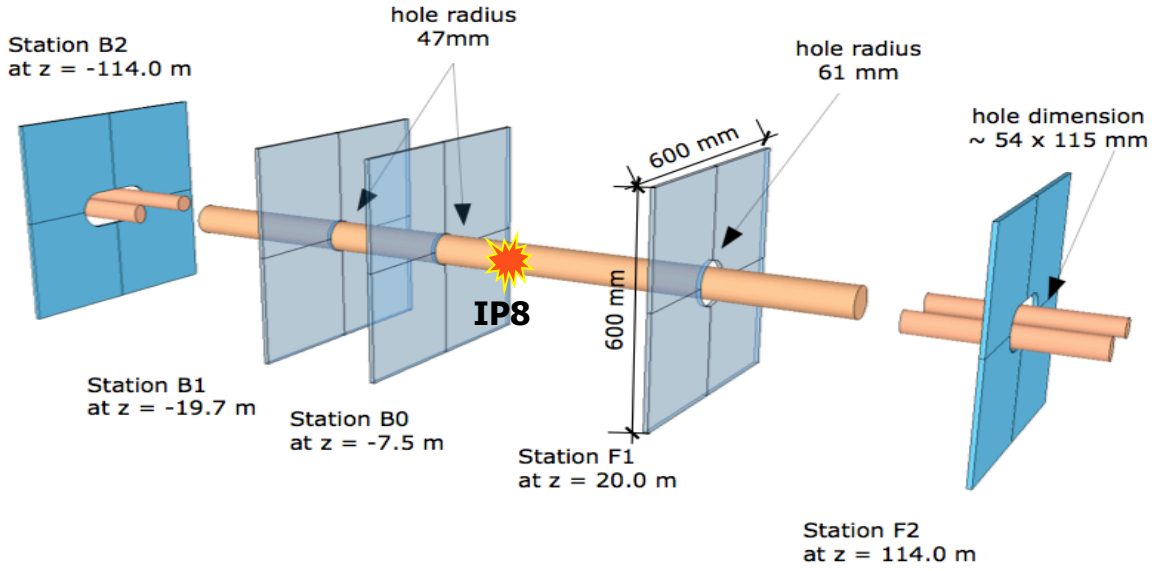
HERSCHEL: Increasing LHCb rapidity coverage

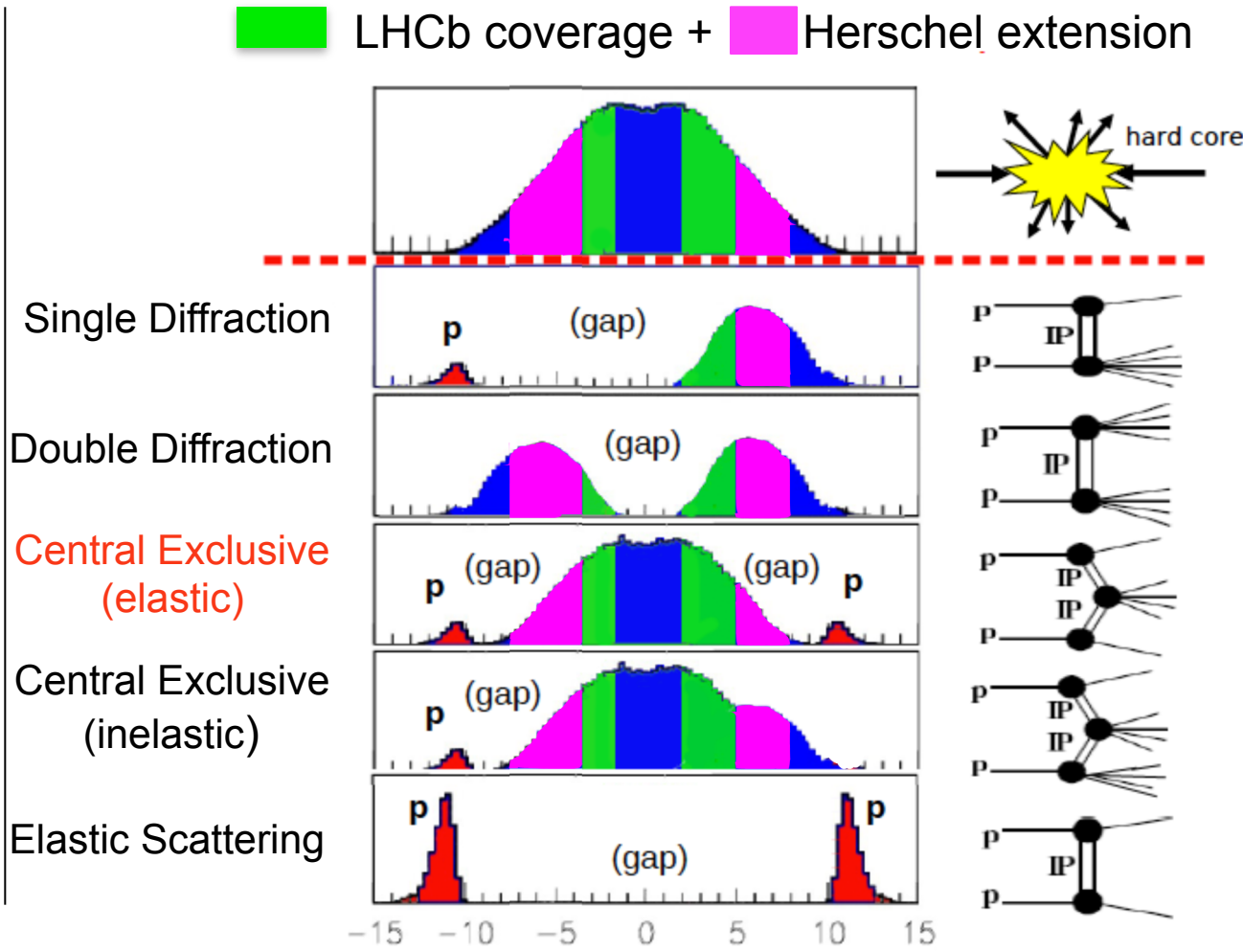
Dan Johnson, CERN
on behalf of the LHCb Herschel group



HERSCHEL: Increasing LHCb rapidity coverage

Aim – to tag/suppress background in the very forward region:

$$5 < |\eta| < 8$$

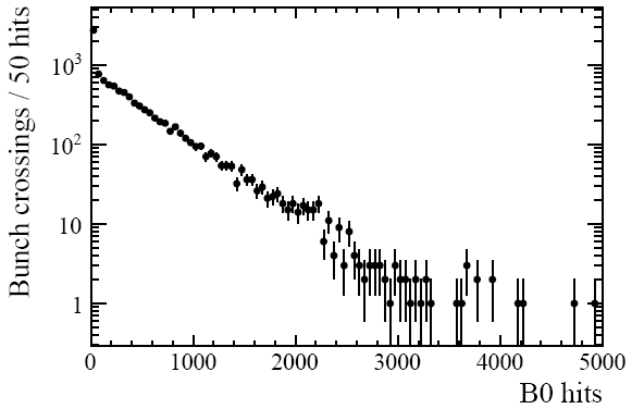


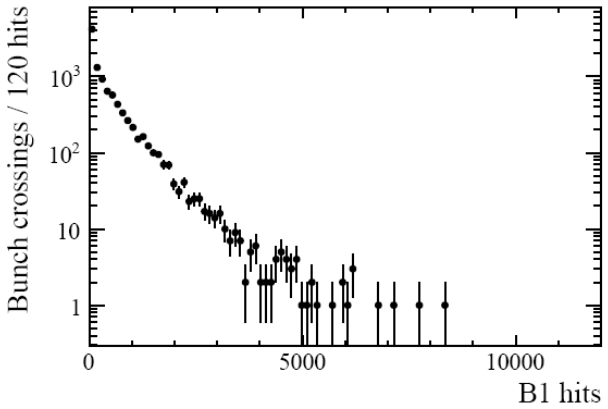
Operating Conditions

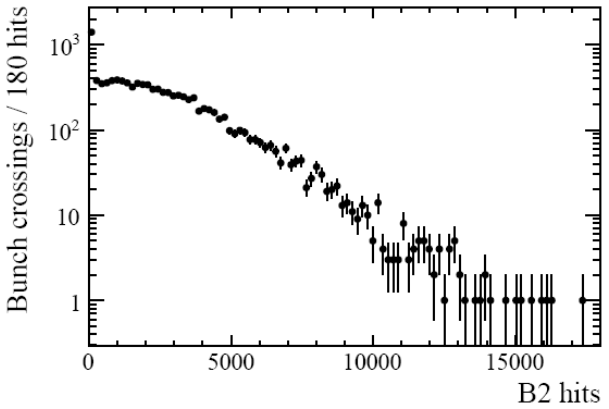
- **Challenging to withstand ultra-high particle rate: ~$10^{10} \rightarrow 10^{11}$ pps**

3.10^7 x 500 x 100ph.e./mip x G x 1.6 10^{-19} < **0.2 mA** → **G ~ 10^3**

Monte Carlo evaluation of mini-bias hits distribution at B0, B1 and B2 stations







- **Ability to detect single "mip" for calibration purposes** → **G ~ 10^6**

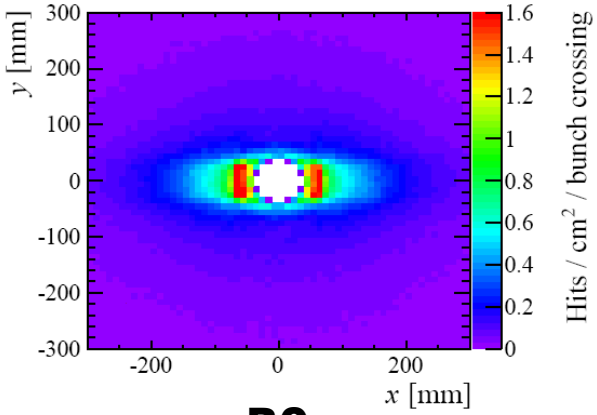
- **Fit signal width within 25 ns** (regardless of pulse height and long cables)

Particle Flux Distribution

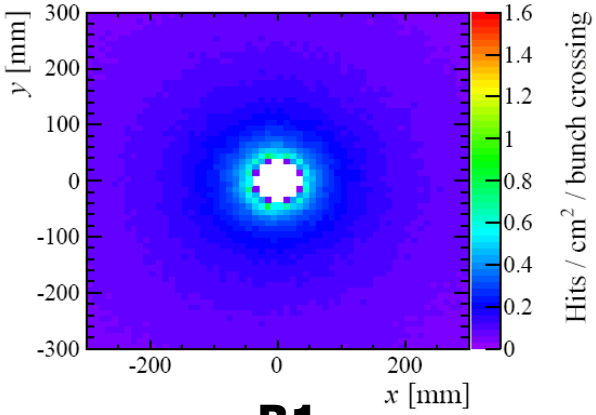
- **Highly non-uniform particle distribution**
  - concentrated around beam pipe

- **~ equally spread between quadrants**
  - in spite of magnets and non-zero bunch crossing angle

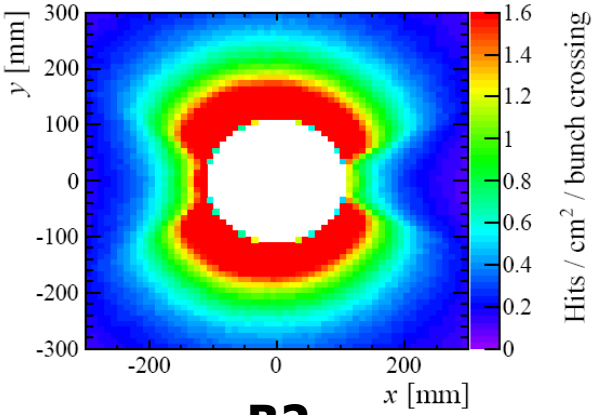
- **Radiation resistance will suffer**
  - radiation tolerance of 1-2 Mrad implies possible plastic counter replacement one or two times during Run 2



B0



B1



B2

Photo-detector

Chosen

R1828-01

51mm, ~200uA

Criteria:

- **high anode current upper limit**
- **large range of gain variation (10^3 – 10^6)**
- **fast time response (to fit in 25 ns)**
- **large entry window to increase light yield**
- **good single electron separation**

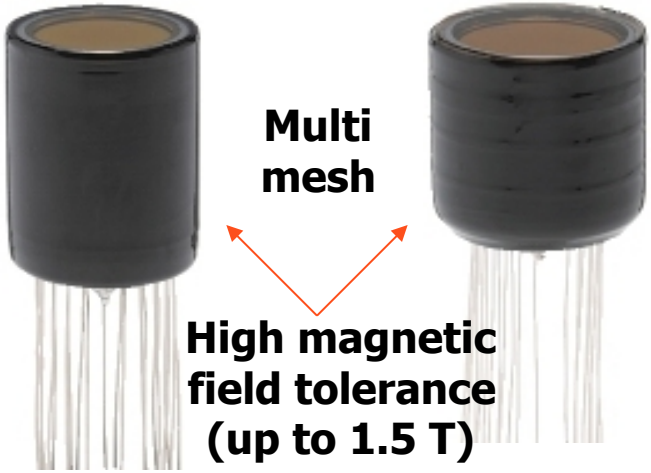
ET-Enterprises	**R7761-70**	**R5924-70**
51mm tubes:	28mm, <10uA	51mm, <100uA

