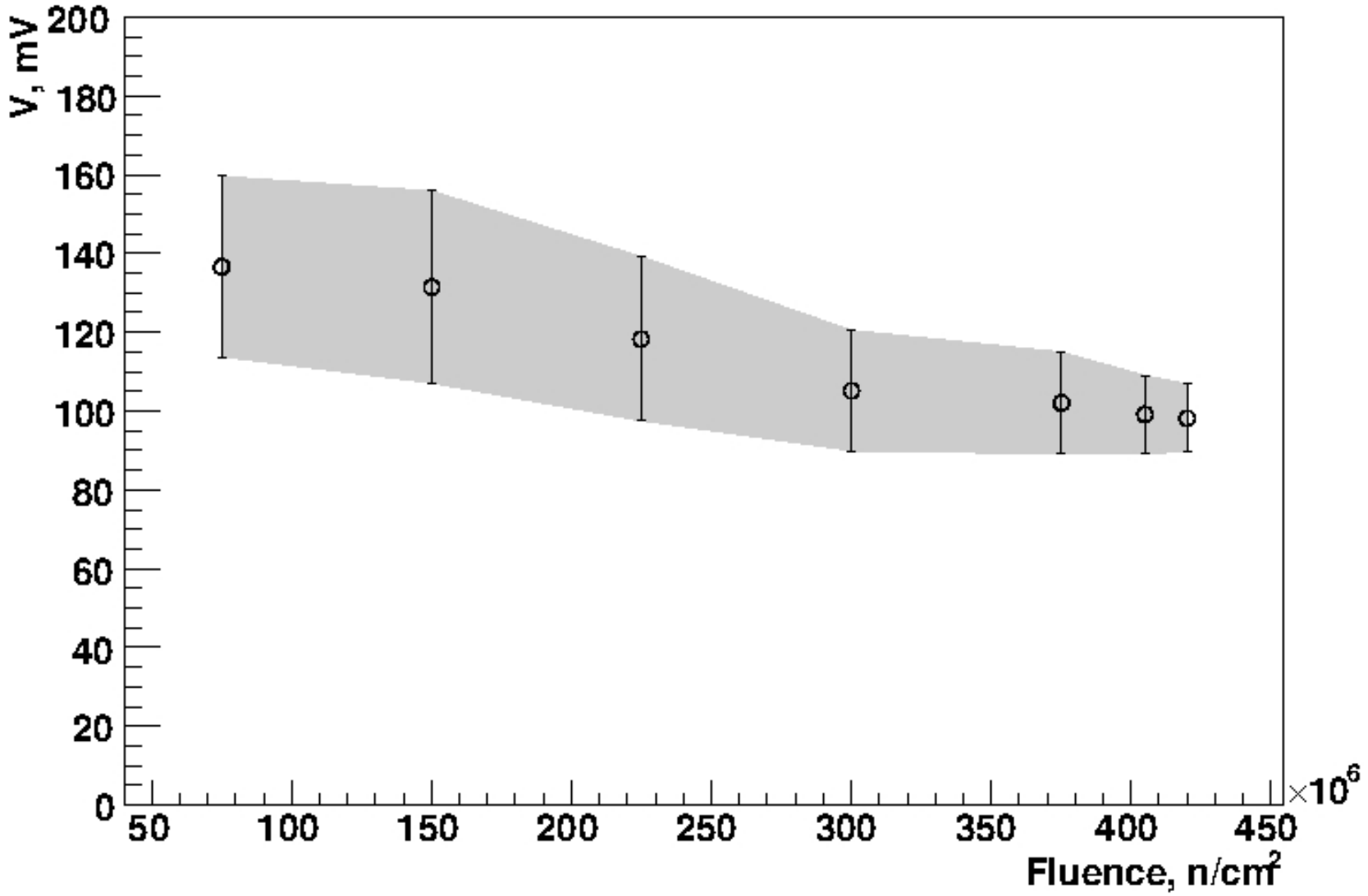
For source NG1
Maximum of Flux

~10^8 - 10^9 - [n/cm^2/s]

For source NG2
Maximum of Flux

~10^{11} [n/cm^2/s]

