Performance of resistive Micromegas in a neutron beam

Yorgos Tsipolitis (NTU Athens)
for the
Muon ATLAS MicroMegas Activity

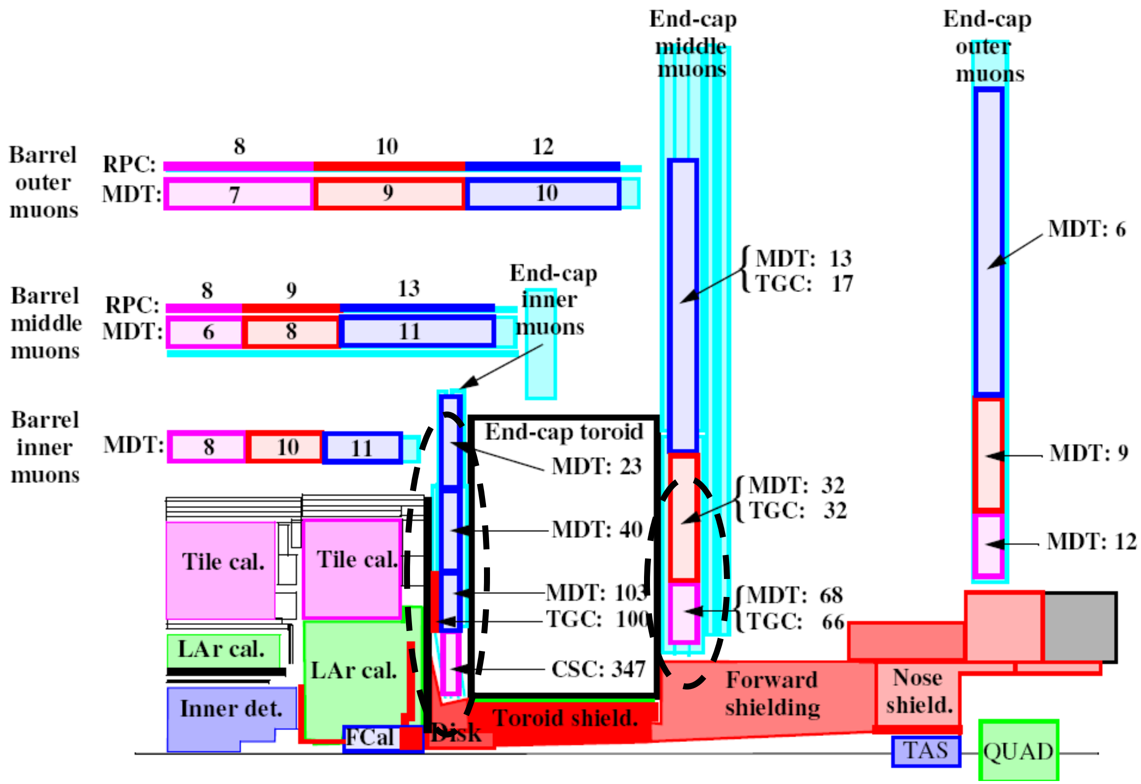
ATLAS upgrade for s-LHC

Muon Spectrometer affected regions :

- End-Cap Inner (CSC,MDT,TGC)
- End-Cap Middle |η|>2 (MDT,TGC)

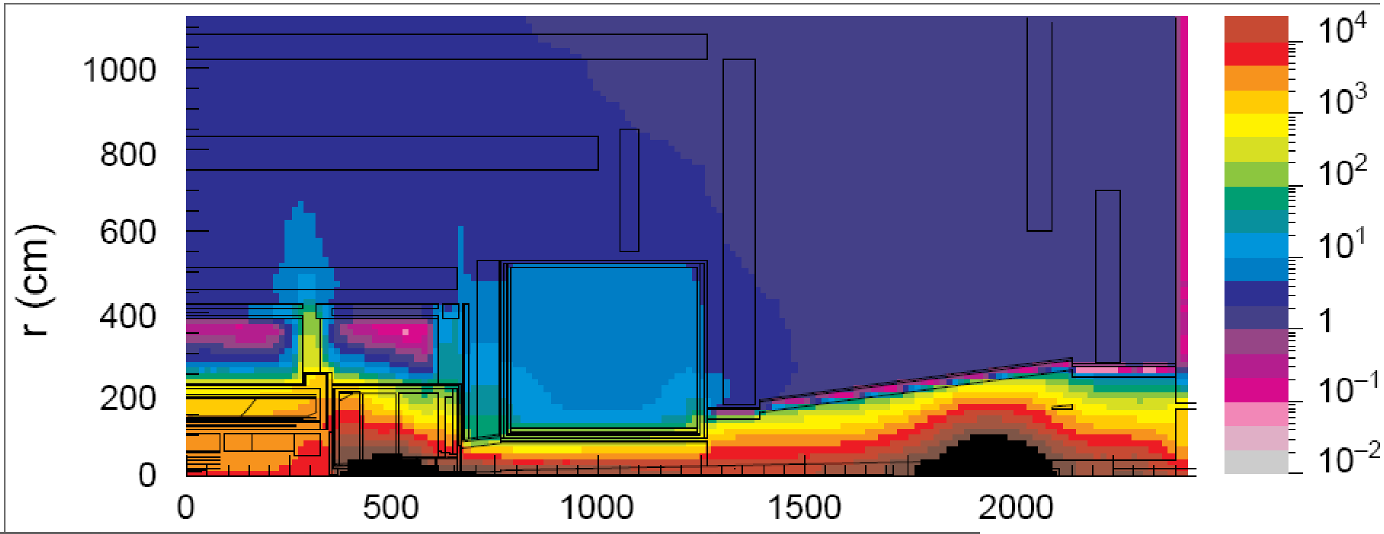
Total area ~400 m^2

Phase I : augment the existing Cathode Strip Chambers

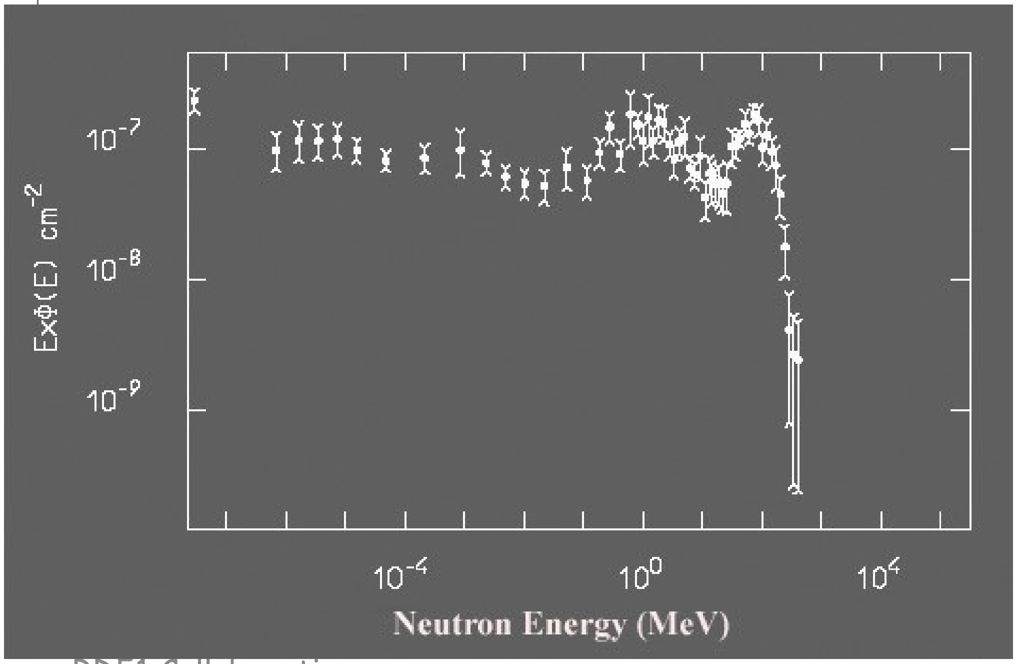


Average single plane counting rate (Hz/cm^2) at the nominal LHC luminosity (CERN-ATL-GEN-2005-001)

Neutron Flux in ATLAS @ LHC



The expected neutron fluence (kHz/cm²) in the ATLAS Hall (ATLAS muon TDR, 1997)



The energy spectrum of the expected neutron background radiation in the Atlas Hall (ATLAS muon TDR, 1997)

Tandem @ Demokritos

- **5.5 MV TN11 HV Tandem Van der Graaff accelerator**
- **Three neutron energy ranges can be produced by this facility, via three different nuclear reactions:**

Nuclear Reaction	Proton/Deuteron Energy Range (MeV)	Neutron Energy Range (MeV)
$^{7}Li(p,n)^{7}Be$	1.9 to 8.4	0.1 to 6.7*
$^{2}H(d,n)^{3}He$	0.8 to 8.4	3.9 to 11.5**
$^{3}H(d,n)^{4}He$	0.8 to 8.4	16.4 to 25.7***

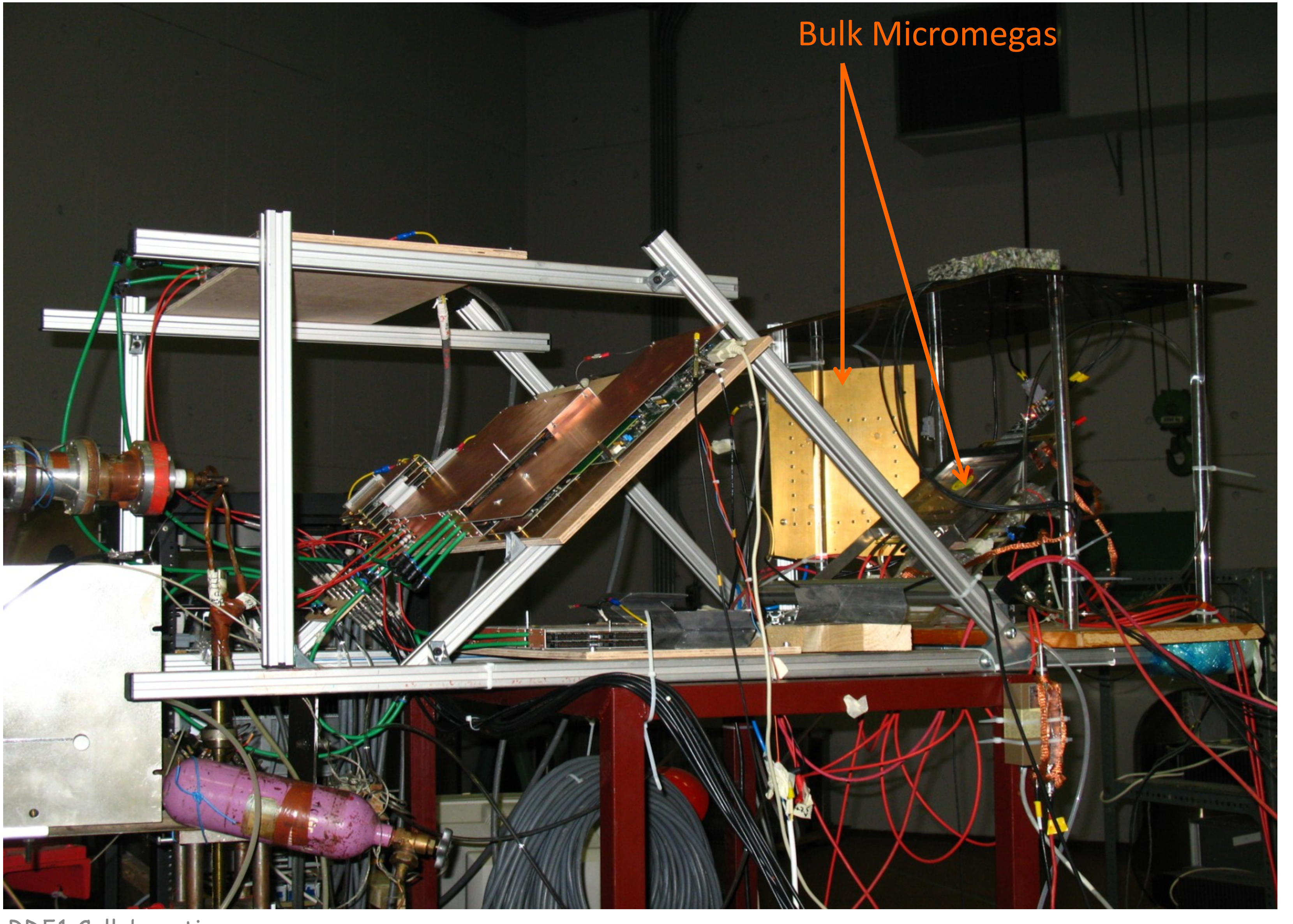
* Monoenergetic neutrons [0.1,0.5] MeV & quasimonoenergetic up to ~2.5 MeV