limit

9214B <100uA

9266B <50uA

9813B <100uA



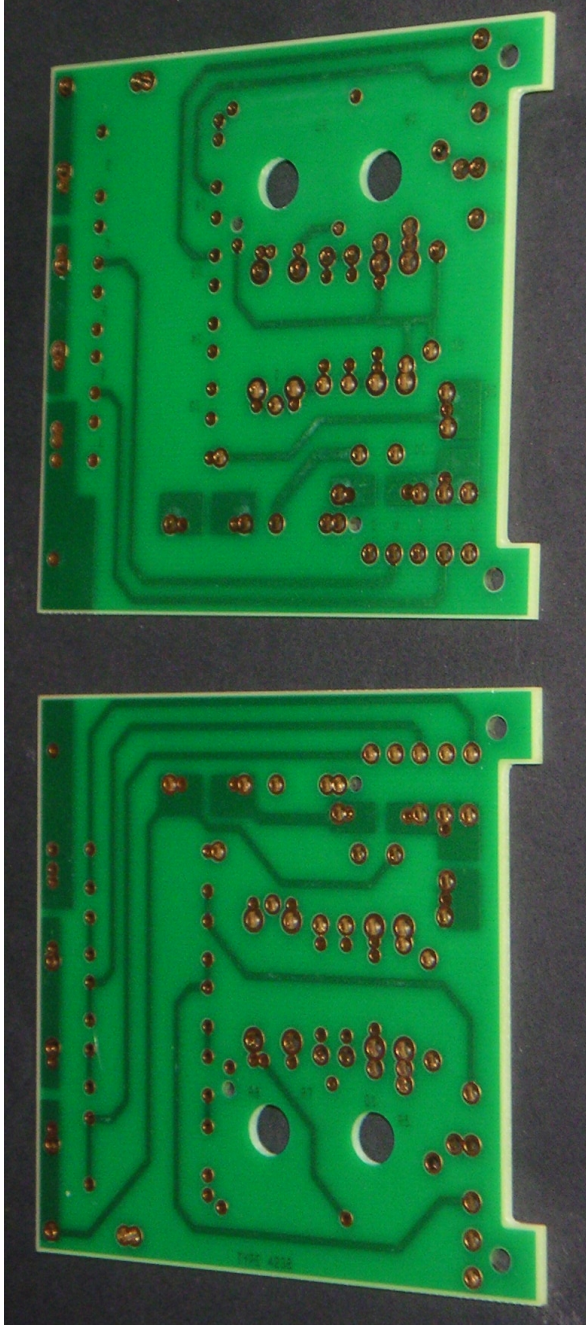
Optimising the Divider

Option chosen:

- **production of PCB for divider**
  - digitised using old sample
  - designed in 1976 for high-rate beam counters
  - additional bias voltage for a few last dynodes
  - used for years in ALICE near beam pipe
  - freedom in selecting basic components (power dissipation, tolerance)
  - reliable (including Zener components)

- **5 sequential steps to reach design goal**
  - start with design for BLS (same dynode structure)
  - increase divider current (both for HV and bias)
  - monitor performance at lowest HV

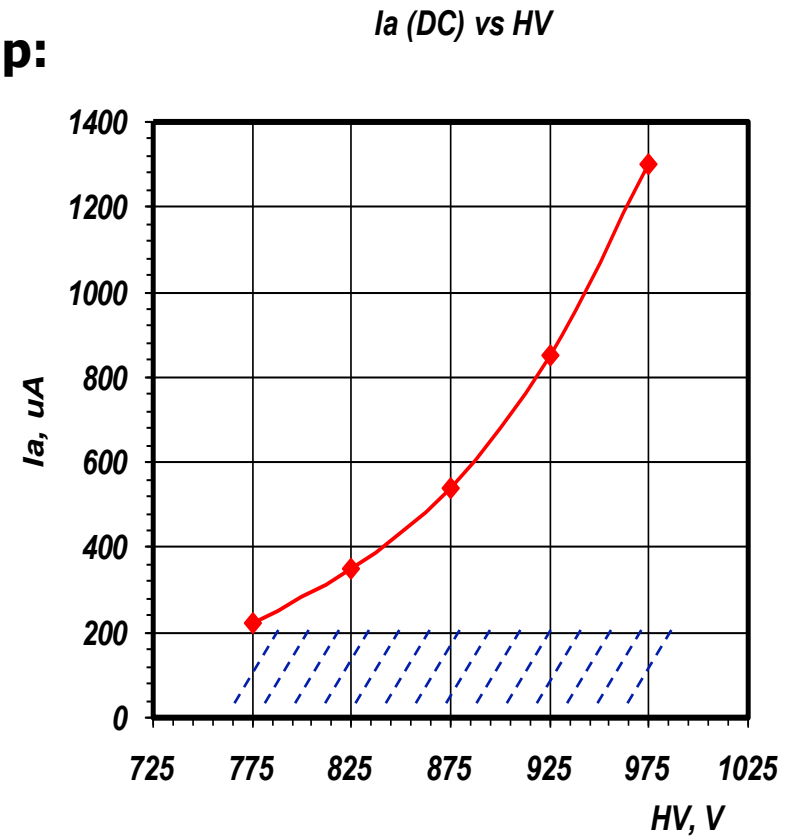
- **production at CERN workshop**
  - produced 25 items
  - all files available for further production



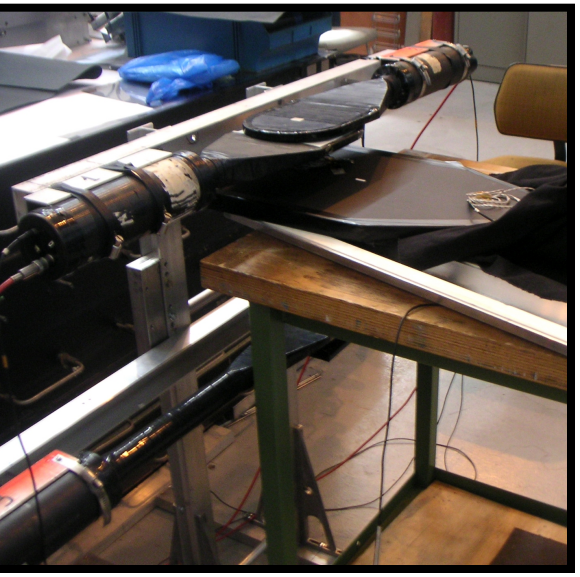
Optimising the Divider

Optimisation completed by inserting stabilizing Zener in 4th inter-dynode gap:

- observed pulsed LED signal in presence of second illuminated LED producing DC anode current
- range of voltages within 200uA limit
- stability checked for pulse-height up to 5V
- optimised divider corresponds to expected operating conditions



Test-bench Setup

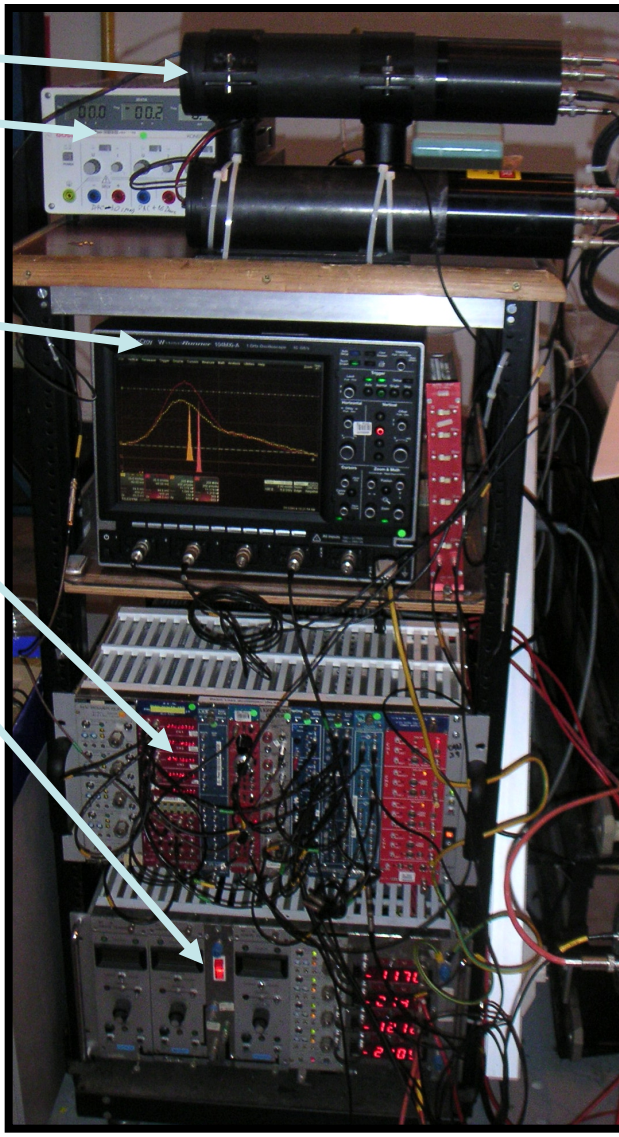


Housing w/LEDs
DC power supply (for LED)