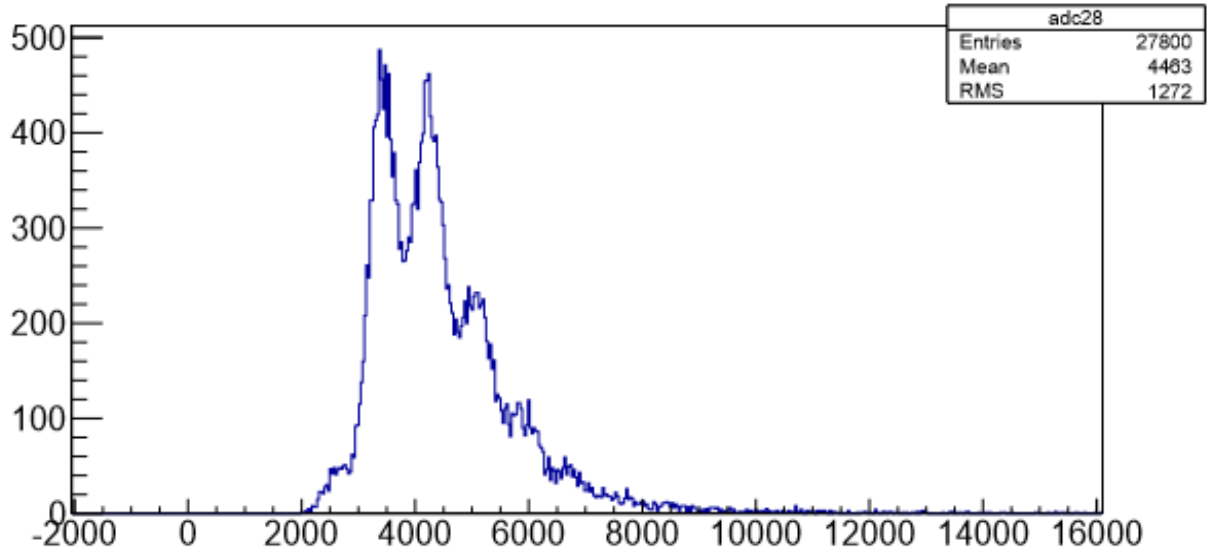
Some results have been published



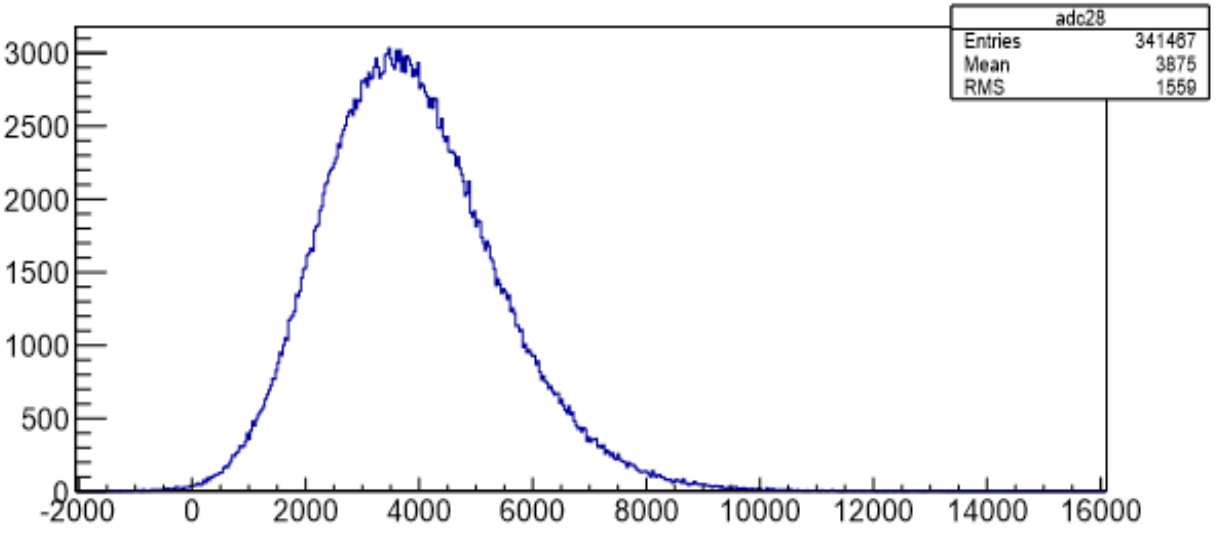
S.G.Reznikov et al., Performance studies of the PSD readout board prototype, CBM Progress Report 2015, GSI, Darmstadt, ISBN: 978-3-9815227-3-0, p.102.