** Quasimonoenergetic neutrons up to ~7.5 MeV

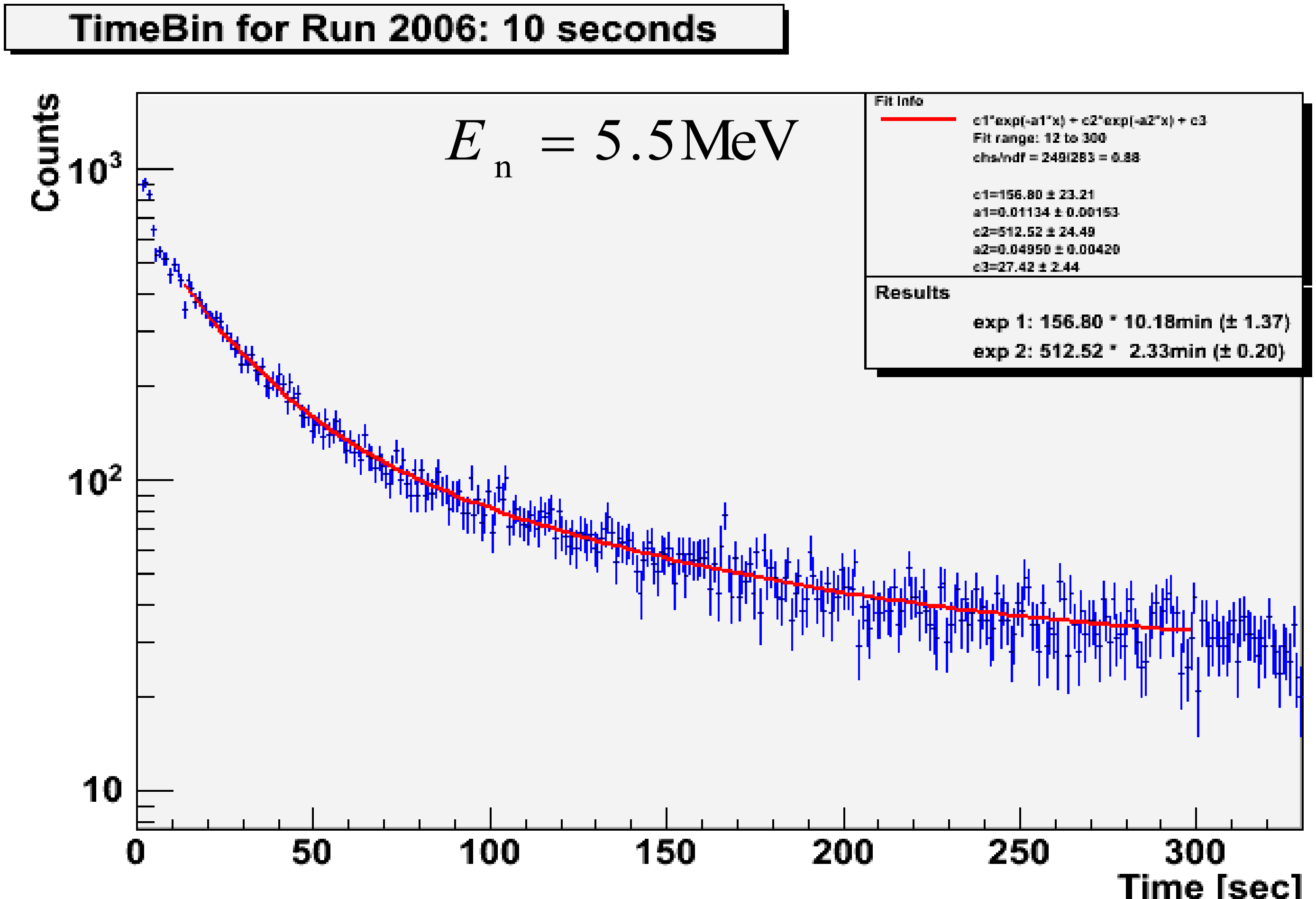
*** Monoenergetic neutrons [16.4,22] MeV

Neutron fluences can reach ~$5x10^{6}$ neutrons/cm^{2} s but for d-^{3}H is lower an order of magnitude compared to the d-^{2}H reaction due to cross section energy dependence

Test @ Demokritos 2009



Activation of the Micromegas Material

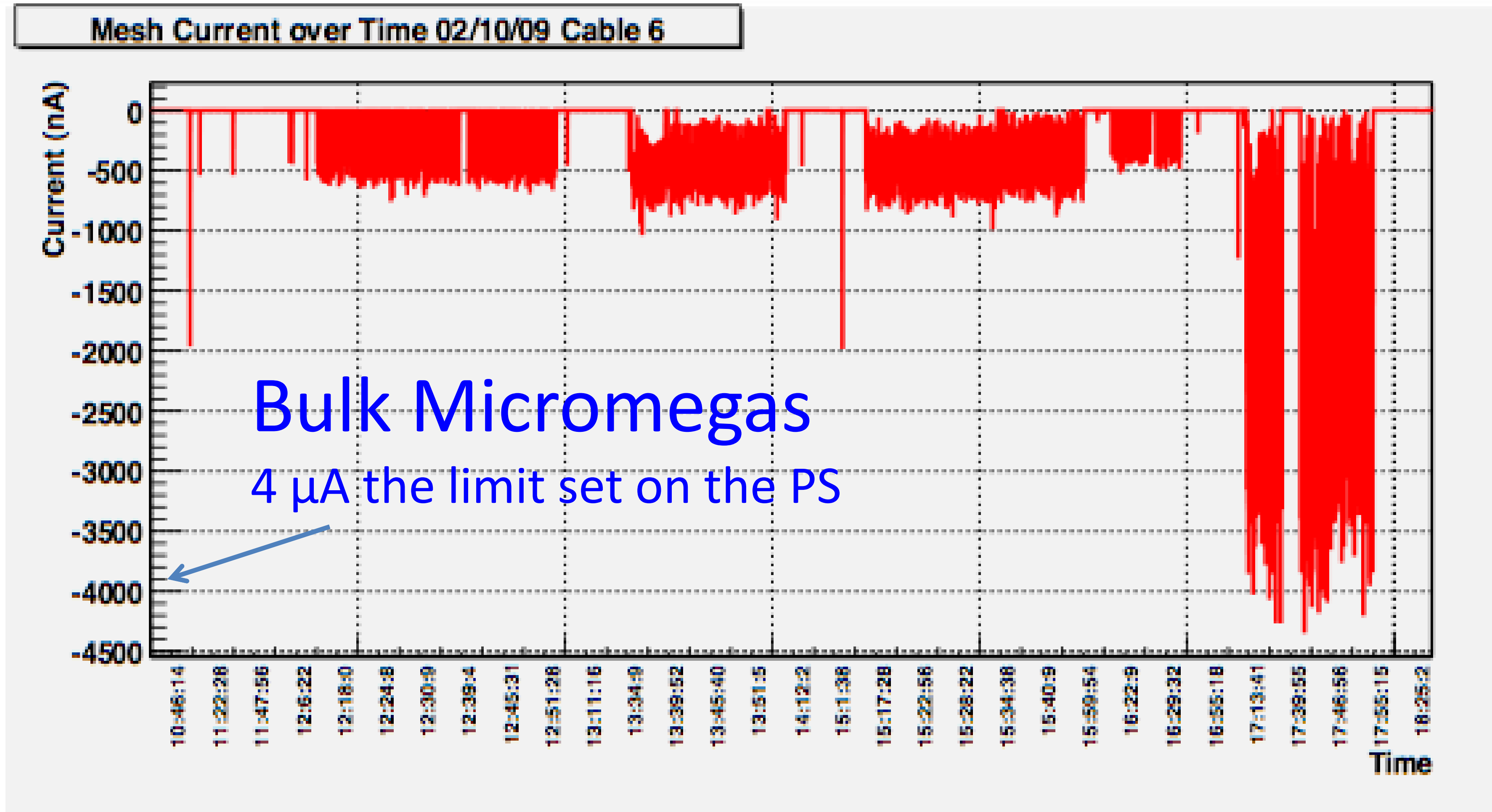


$^{27}_{13}\mathrm{Al}(n,\gamma)^{28}_{13}\mathrm{Al}$ $\tau_{1/2} = 2.24\,\mathrm{m},\ E_\gamma = 1.8\,\mathrm{MeV}\ (100\%),\ E_e = 2.9\,\mathrm{MeV}\ (99\%)$

$^{27}_{13}\mathrm{Al}(n,p)^{27}_{13}\mathrm{Mg}$ $\tau_{1/2} = 9.46\,\mathrm{m},\ E_\gamma = 0.8\,\mathrm{MeV}\ (72\%),\ E_e = 1.6\,\mathrm{MeV}\ (29\%)$