Scope LeCroyWR104MXi

NIM logic & HV

HV power supply



The test-bench includes:

- **Cosmic stand**
- **Scope with extended functions** (histograming)
- **Coincidence logic** (NIM)
- **HV power supplies**
- **I-V meter**
- **Scalers**
- **Separate housing with two LEDs in each**
- **DC power supply for one of LED**
  - can permanently illuminate one LED…
  - … whilst pulsing the second

Cosmic Trigger

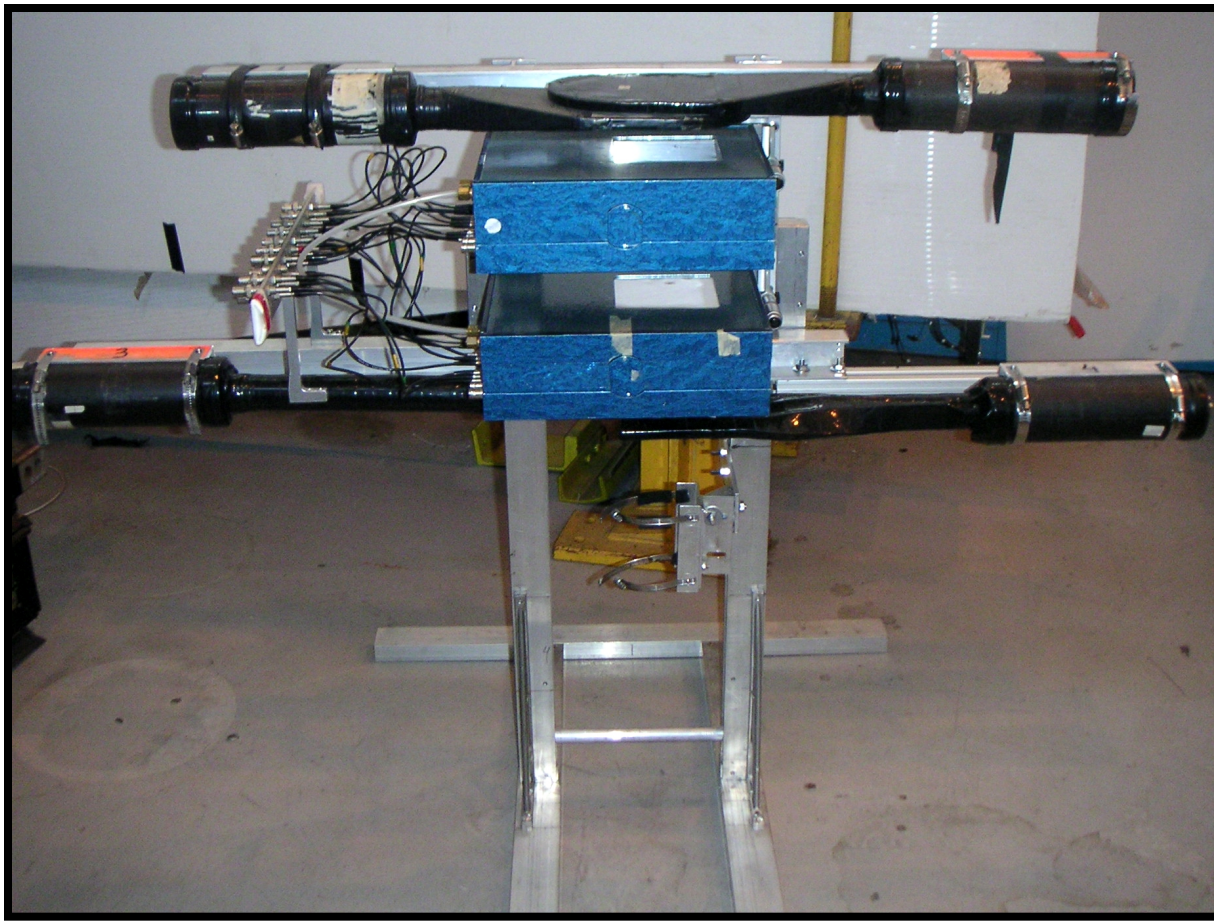
Simple four-fold coincidence:

- **upper**
  16 cm diameter counters
- **lower**
  10x10 cm² square counters

- **Spacing**
  distance ~32 cm

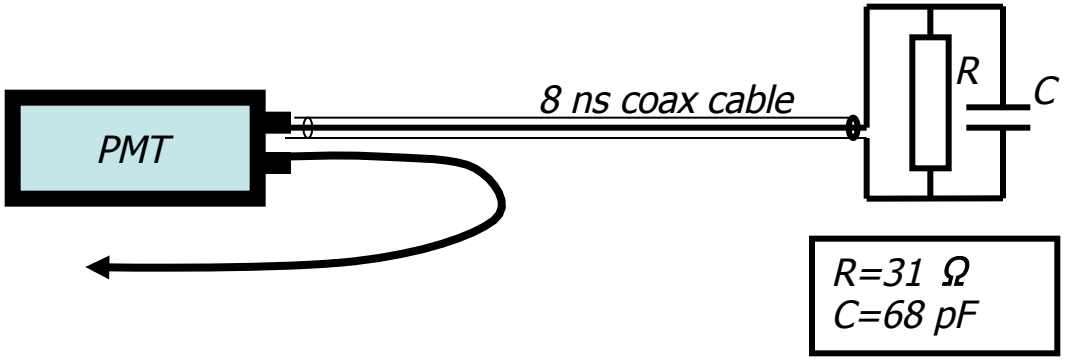
- **Discrimination threshold**
  30-32 mV