Beta source spectra

Before irradiation

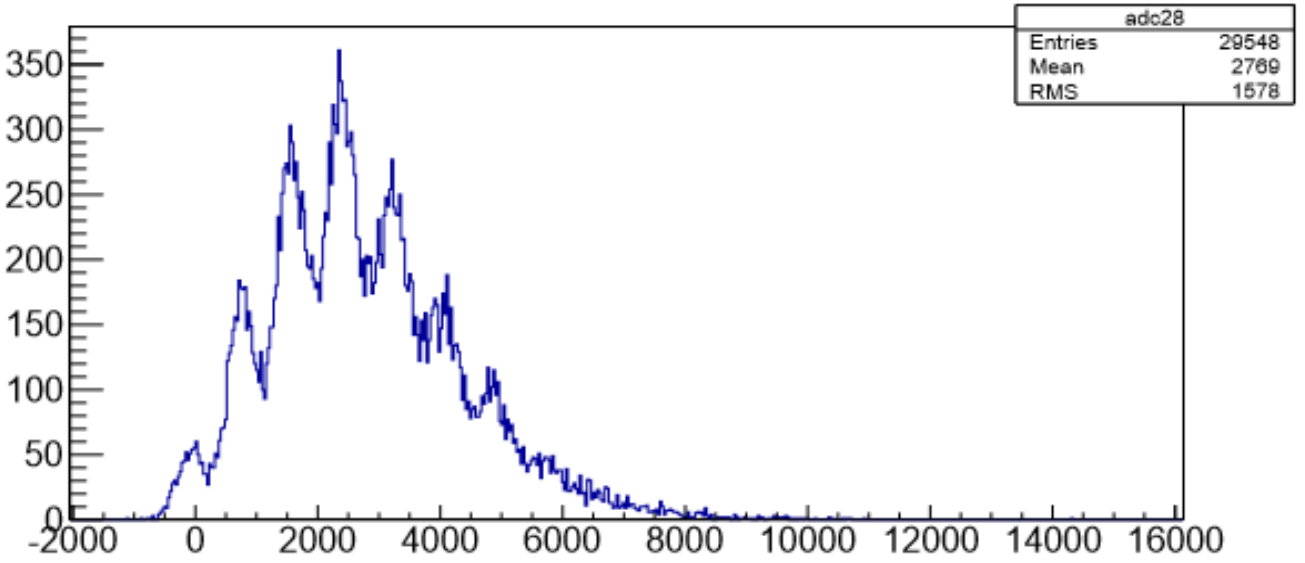


After ~4.2x10^8 n/cm2

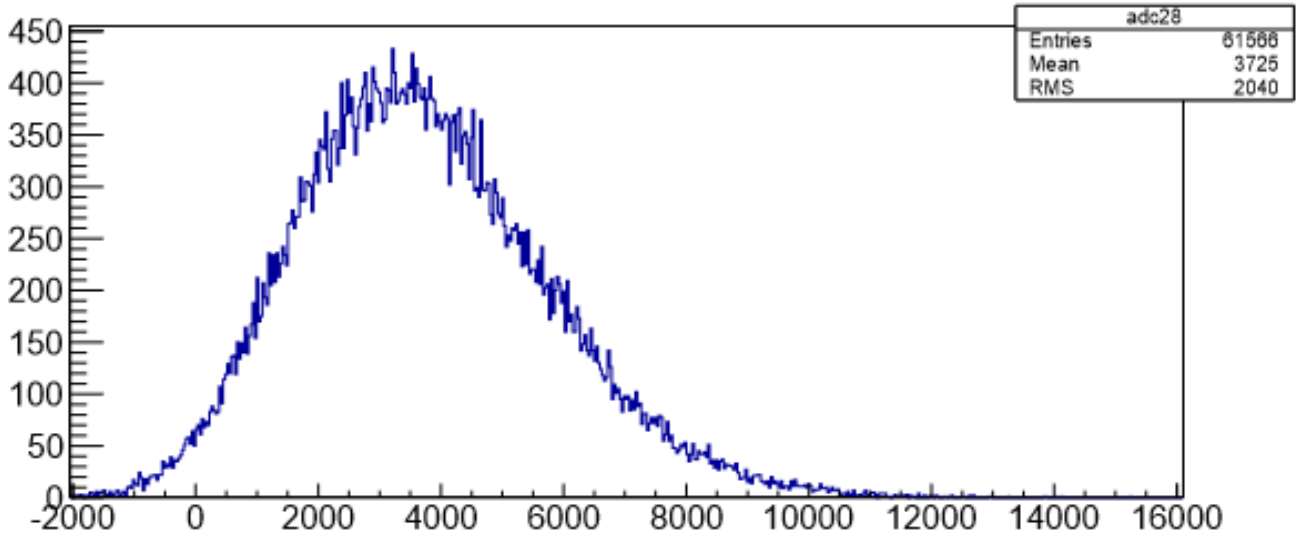


LED spectra

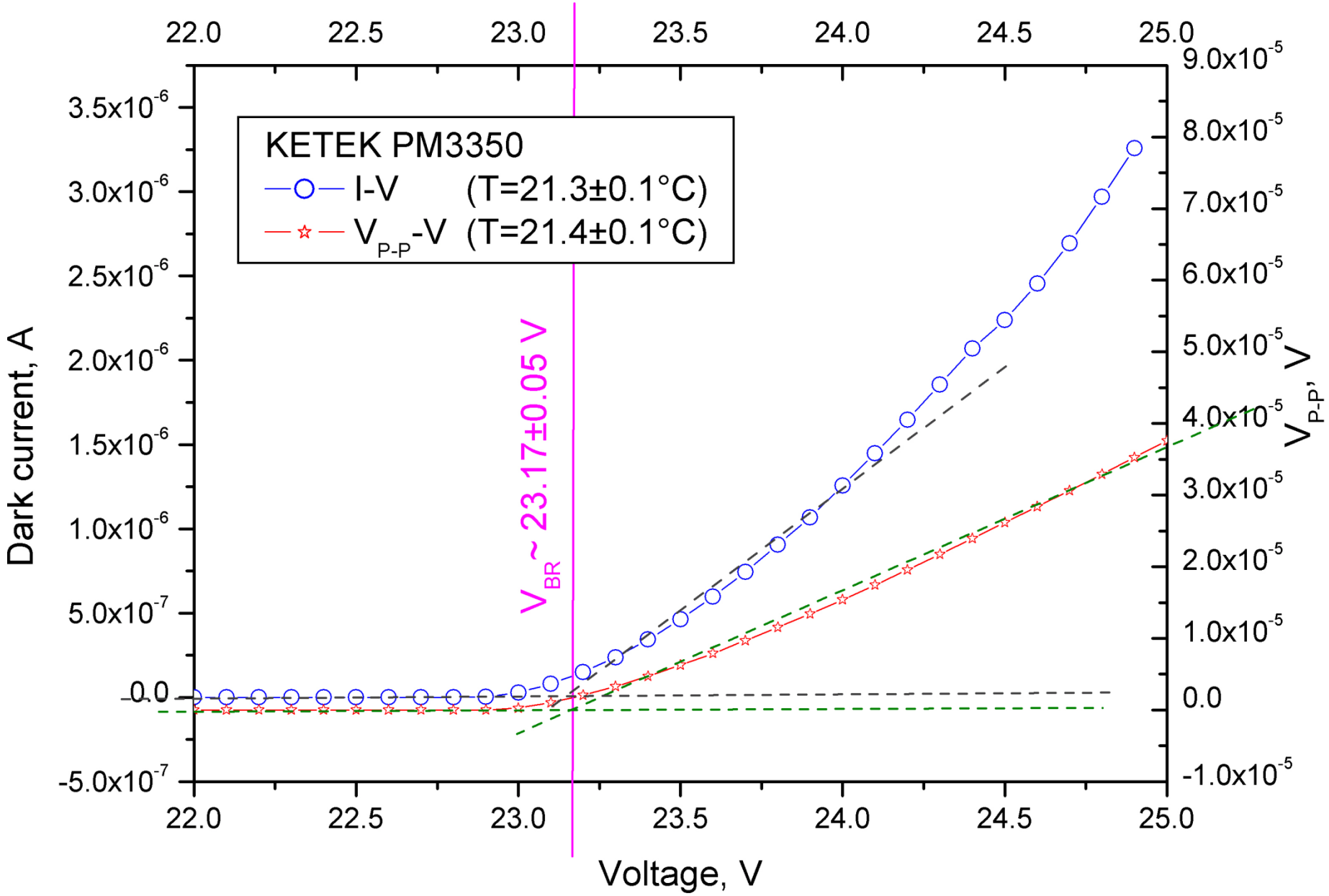