$E_\gamma = 1.1\,\mathrm{MeV}\ (28\%),\ E_e = 1.8\,\mathrm{MeV}\ (71\%)$

Monitor of the HV Current

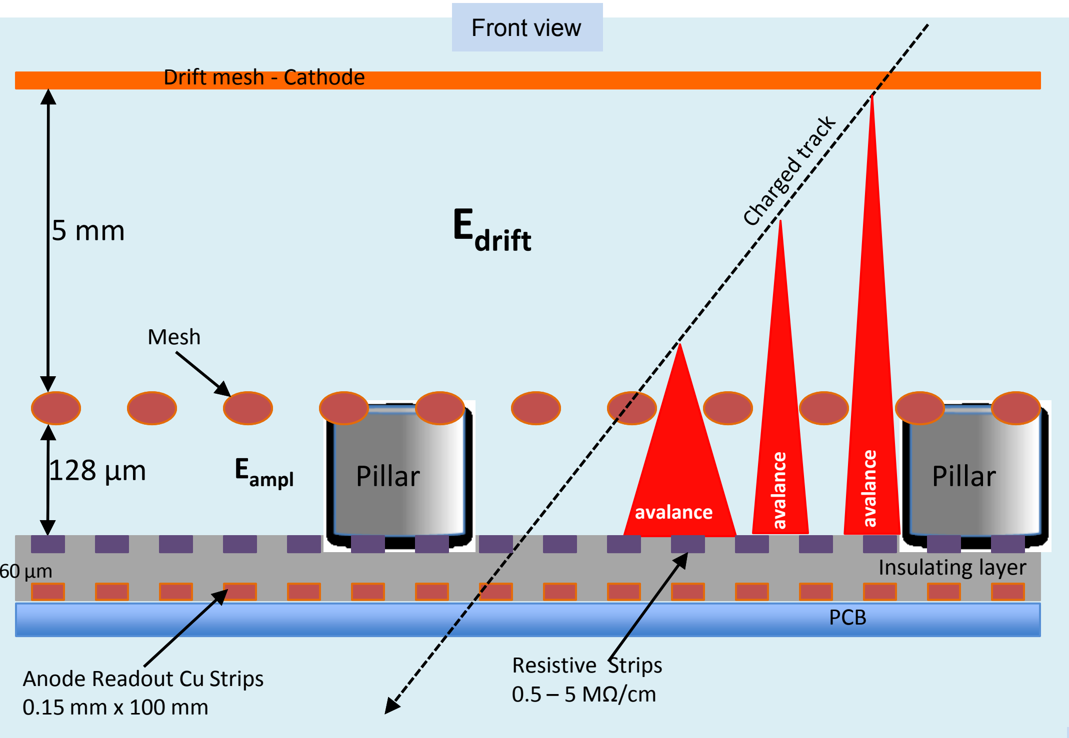


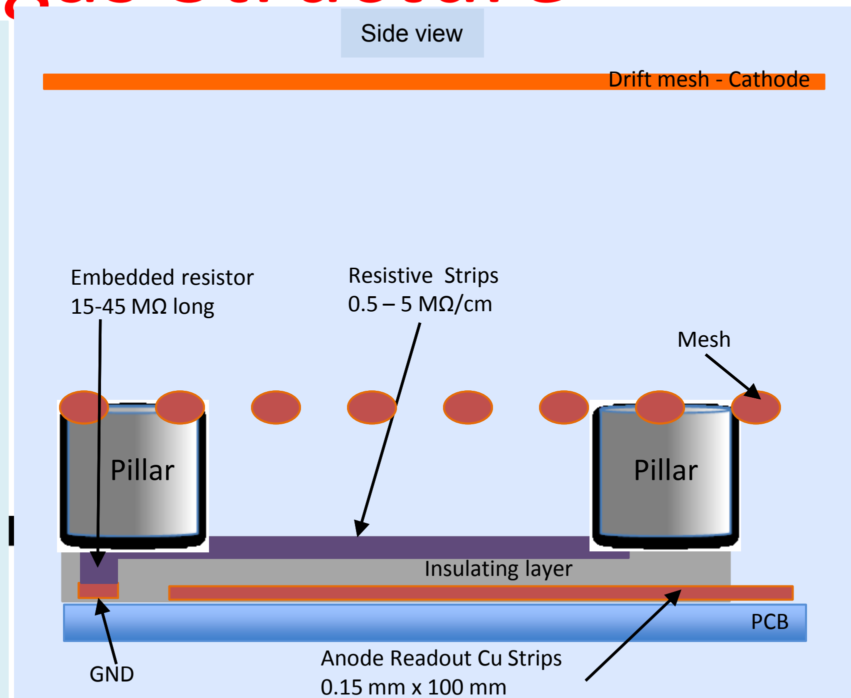
Sparks

- Sparks are a major concern: they can create dead time and/or damage in the detector
- Sparks develop when local electron charge concentrations exceed a few 10^7 e^- (Raether limit)

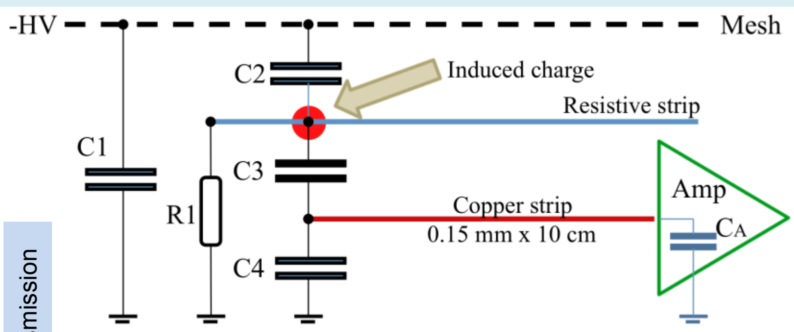
  For a gas gain of 10^4 any ionization process creating ≥1000 electrons in a small volume risks the development of a spark, e.g. heavily ionizing particles induced by neutrons
- Two ways to approach the problem
  1. Avoid high concentrations of charge, e.g. by spreading the charge (multi-stage GEMs or MMs)
  2. Live with it and make the detector insensitive to sparks
- We opted for the latter and evaluated different resistive coating options … and it seems we found one doing the job

Resistive Micromegas Structure



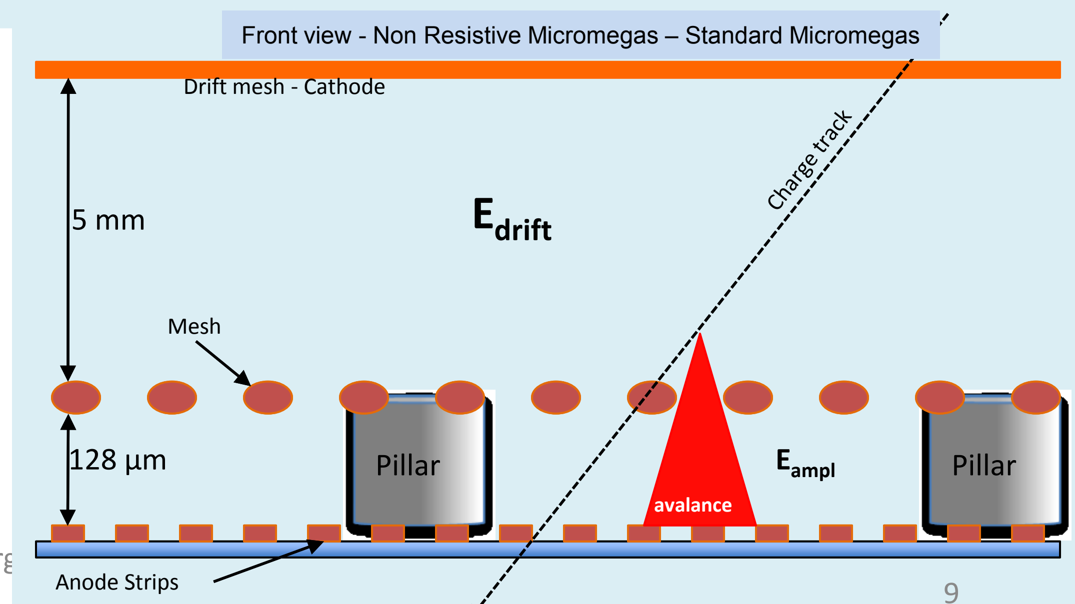


Signal transmission



C1 – capacitance Mesh to ground
C2 – capacitance R-strip to ground
C3 – capacitance R-strip to readout strip
C4 – capacitance readout strip to ground
C_A – input capacitance of preamplifier