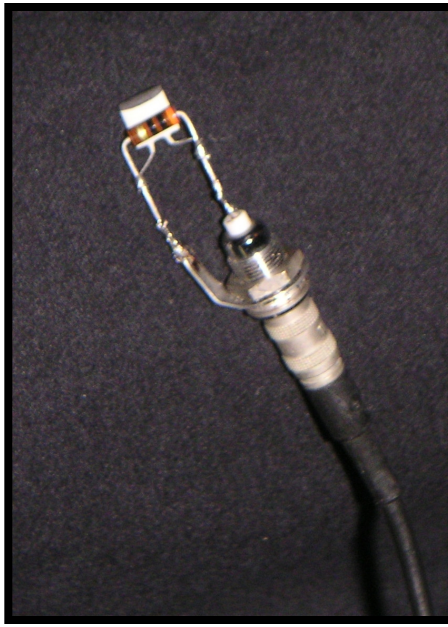
- **Coincidence rate**
  0.21 Hz

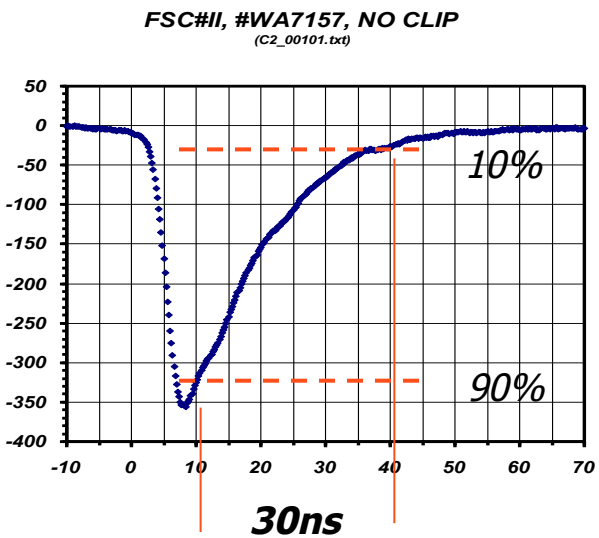


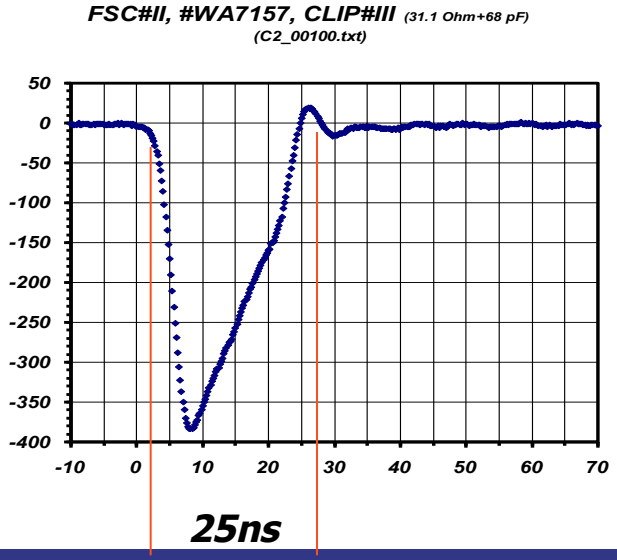
Clipping the Pulse

Linear passive clipping applied (as in the LHCb HCAL)