Before irradiation

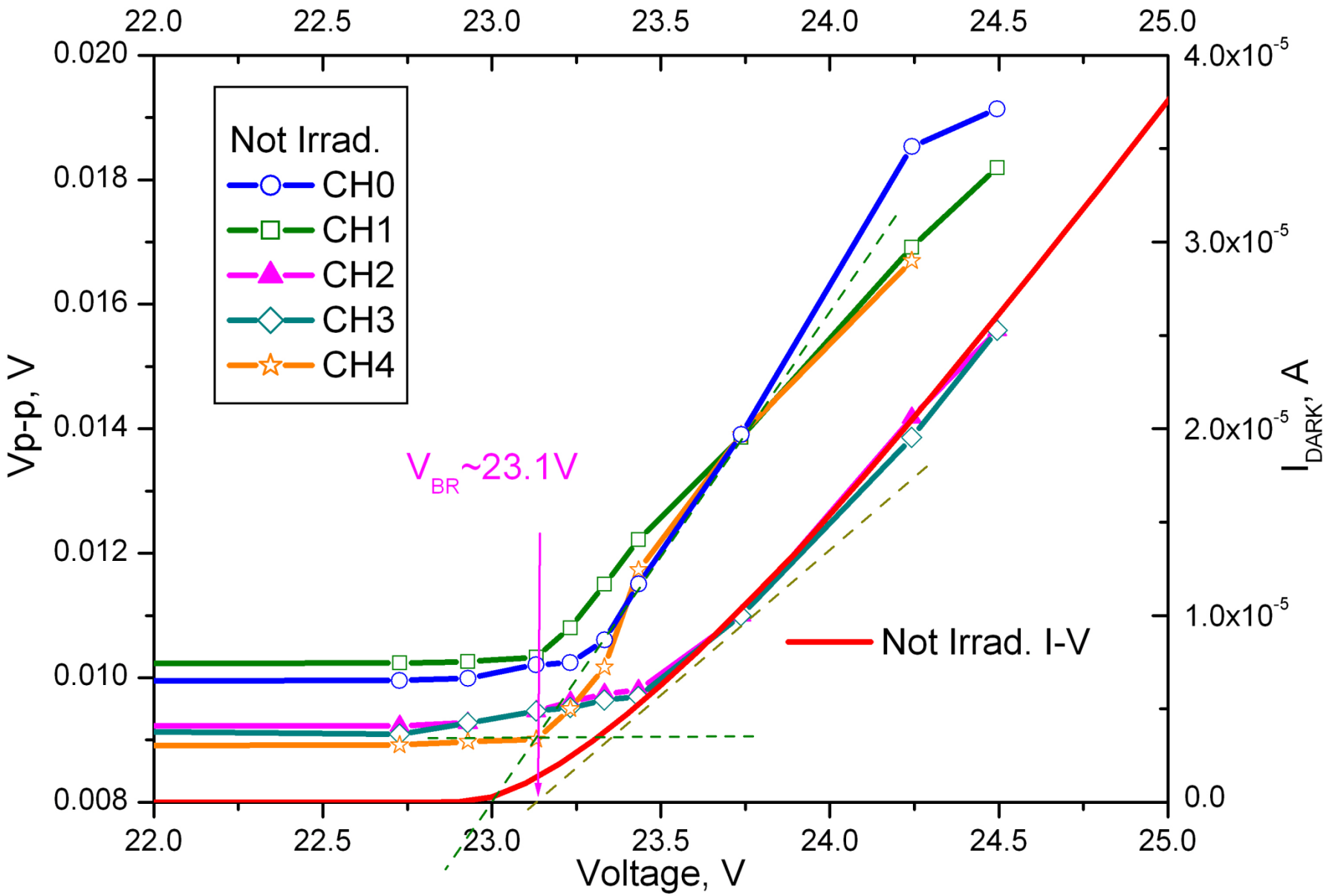


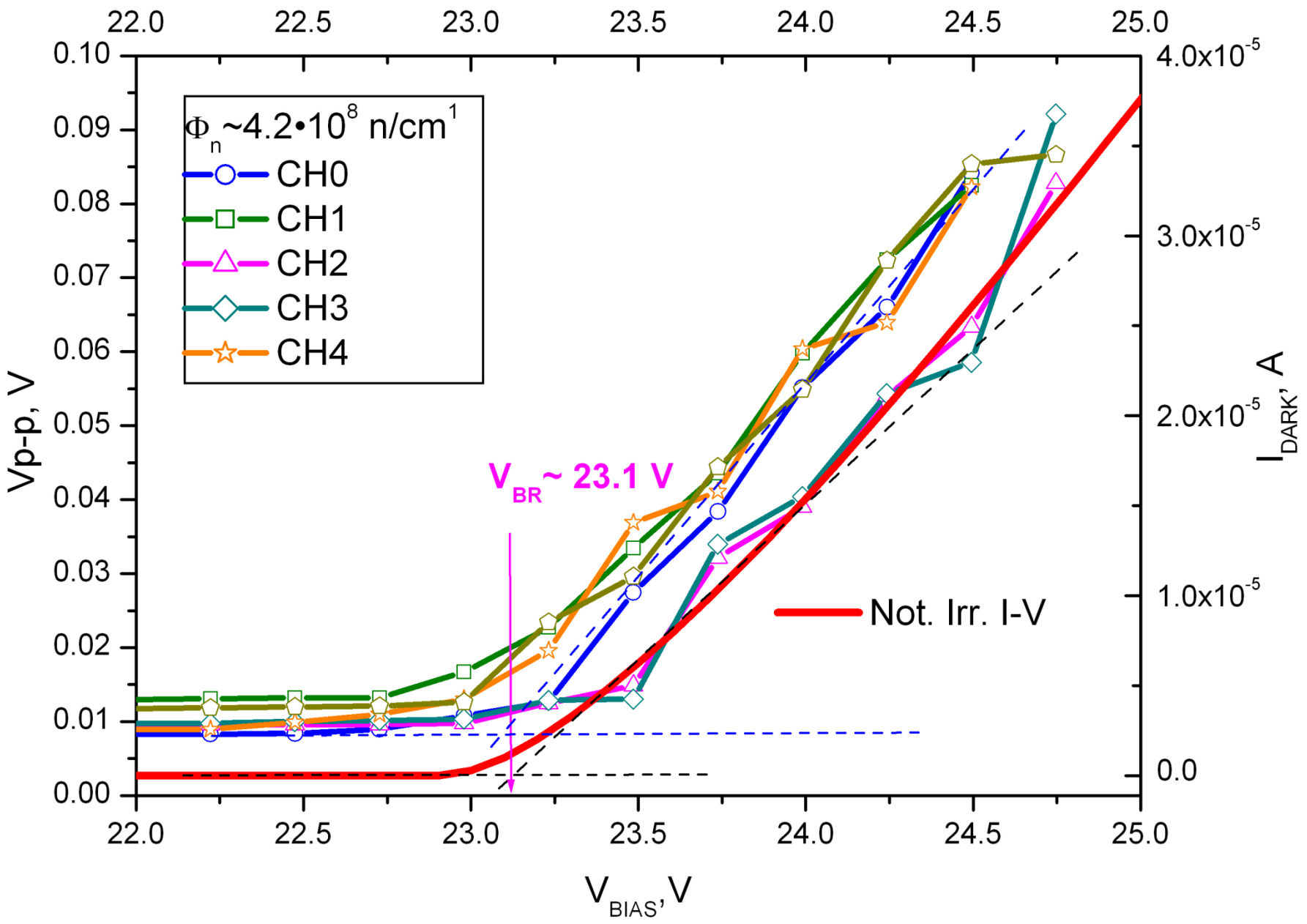
After ~4.2x10^8 n/cm2

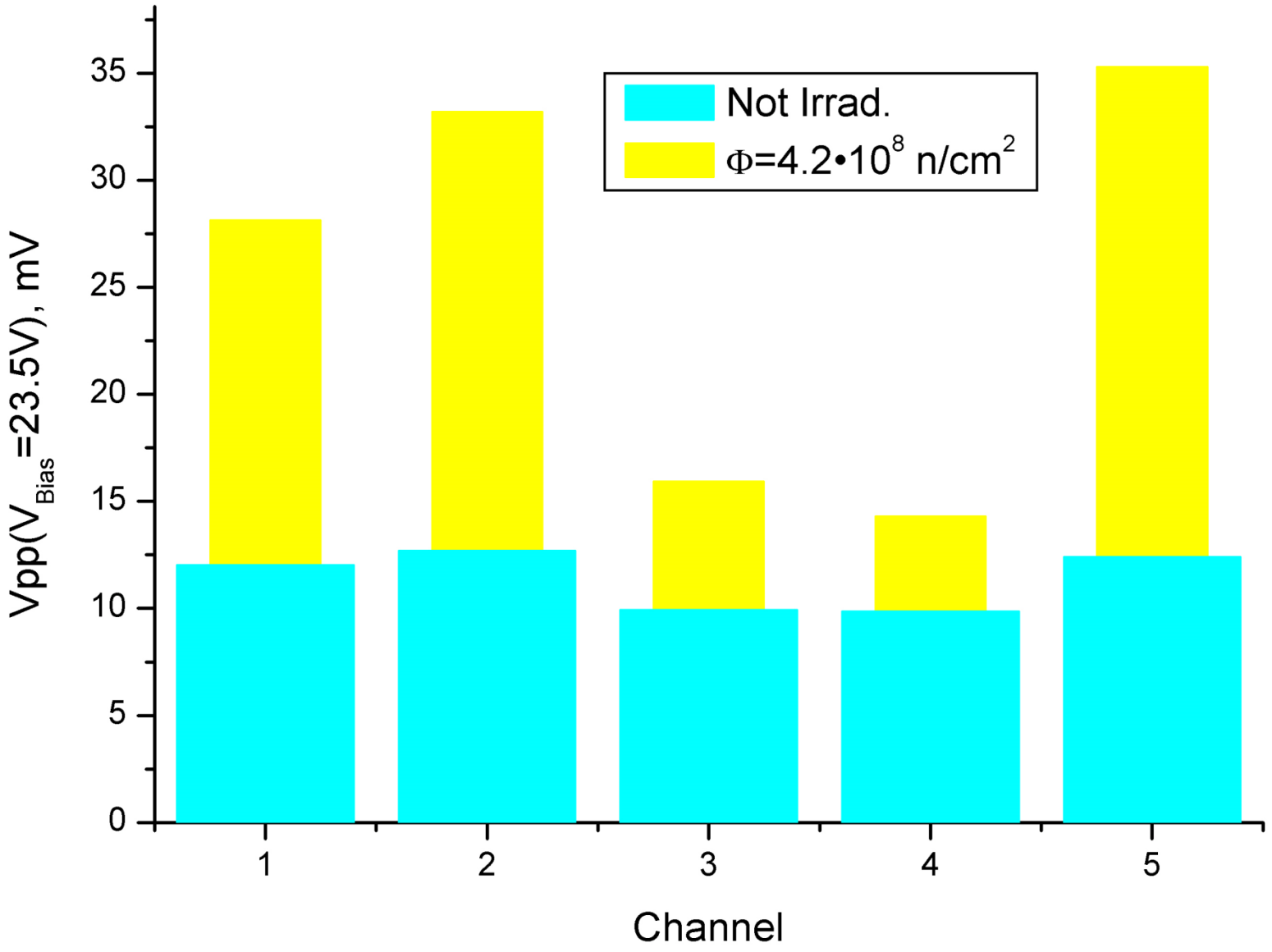


Vpp-V & I-V curves




Not Irrad.
CH0
CH1
CH2
CH3
CH4
V_{BR}~23.1V
Not Irrad. I-V
Vp-p, V
I_{DARK}, A
Voltage, V
22.0
22.5
23.0
23.5
24.0
24.5
25.0
0.020
0.018
0.016
0.014
0.012
0.010
0.008
4.0x10^{-5}
3.0x10^{-5}
2.0x10^{-5}
1.0x10^{-5}
0.0