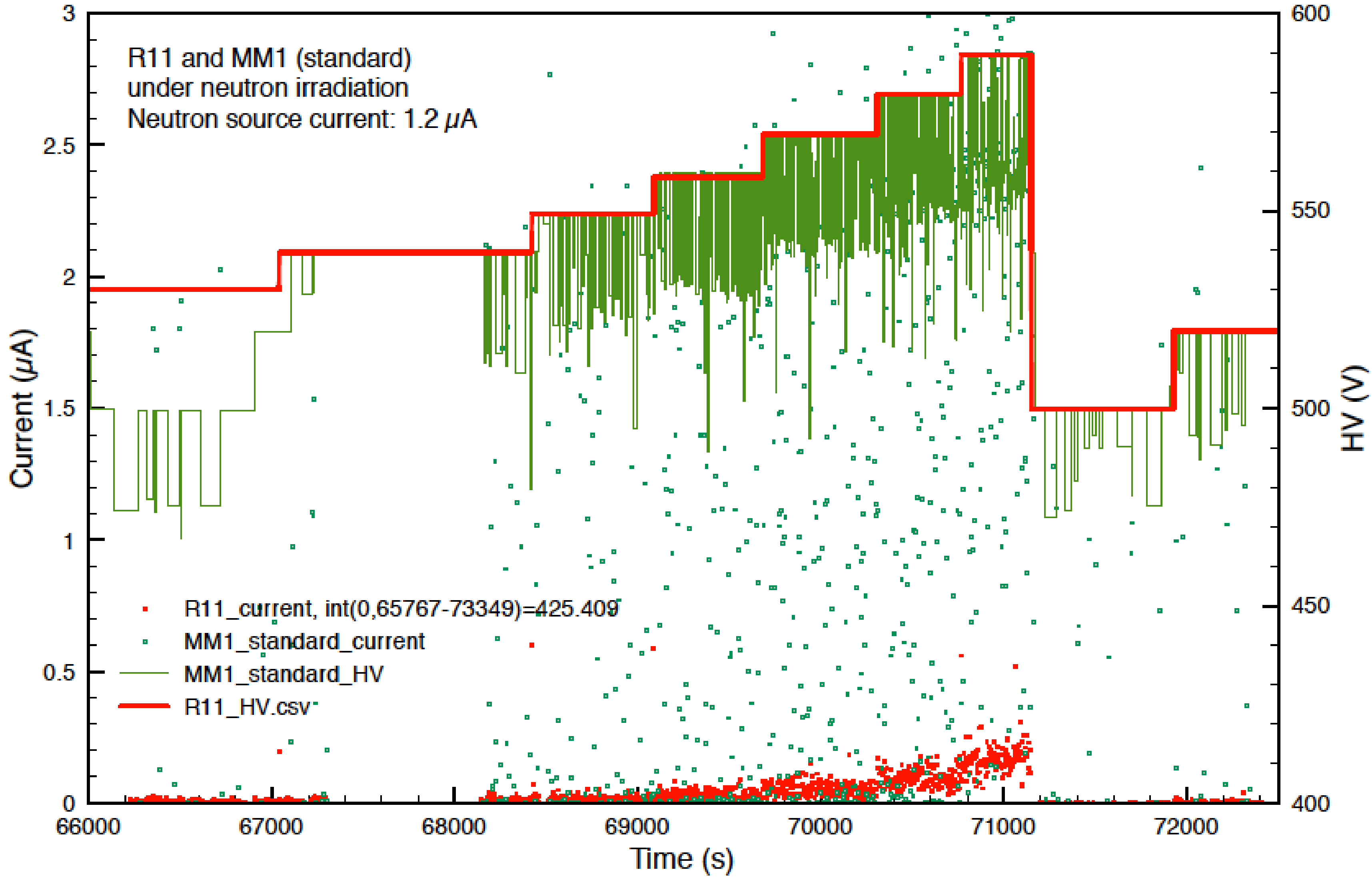
Yorg

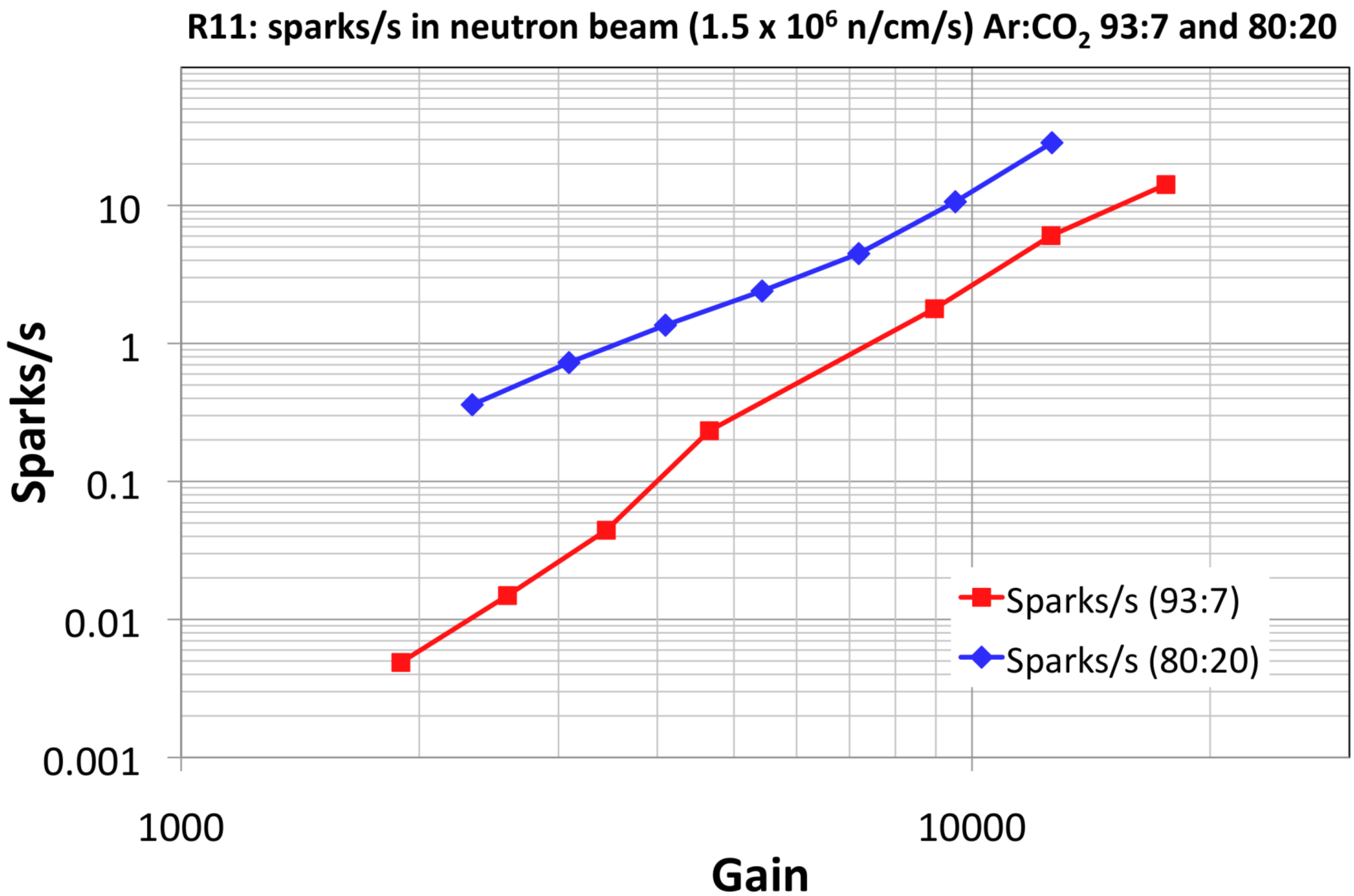


Detectors under Test

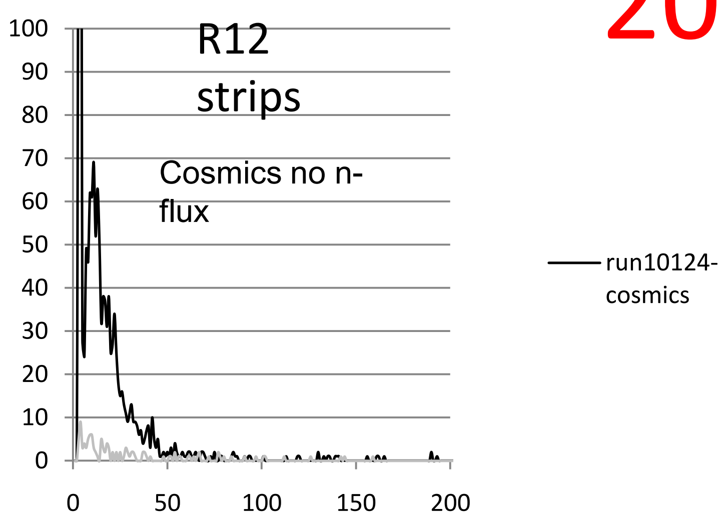
CHAMBER	R11	R12	R13	R16
Resistance to Ground (MΩ)	15	45	20	55
Resistance along strip (MΩ/cm)	2	5	0.5	35

R11 performance 2010 run

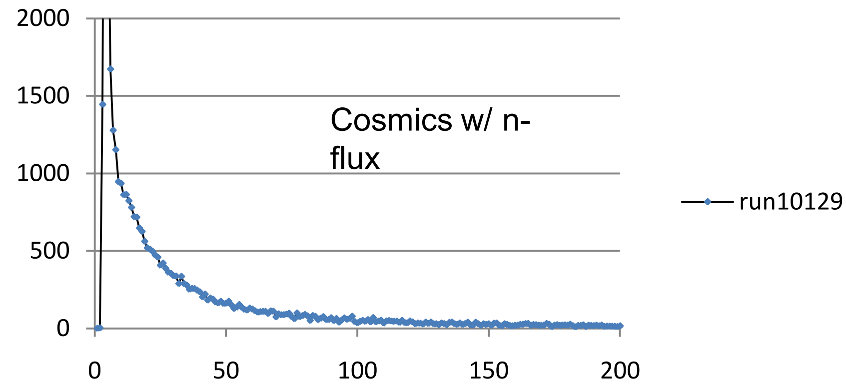



R11: sparks/s in neutron beam (1.5 x 10^6 n/cm/s) Ar:CO2 93:7 and 80:20
Sparks/s
10
1
0.1
0.01
0.001
1000
10000
Gain
Sparks/s (93:7)
Sparks/s (80:20)