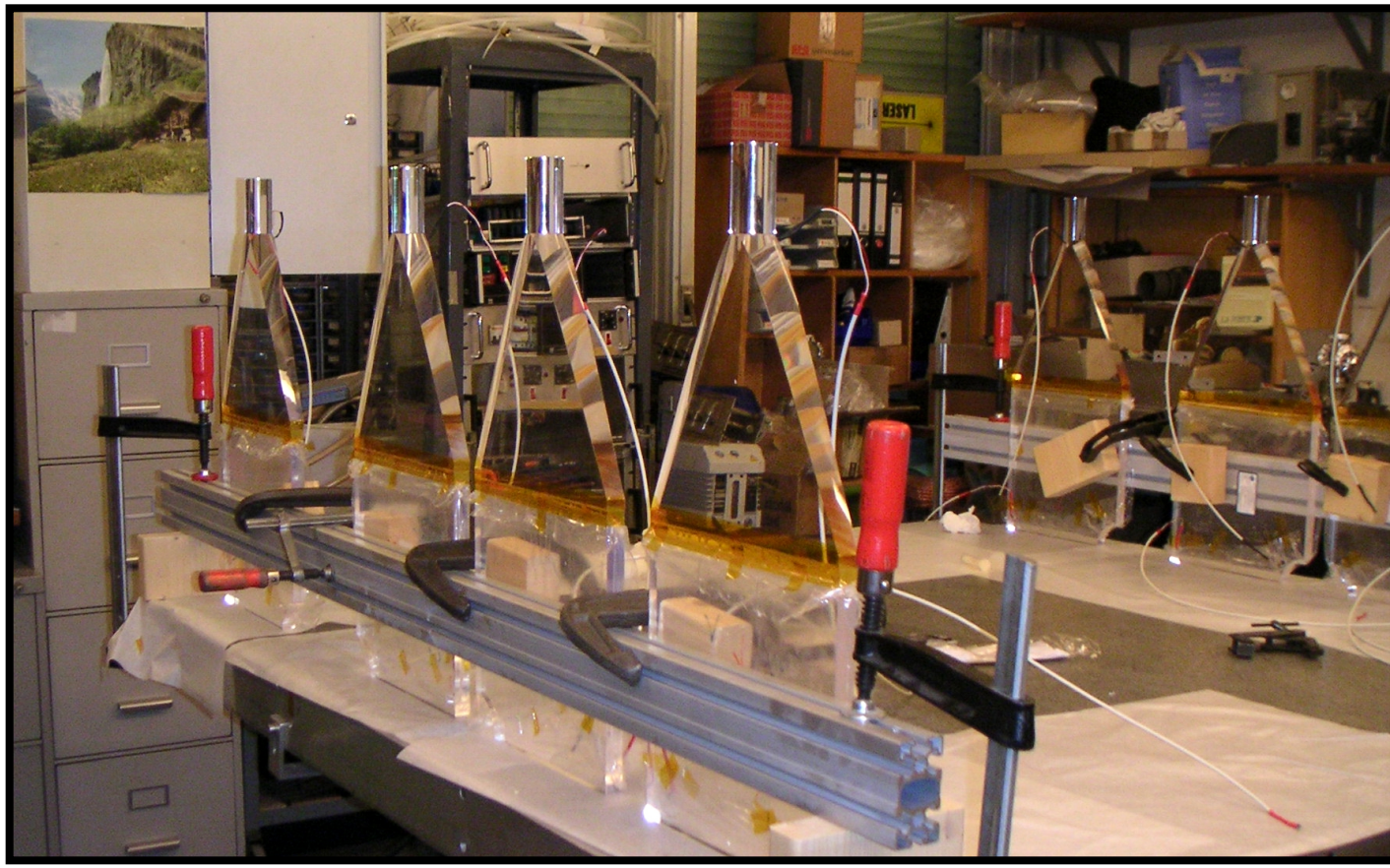
Possible to fit signal within 25 ns gap

Divider and Cabling Production

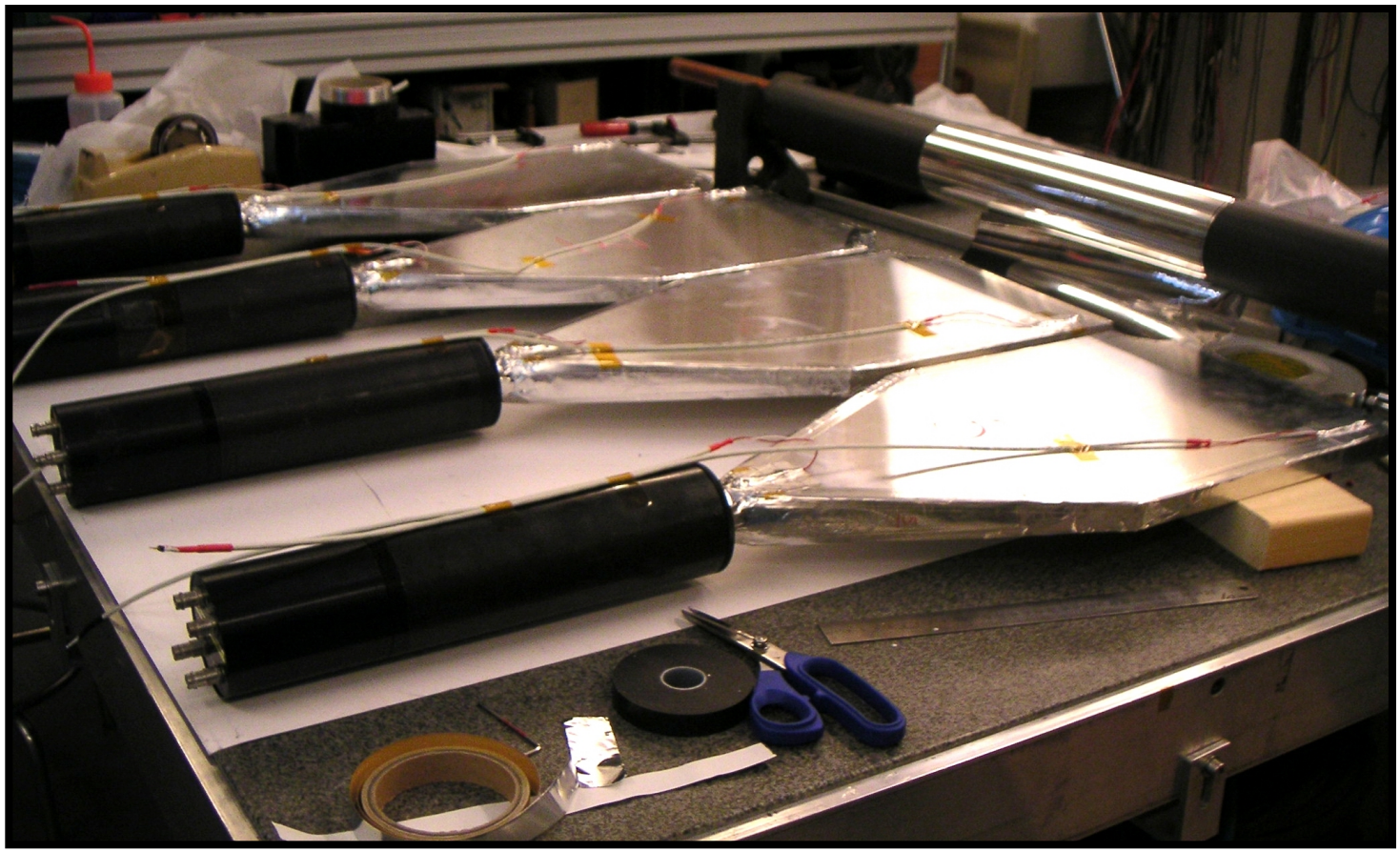
- **25 dividers assembled and checked (5 spare)**
- **2x25 set of LED cables soldered (5 spare)**
- **25 clipping cables prepared (5 spare)**
- **2x20 LED's have been prepared for counters assembly**
  red – for far-end LED,
  black – for near-end LED

Scintillator Assembly

- **Mass-production of scintillators**
- **Here: light-guides -"fish-tail"**

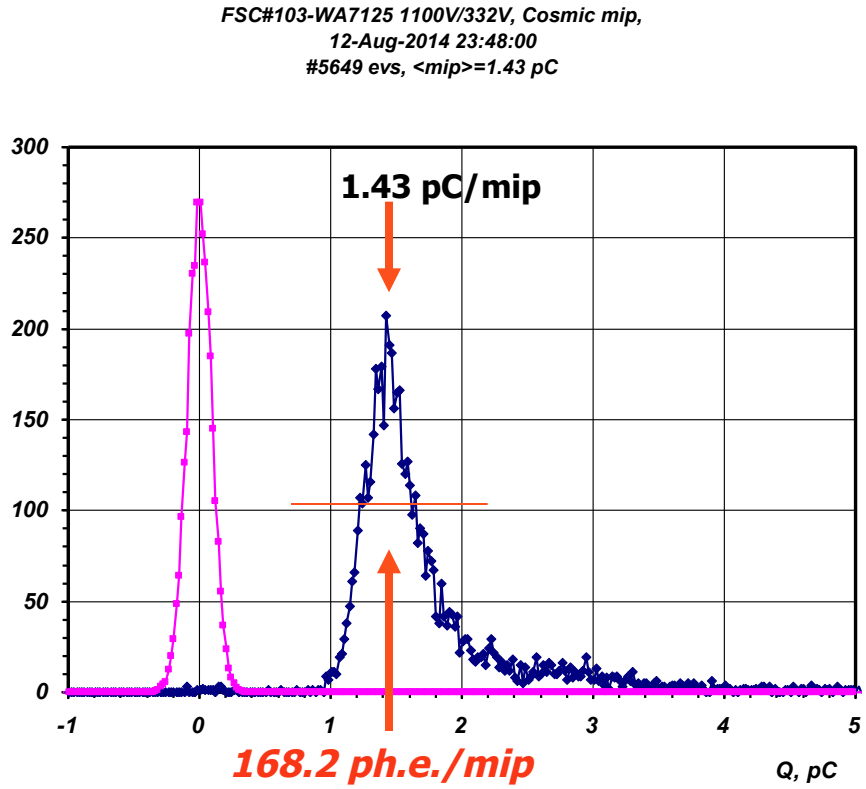


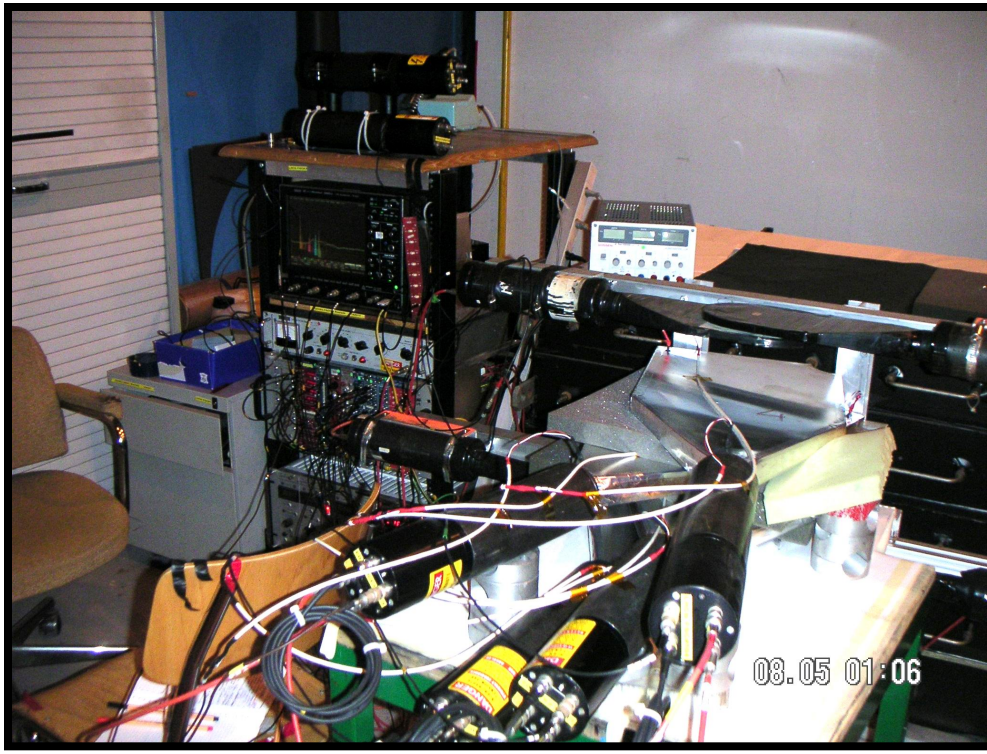
Counter Assembly



- **LED's glued**
- **Counter wrapped in foil to exclude light**
- **PMT attached** (without optical contact)
- **Calibrated using a cosmic stand**