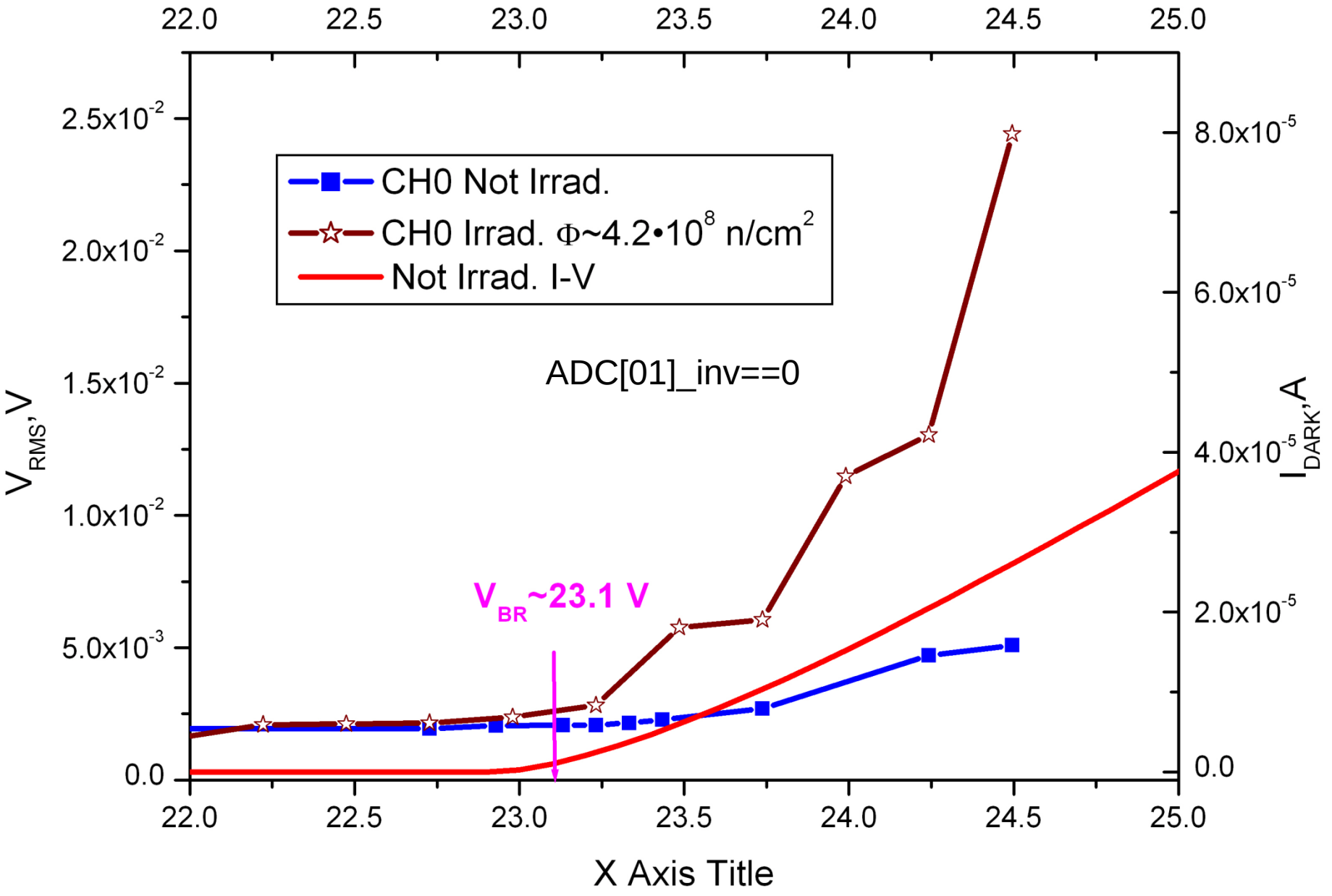

22.0
22.5
23.0
23.5
24.0
24.5
25.0
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
4.0x10-5
3.0x10-5
2.0x10-5
1.0x10-5
0.0
Vp-p, V
I_DARK, A
V_BIAS, V
Φn ~4.2•10^8 n/cm^1
CH0
CH1
CH2
CH3
CH4
V_BR ~ 23.1 V
Not. Irr. I-V


Not Irrad.
Φ=4.2•10^8 n/cm^2
Vpp(V_Bias=23.5V), mV
0
5
10
15
20
25
30
35
1
2
3
4
5
Channel

Conclusions

1. KETEK PM3350 and corresponding electronics behave good enough till fluence of about 4.2x10^8 n/cm2.
2. The decreasing of signal amplitude by a factor of 1.4 could be explained by uncontrolled temperature drift at least partially.
3. The main effect of neutron irradiation is noise increased by a factor of 2-3 depending on bias voltage. Again it could be explained by temperature rise, but only to some extent. The increased noise also spoiled resolution.
4. The proposed procedure of estimation of breakdown voltage by measuring dependence of noise Vpp (or Vrms as alternative) vs bias voltage seems to be adequate for practical use. No changes of breakdown voltages were observed after irradiation to the fluence mentioned above.

Thank you
for your attention!


22.0
22.5
23.0
23.5
24.0
24.5
25.0
2.5x10-2
2.0x10-2
1.5x10-2
1.0x10-2
5.0x10-3
0.0
8.0x10-5
6.0x10-5
4.0x10-5
2.0x10-5
0.0
CH0 Not Irrad.
CH0 Irrad. Φ~4.2•10^8 n/cm^2
Not Irrad. I-V
ADC[01]_inv==0
V_BR~23.1 V
V_RMS, V
I_DARK, A
X Axis Title