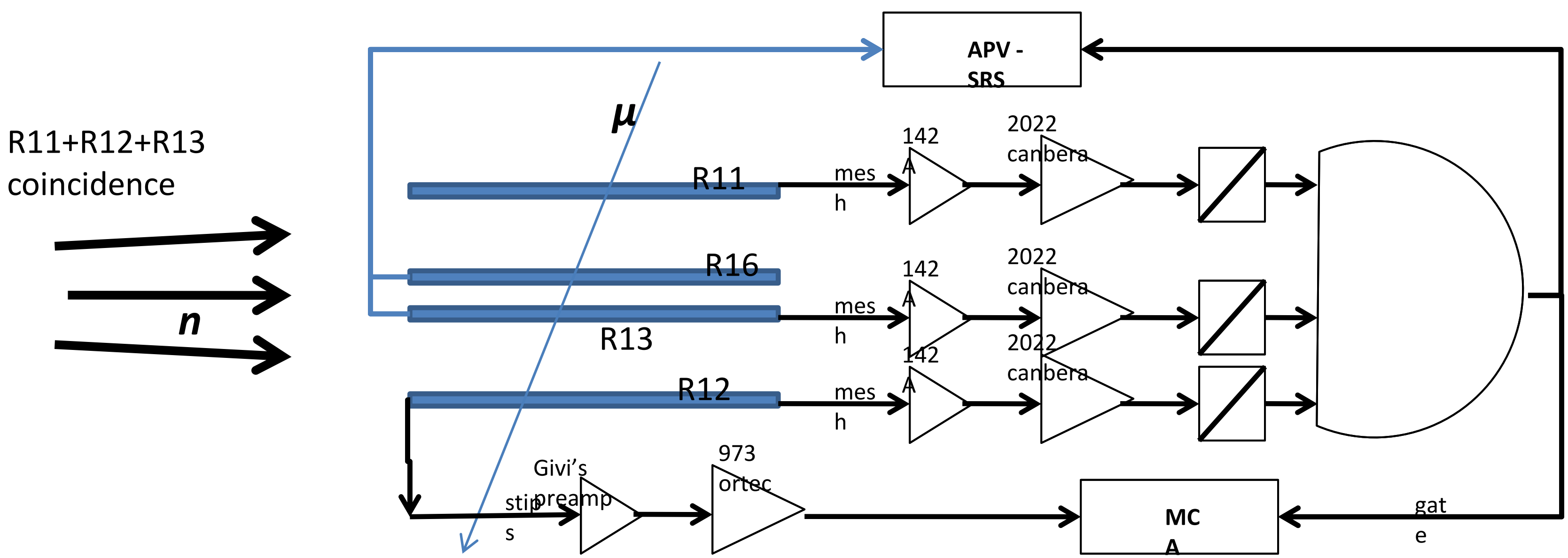
2011 test **n - run10129**



R11+R12+R13
coincidence



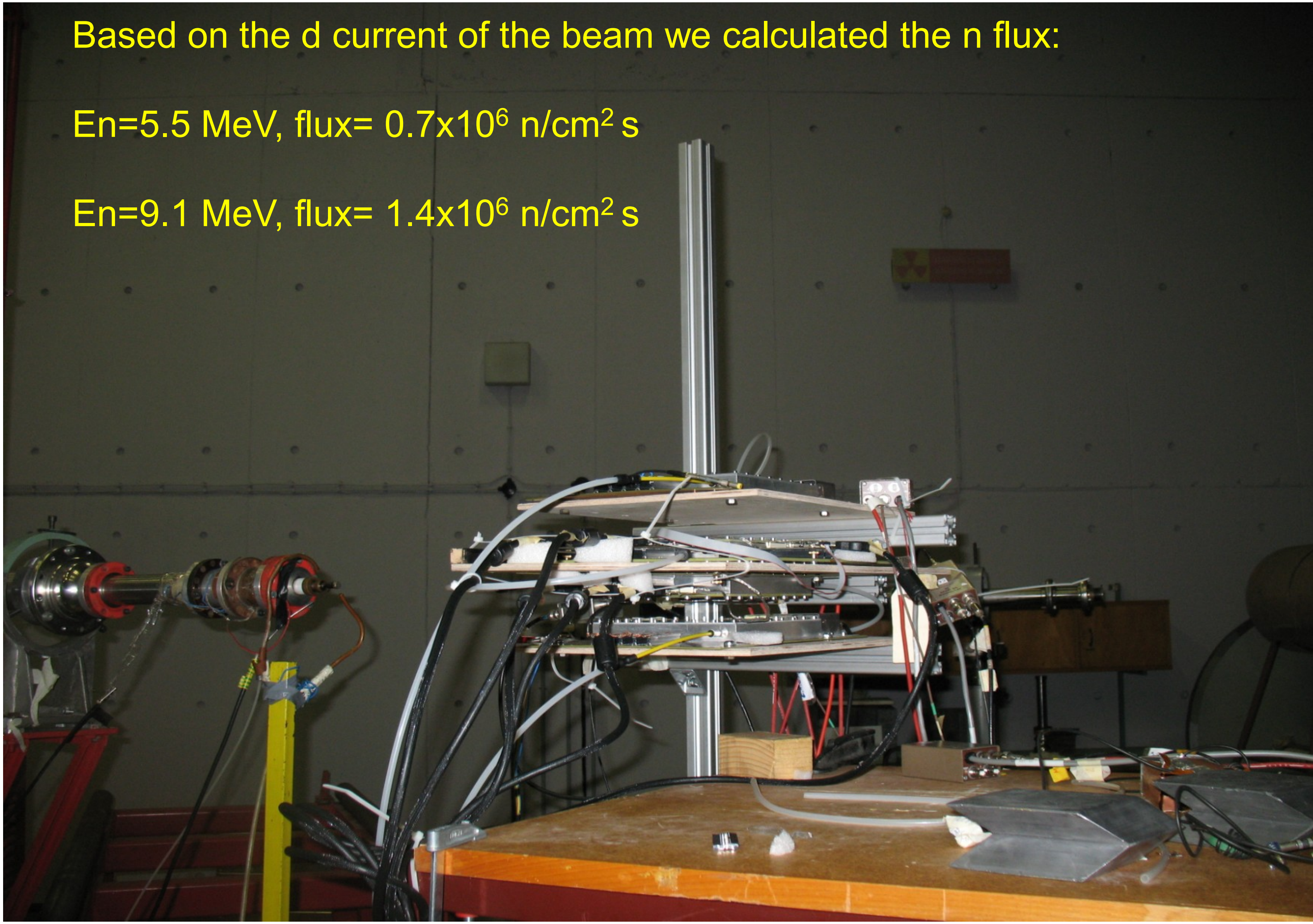
R11+R12+R13
coincidence



Based on the d current of the beam we calculated the n flux:

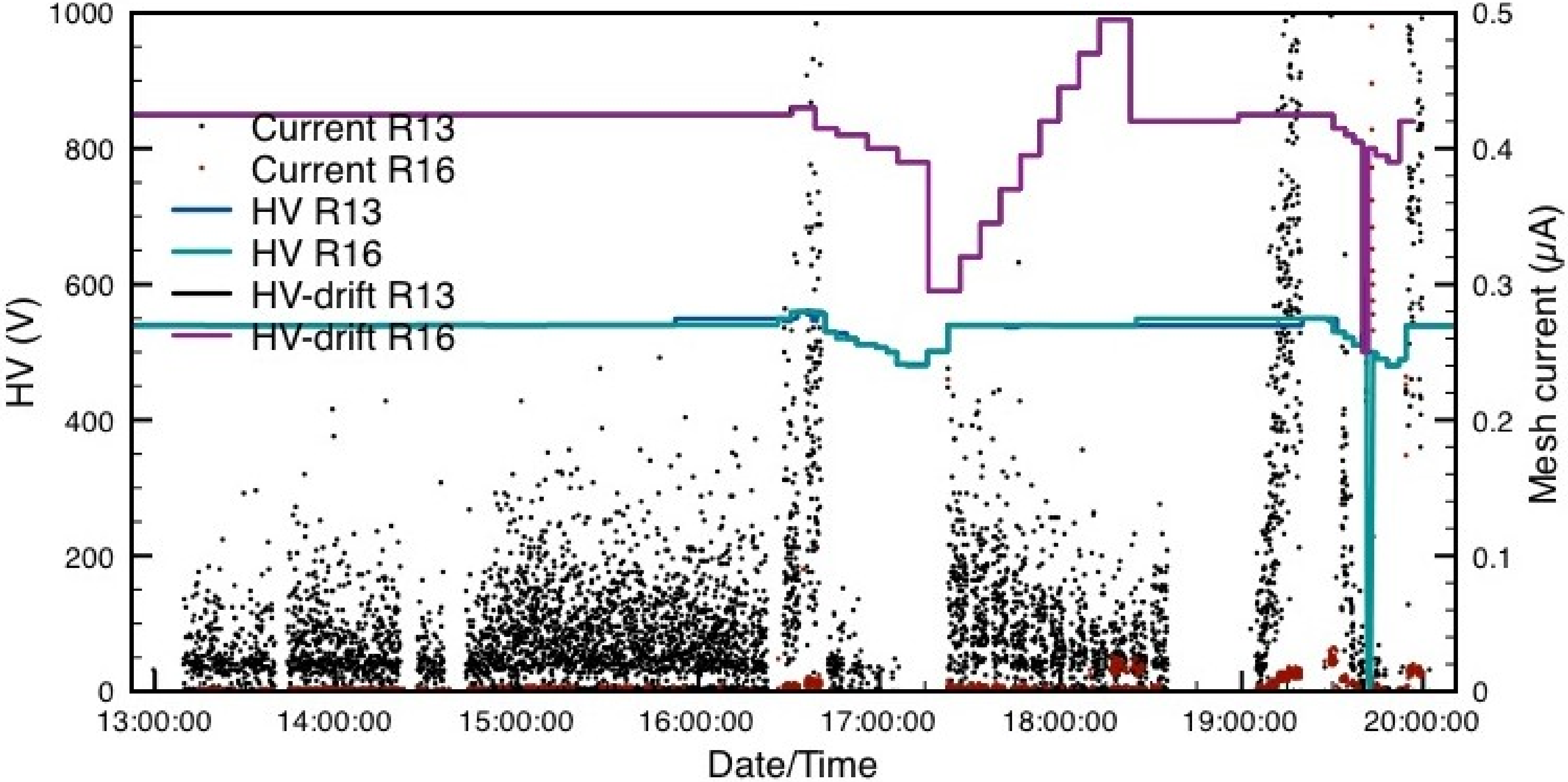
En=5.5 MeV, flux= 0.7×10^6 n/cm^2 s

En=9.1 MeV, flux= 1.4×10^6 n/cm^2 s



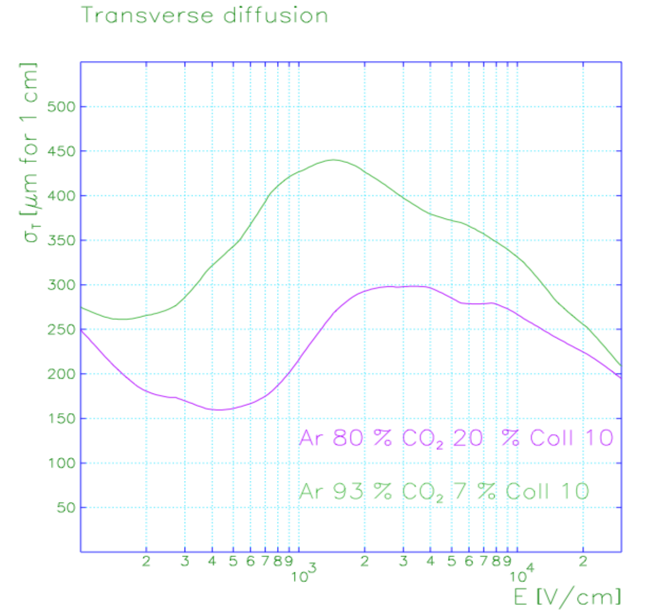
HV and currents

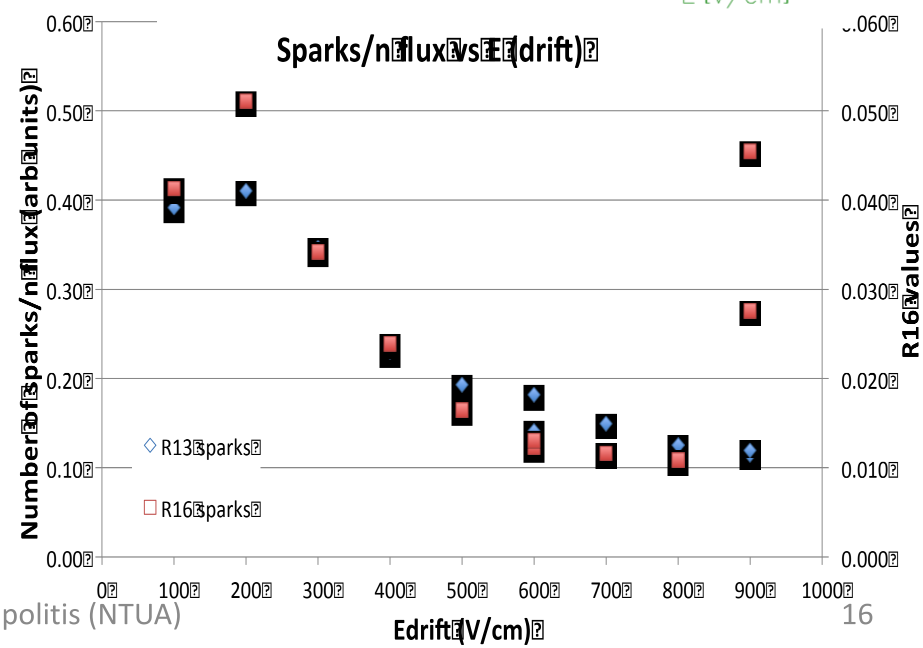
En=5.5 MeV, flux= 0.7x10^6 n/cm^2 s

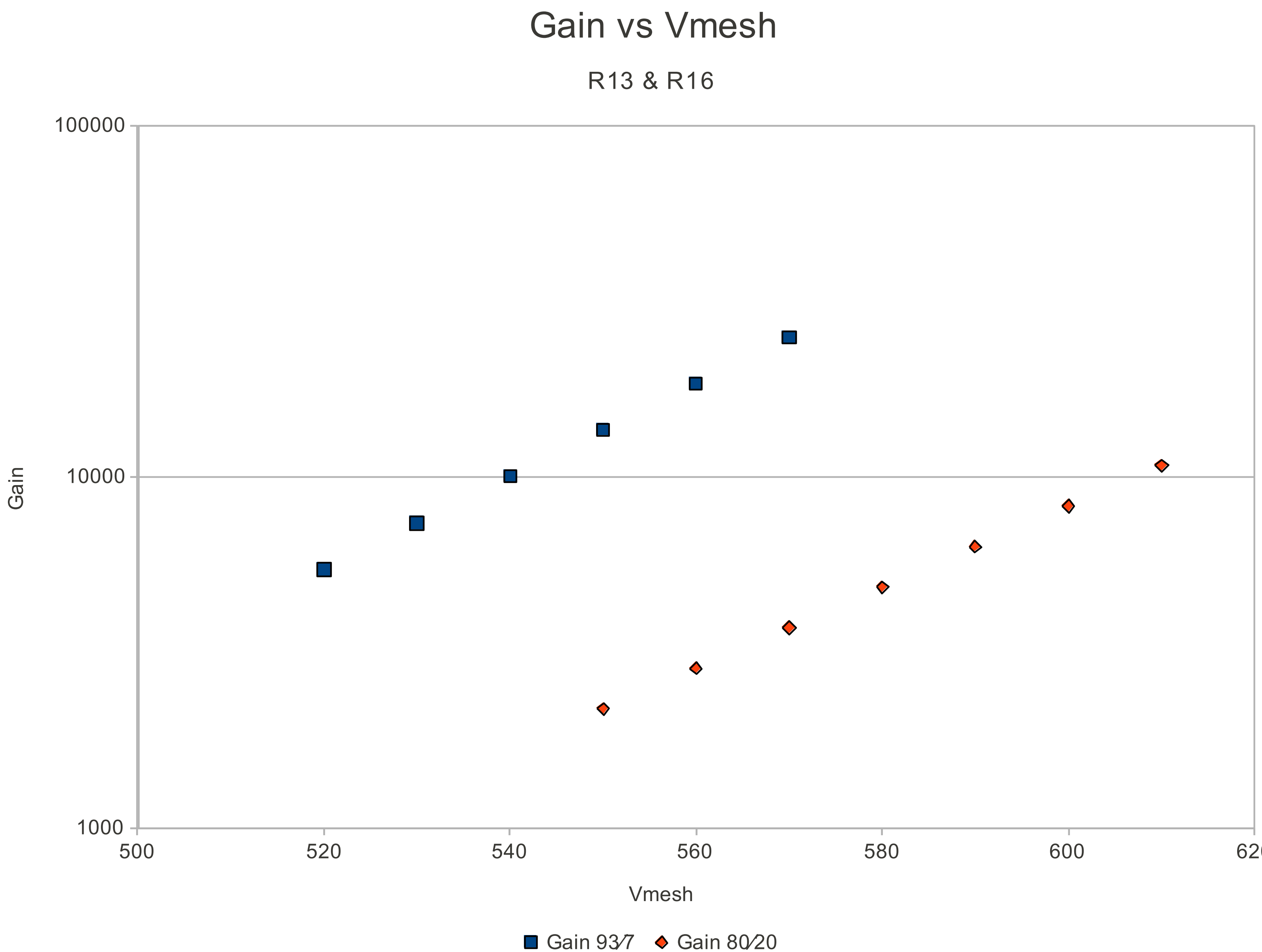


Drift field scan (R13 & R16)

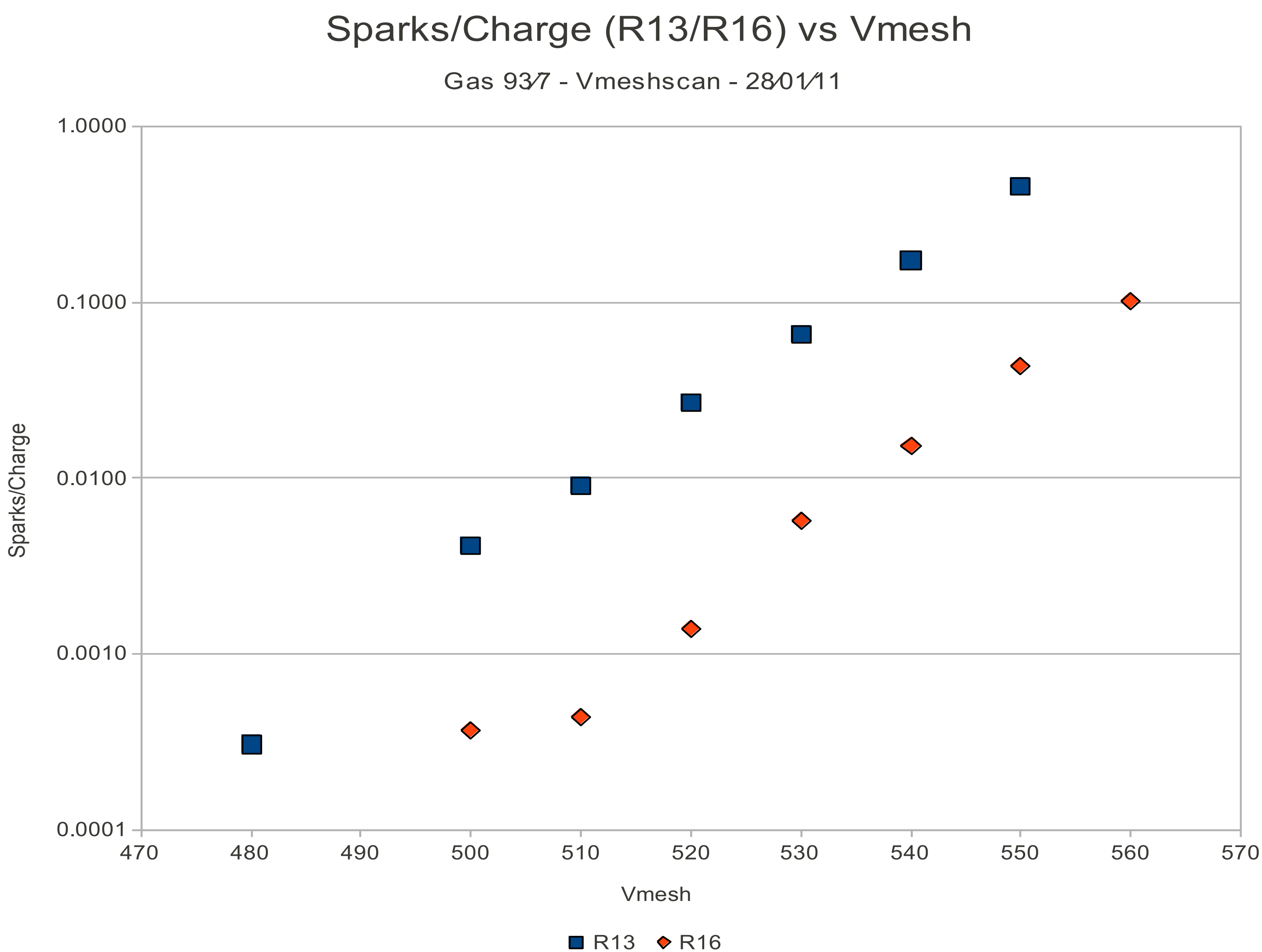
- In May 2010 found 4 x higher spark rate in Ar:CO² 80:20 than in 93:7 mixture. A puzzle.
- Both chambers were operated at the same drift field (600 V/cm)
- Transverse diffusion is very different for the two gases
- Measured the spark rate for 93:7 as function of drift field
- Spark rate follows nicely the change in transverse diffusion
- Puzzle probably solved !!!



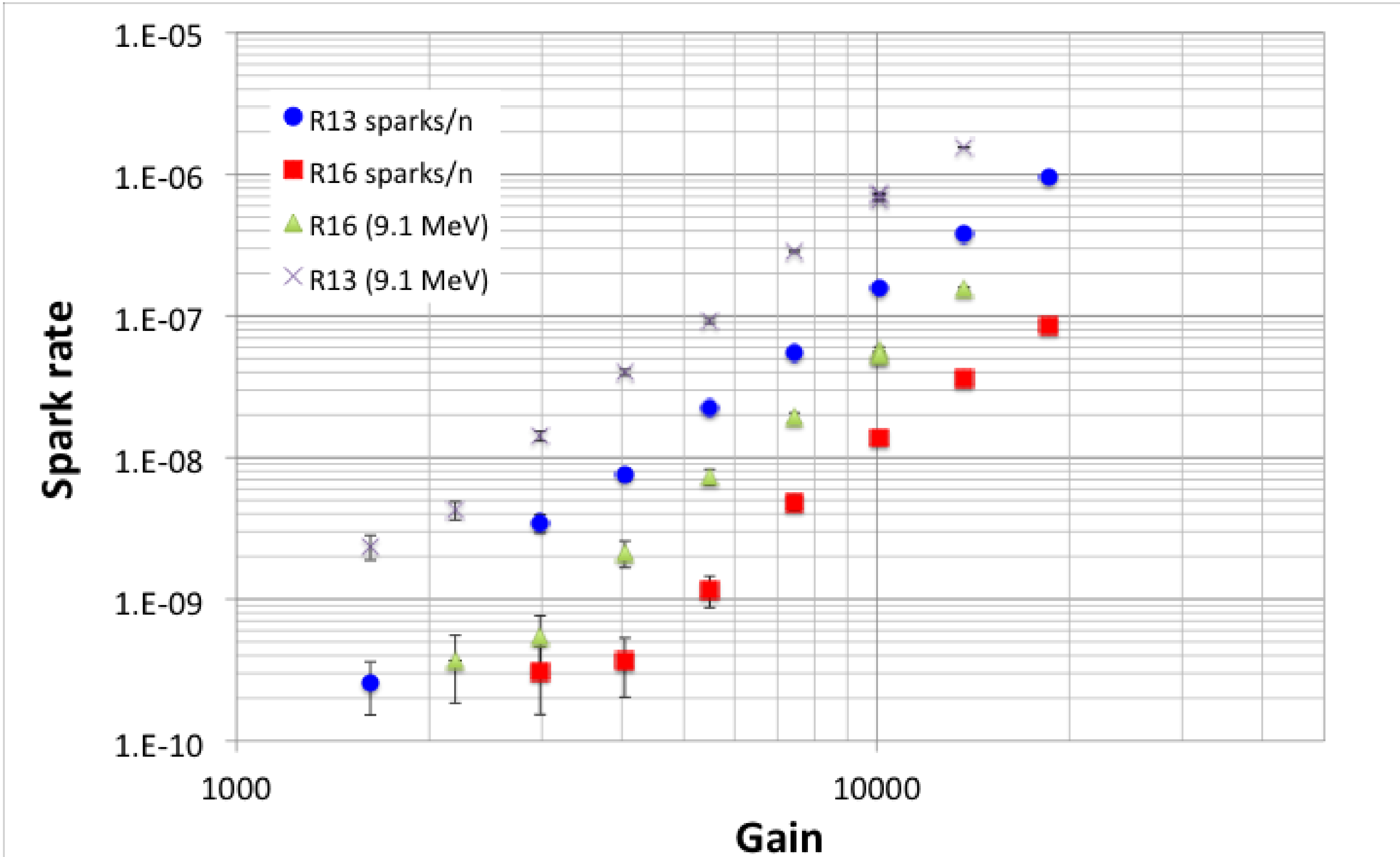




Gain vs Vmesh
R13 & R16
100000
10000
1000
Gain
500
520
540
560
580
600
620
Vmesh
Gain 93/7
Gain 80/20