Cosmic Calibration





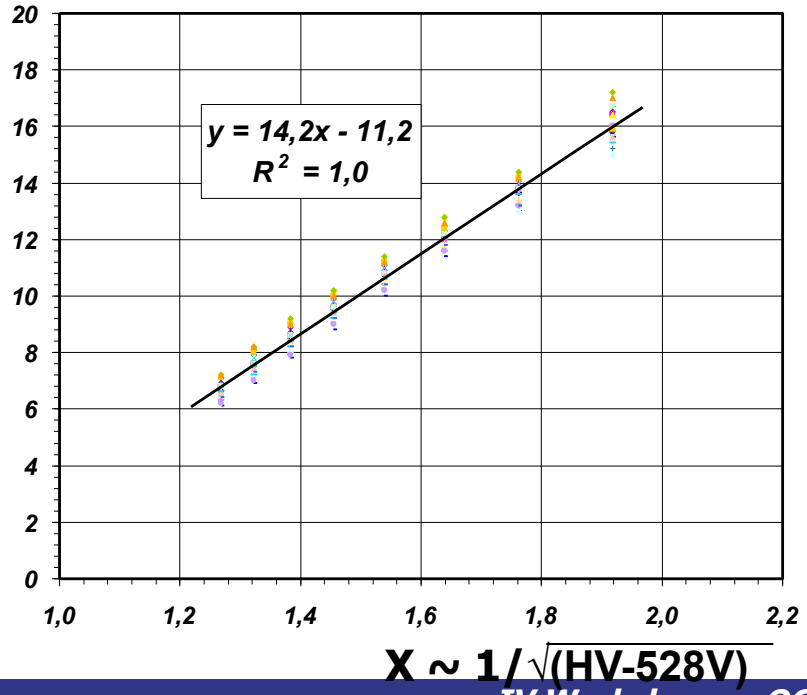
Cosmic calibration for all 20 counters done after assembly
(4 counters on the stand at once)
All PMTs pass LED calibration at different HV
(800V-850V-…-1450V-1500V, Gain .vs. HV obtained)
Light yield ~170 ph.e. per mip

Combined Calibration

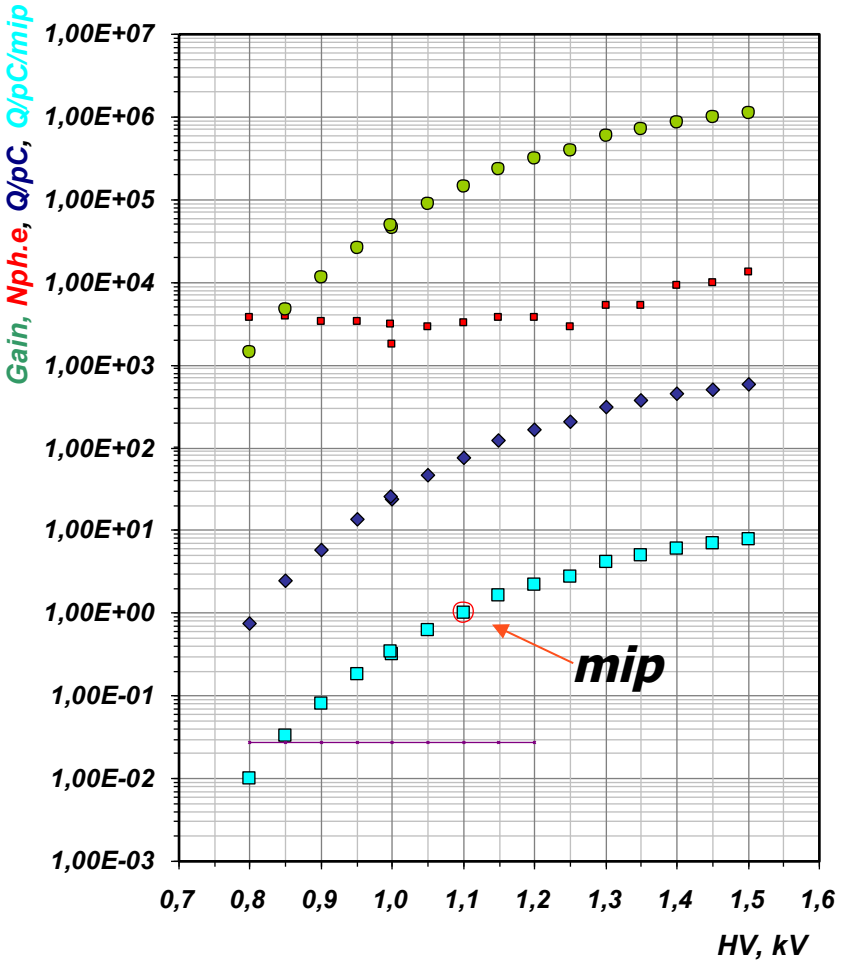
Each counter has own HV dependence of signal charge produced by "mip"