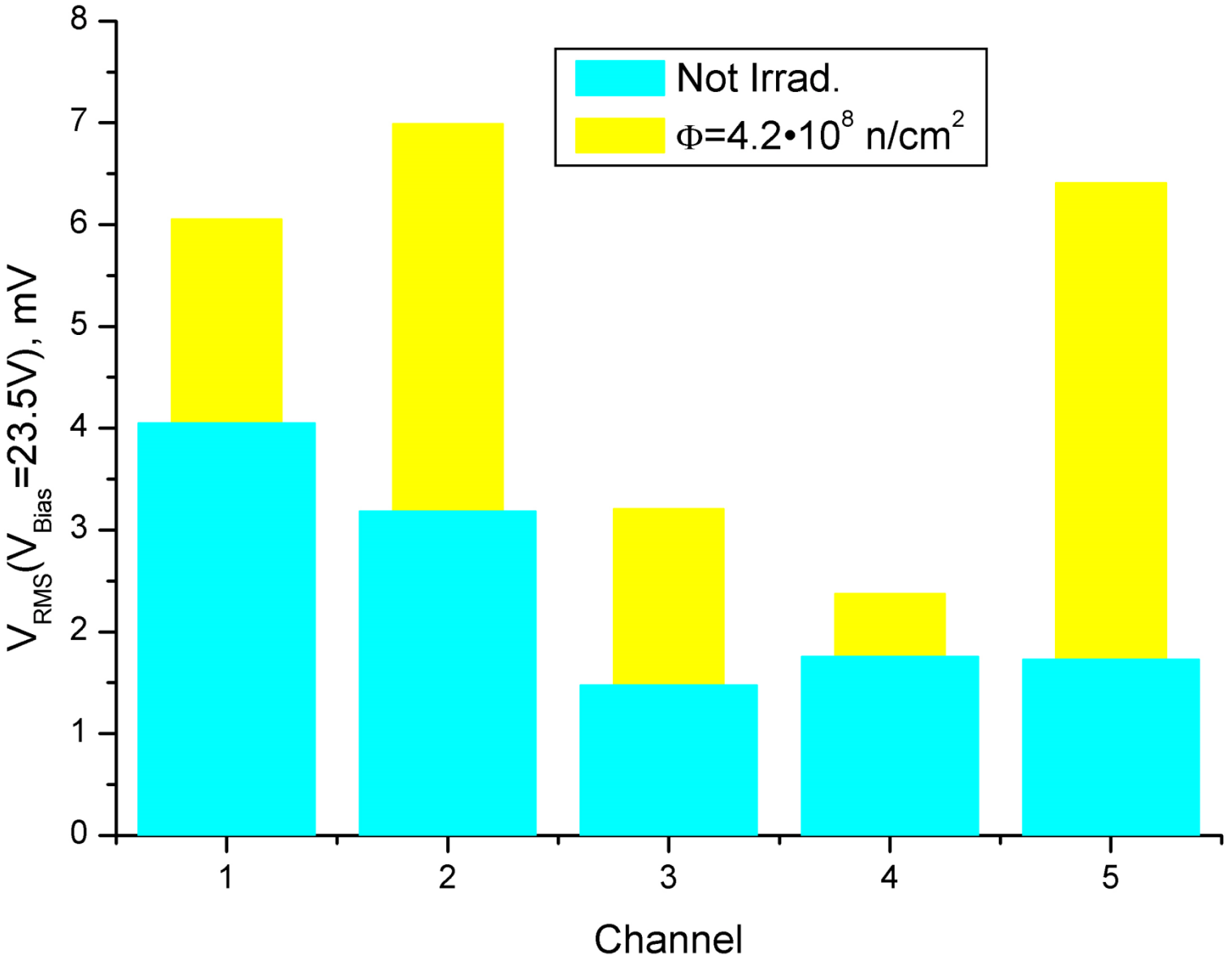
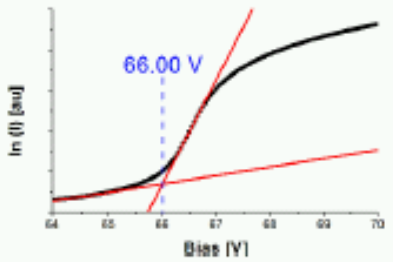
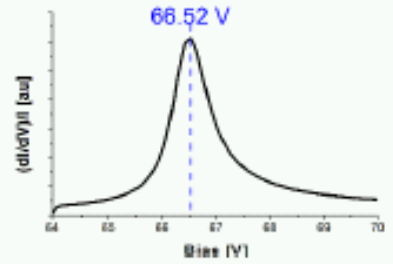
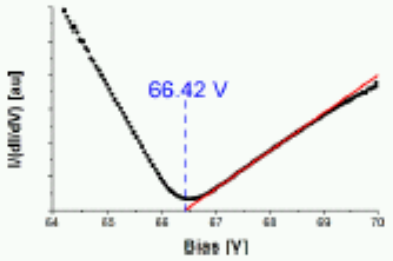
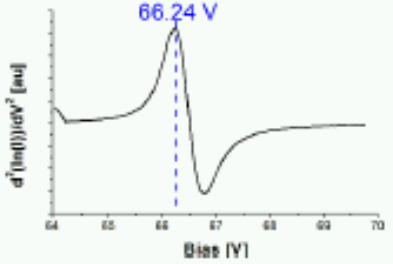
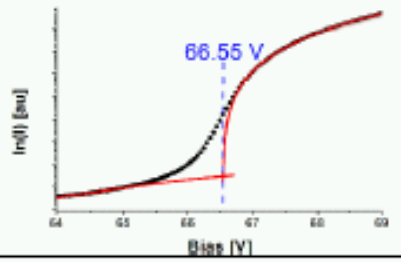
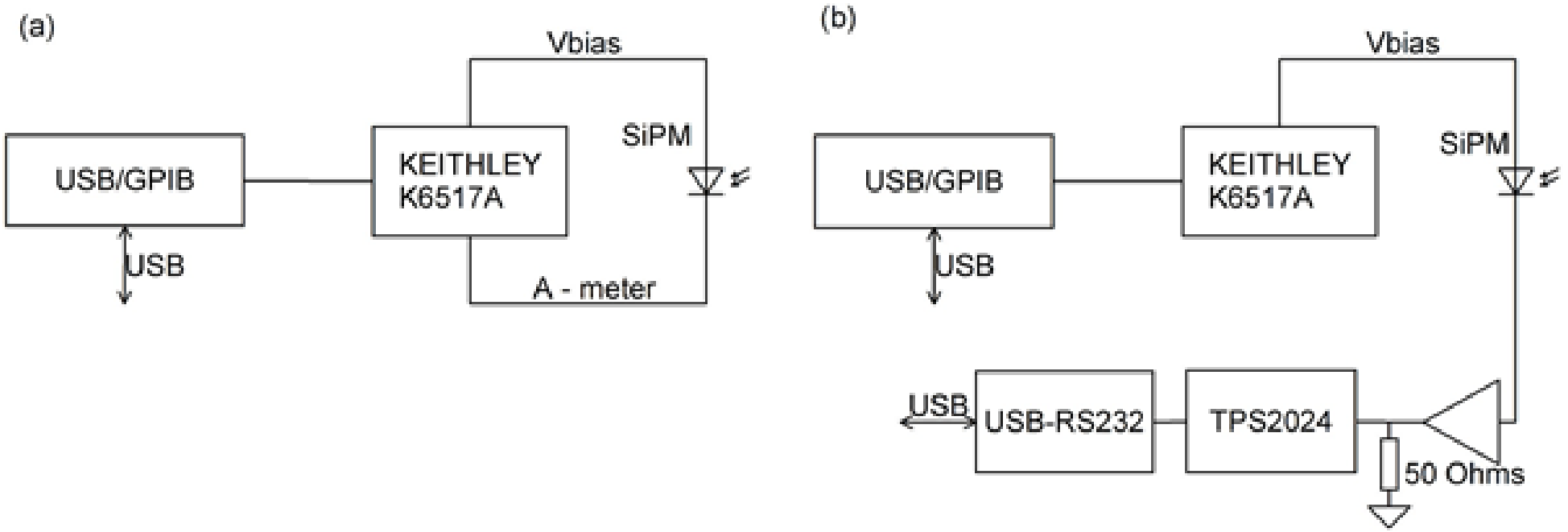
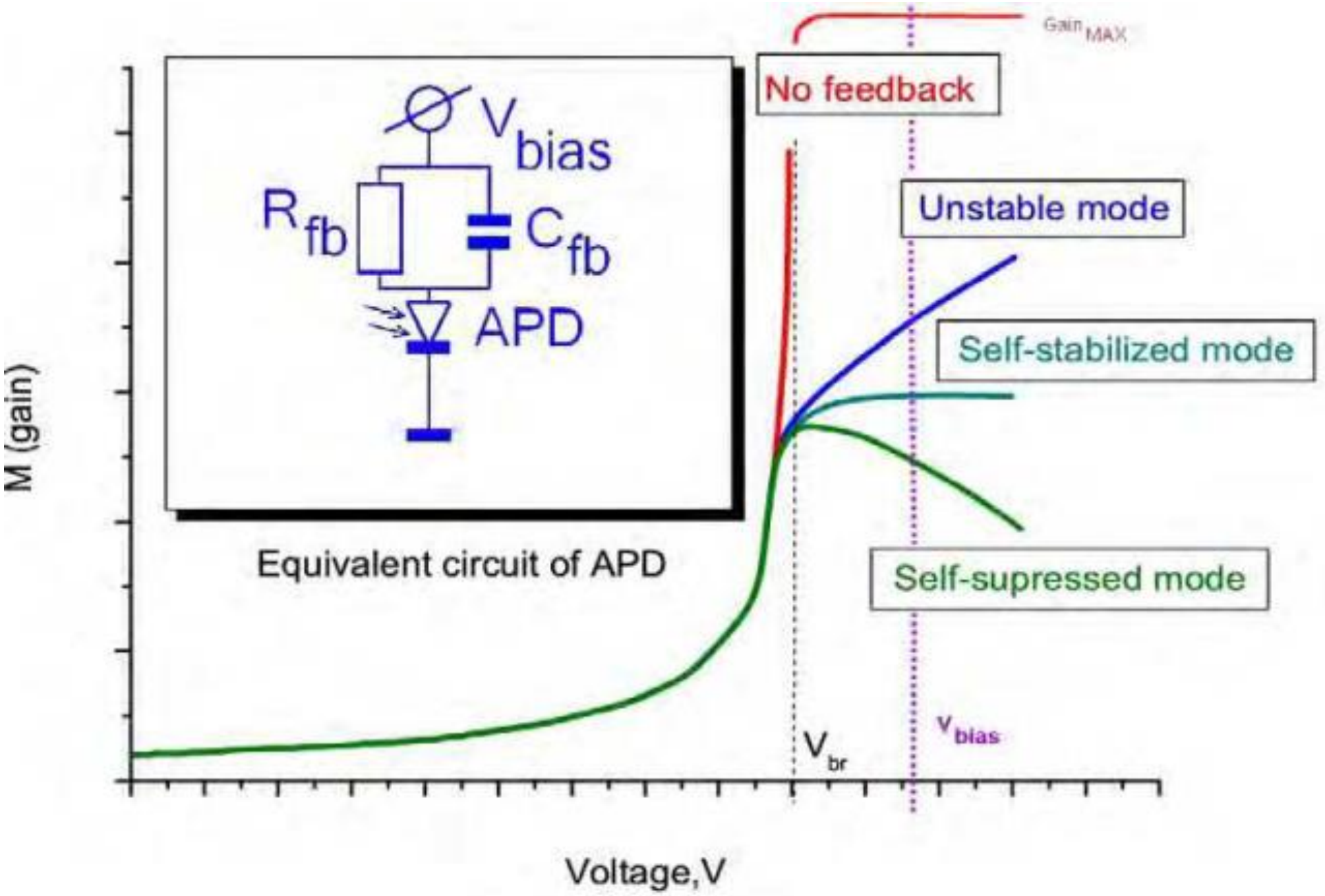