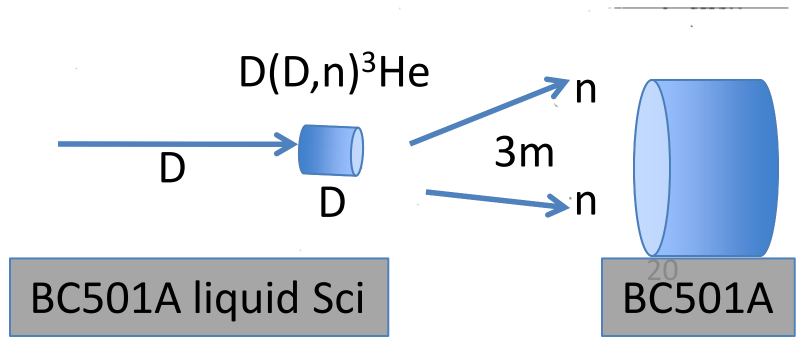


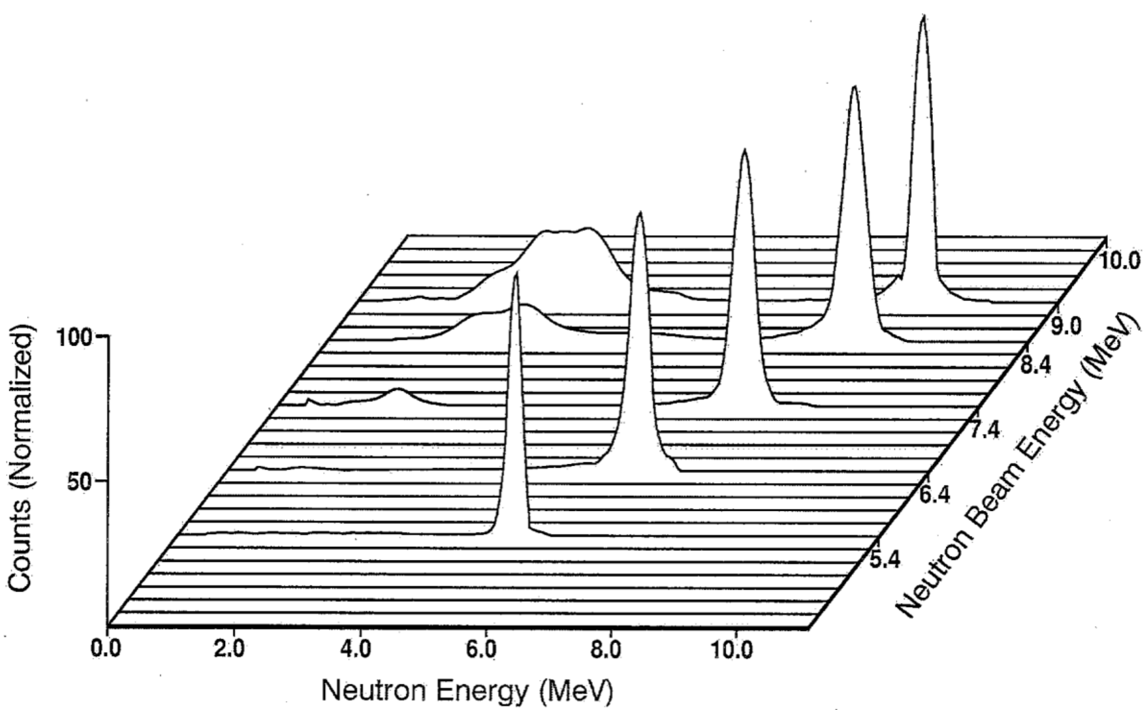
Sparks/Charge (R13/R16) vs Vmesh
Gas 93/7 - Vmeshscan - 28/01/11
1.0000
0.1000
0.0100
0.0010
0.0001
Sparks/Charge
470
480
490
500
510
520
530
540
550
560
570
Vmesh
R13
R16



1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
R13 sparks/n
R16 sparks/n
R16 (9.1 MeV)
R13 (9.1 MeV)
Spark rate
1000
10000
Gain

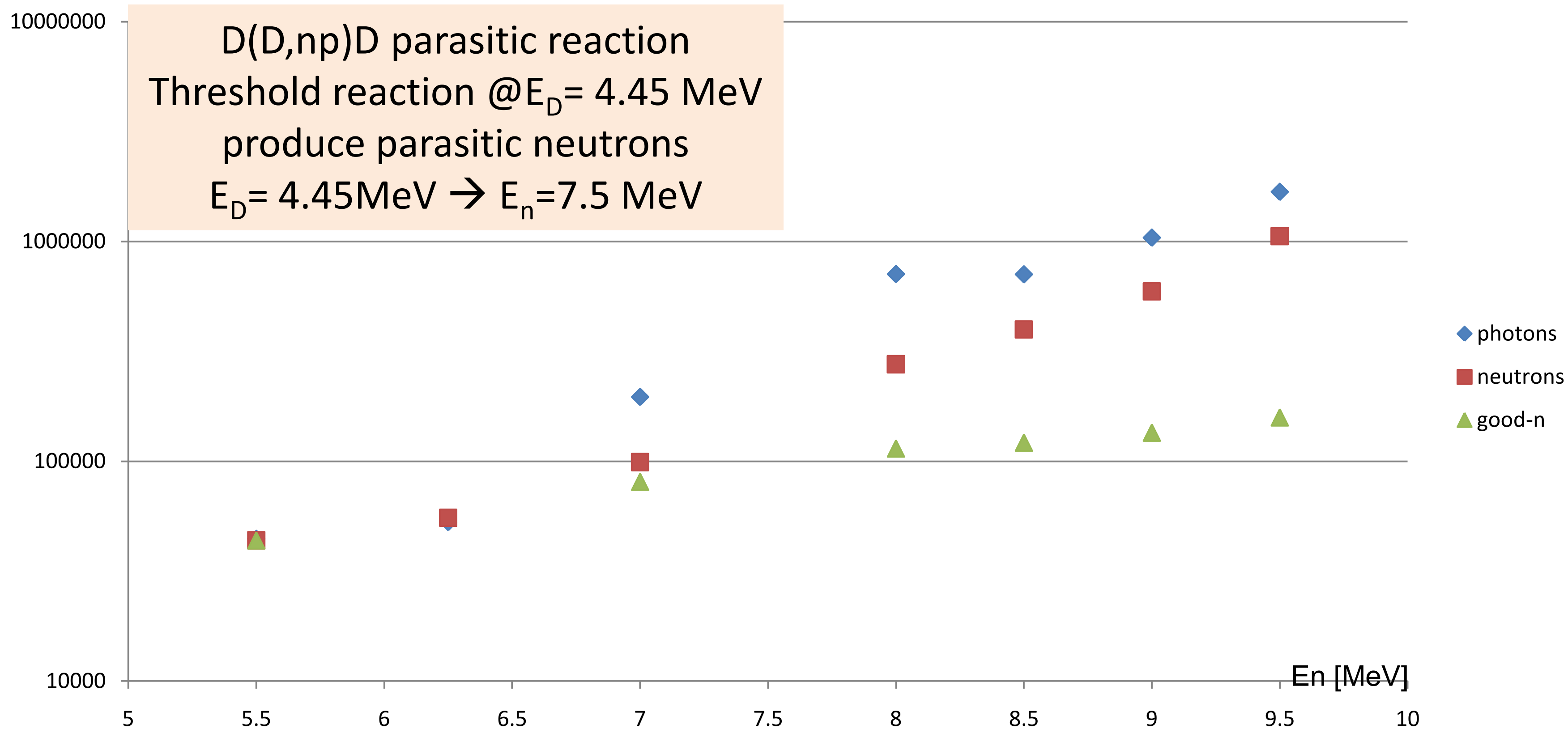
Neutron Beam

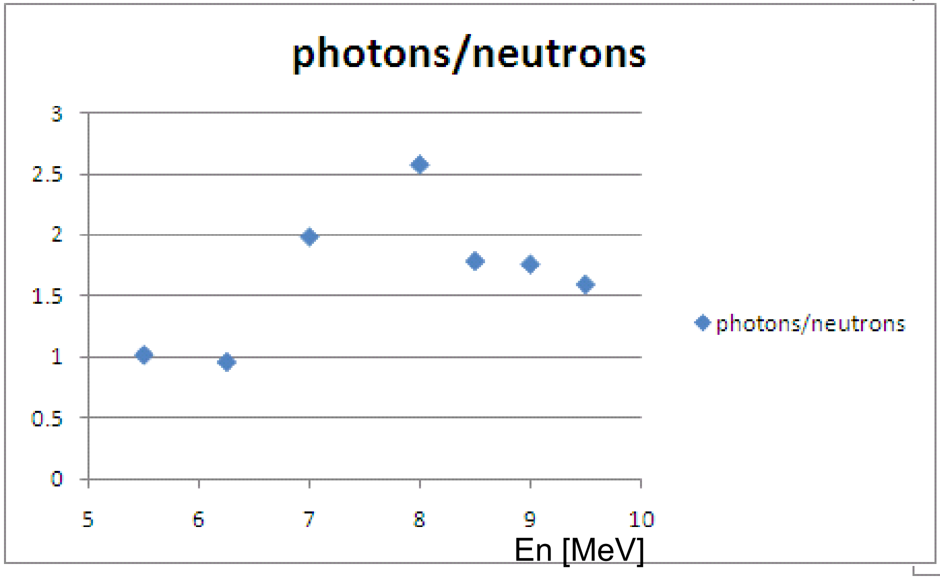


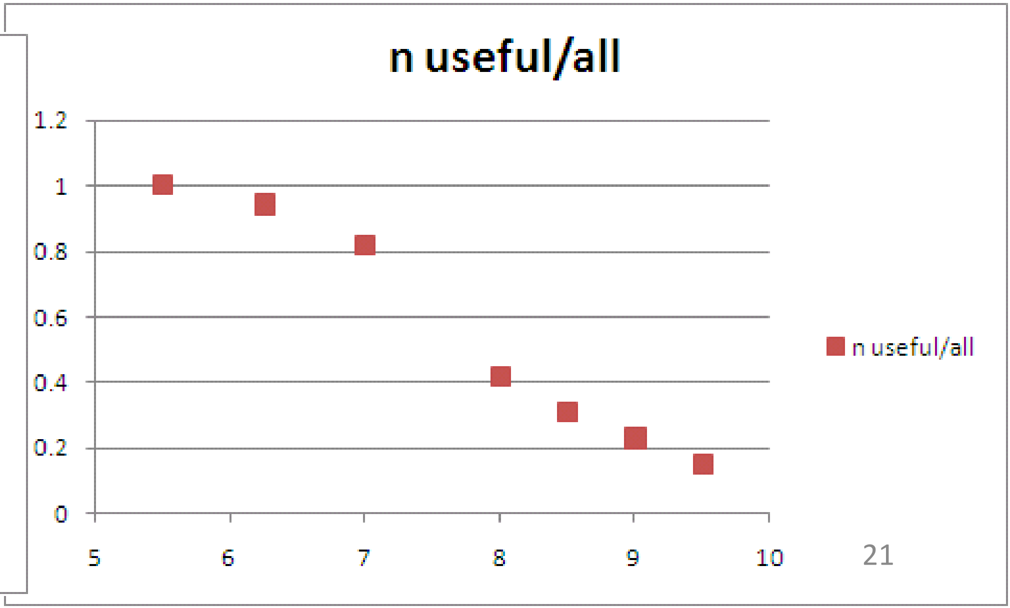


D(D,np)D
Threshold reaction @E_D= 4.45 MeV
produce parasitic neutrons
E_D= 4.45MeV → E_n=7.5 MeV