Not Irrad.
Φ=4.2•10^8 n/cm^2
V_RMS(V_Bias=23.5V), mV
0
1
2
3
4
5
6
7
8
1
2
3
4
5
Channel

Table 1: Known DC methods to determine the SiPM breakdown voltage from a real I-V curve

Tangent	Linear fitted "baseline" and tangent drawn to $ln(I)$	Intercept of tangent and the "baseline"	
Relative derivative	$\frac{d}{dV} ln(I)$ $= I'/I$	Position of the maximum	
"Inverse" relative derivative	$1/\frac{d}{dV} ln(I)$ $= I/I'$	Intercept of the x-axis and the fitted line	
Second derivative	$\frac{d^2}{dV^2} ln(I)$	Position of the maximum	
Parabolic fitting	Linear fitted "baseline" and parabola fitted to I	Intercept of the fitted parabola and the "baseline" on semi-log scale	


(a)
Vbias
SiPM
USB/GPIB
KEITHLEY
K6517A
USB
A - meter
(b)
Vbias
SiPM
USB/GPIB
KEITHLEY
K6517A
USB
USB
USB-RS232
TPS2024
50 Ohms


Gain MAX
No feedback
Unstable mode
Self-stabilized mode
Self-supressed mode
V bias
R fb
C fb
APD
Equivalent circuit of APD
M (gain)
V br
V bias
Voltage,V