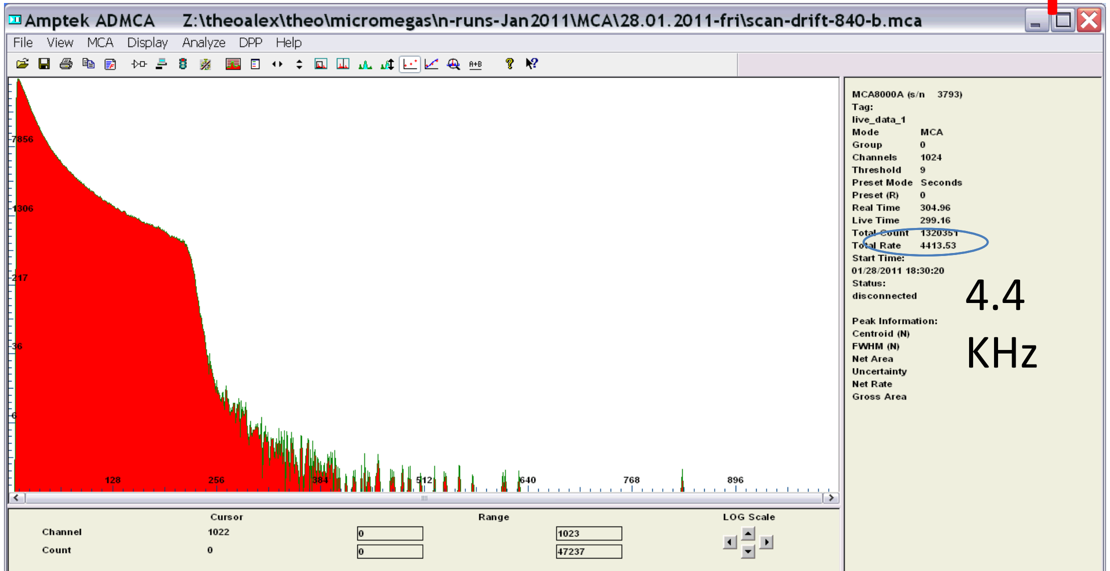
When n hits material
n,inl; n,el; n,γ; n,a; n,p


D(D,np)D parasitic reaction
Threshold reaction @E_D= 4.45 MeV
produce parasitic neutrons
E_D= 4.45MeV → E_n=7.5 MeV
10000000
1000000
100000
10000
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
En [MeV]
photons
neutrons
good-n

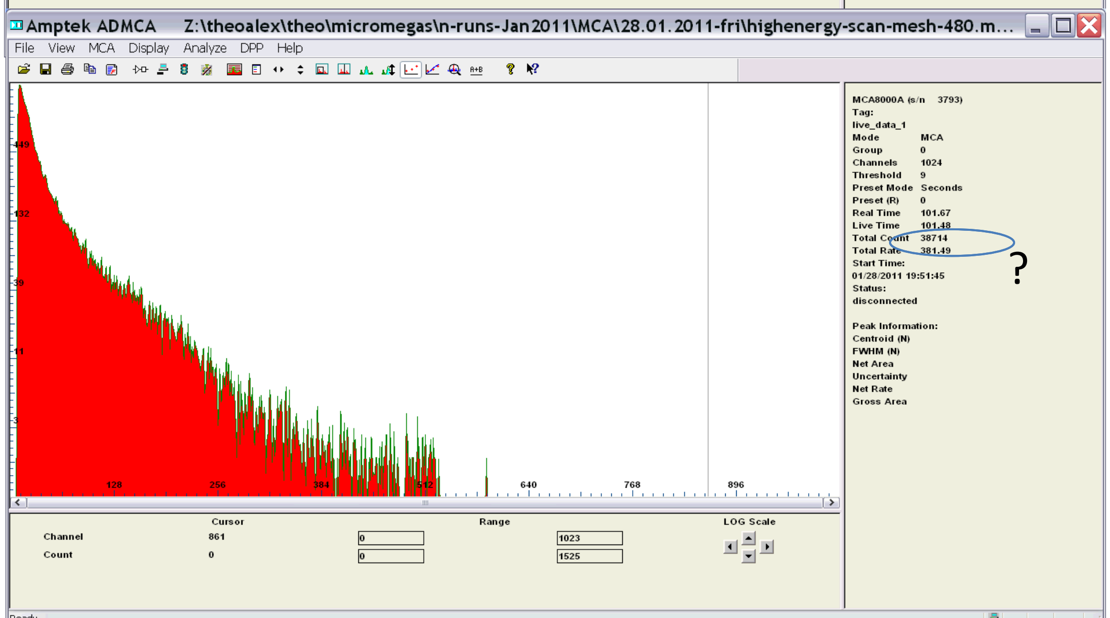

photons/neutrons
3
2.5
2
1.5
1
0.5
0
5
6
7
8
9
10
En [MeV]
photons/neutrons


n useful/all
1.2
1
0.8
0.6
0.4
0.2
0
5
6
7
8
9
10
n useful/all

Neutron Spectra

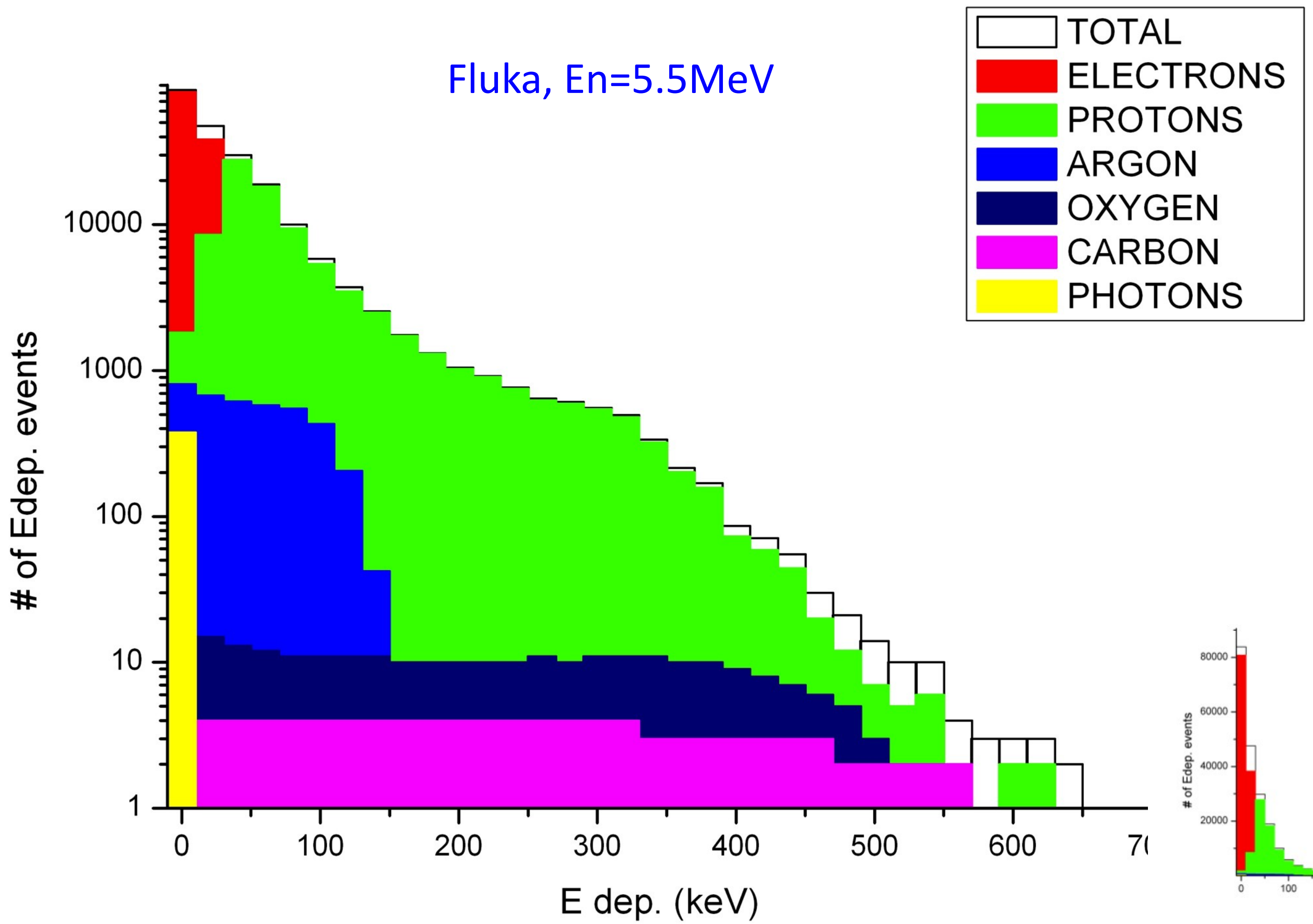


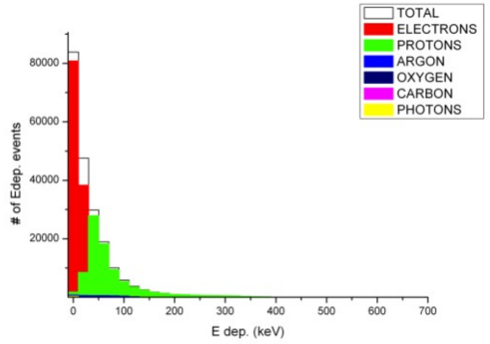
En = 5.5 MeV



En = 9.1 MeV

"Modified" Fluka simulation





Summary

- R11, R12, R13 and R16 show very similar behavior; robust & stable
- Robust & stable, no breakdown at all, excellent performance in neutron beams
- Sparks are controlled
- Still a few more things to check in a next run