At very high gain/pulse-heights the divider starts to saturate

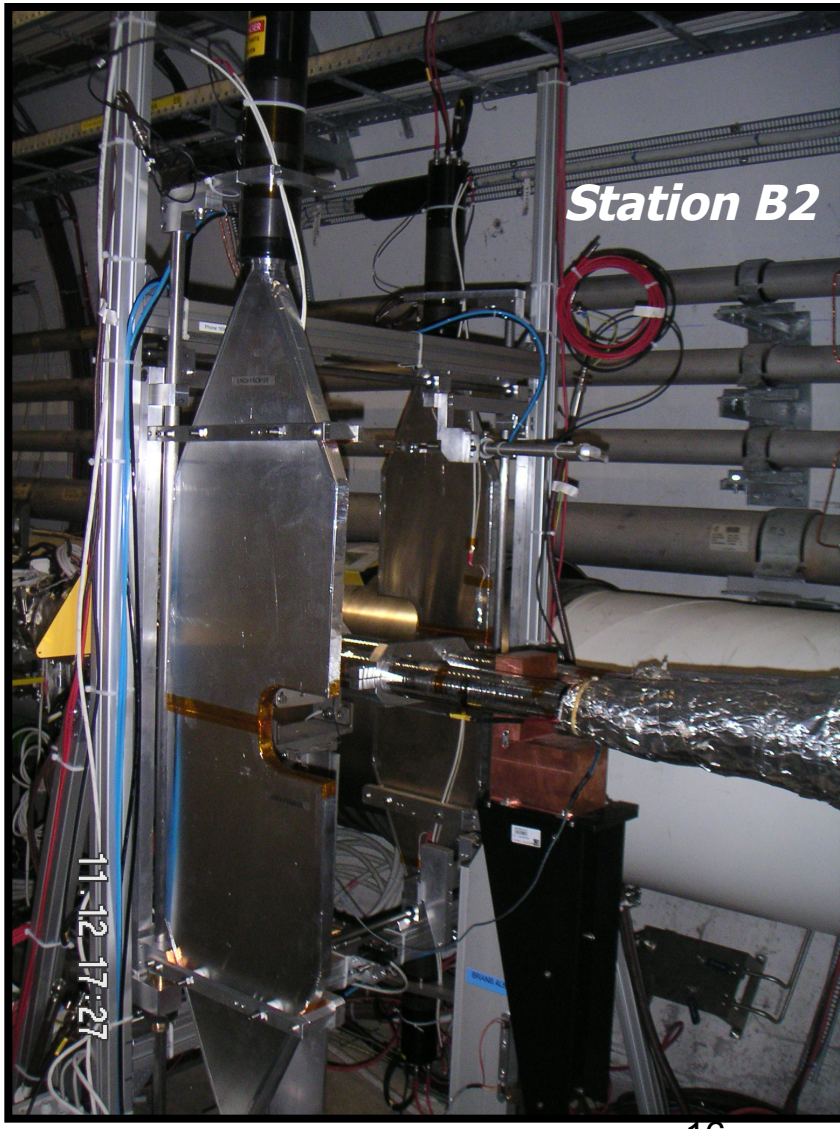
Delay in PMT show common behavior



Counter FSC#20 Base#125 PMT WA7174



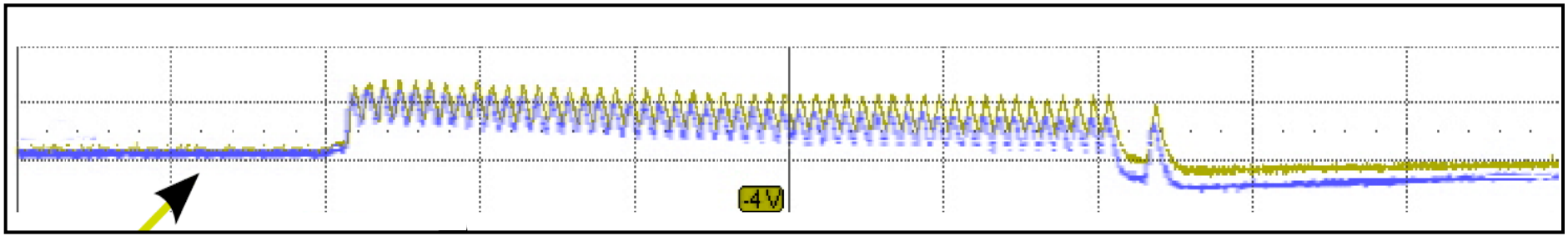
Tunnel Installation of Counters



Front-end Electronics

Study of FE reveals drifting pedestal under heavy load:

- XCALO FE boards designed for 5-10% occupancies
- for Herschel ~100% occupancy: require alternative approach
- possible solution to adapt Pre-Shower FE

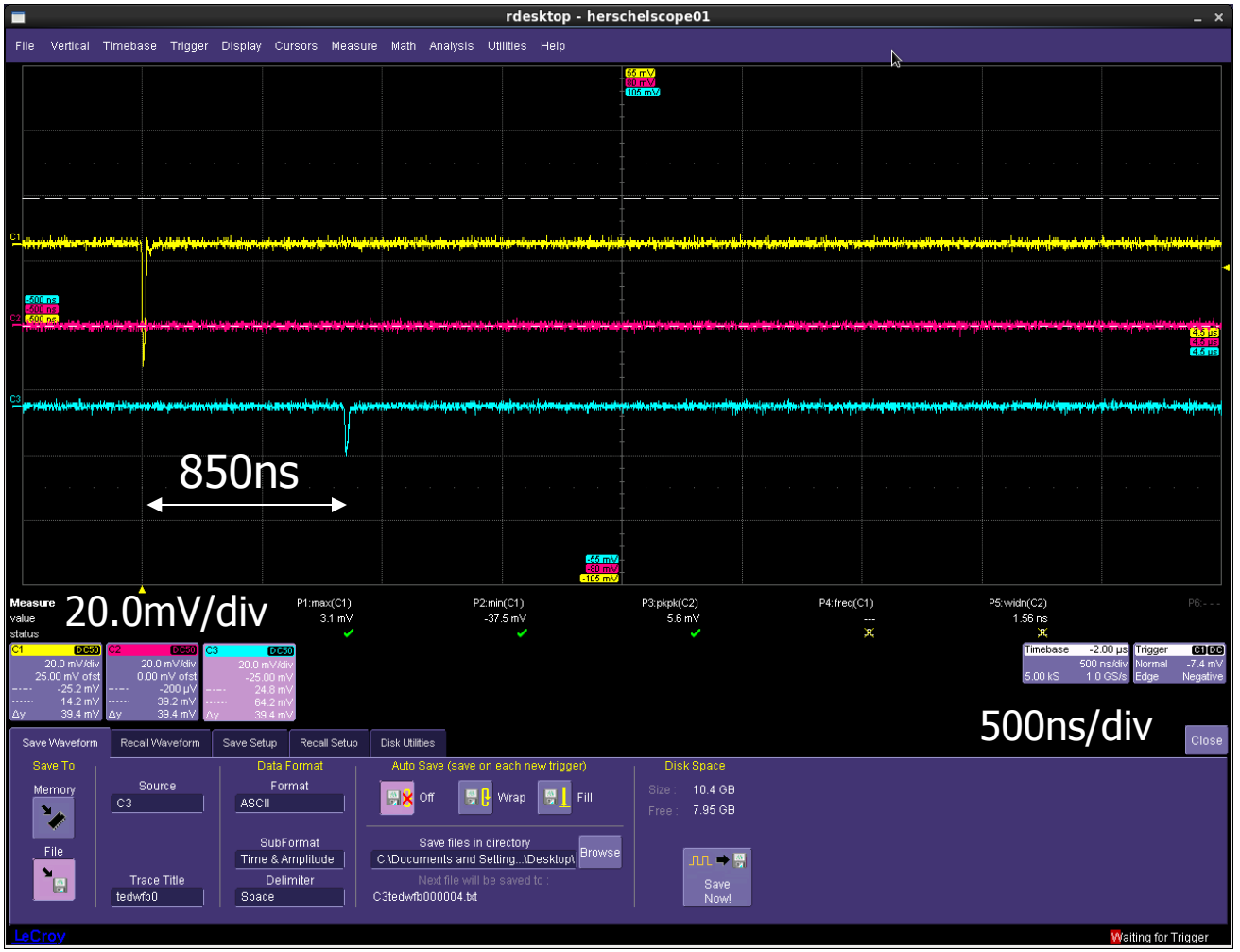


At this point, VELO-side detector stations ready for first test in the LHC tunnel

(two counters in the Forward (muon) side are being connected this week)

LHC Injection Tests

1) Counters checked for LED signal before TED
2) Three counters connected to scope (one in each station)
3) Two counters immediately show the signal (one poor connection)
4) All remaining 9 counters read-out using current FE successfully



First signal in Herschel!

LHC Injection Tests

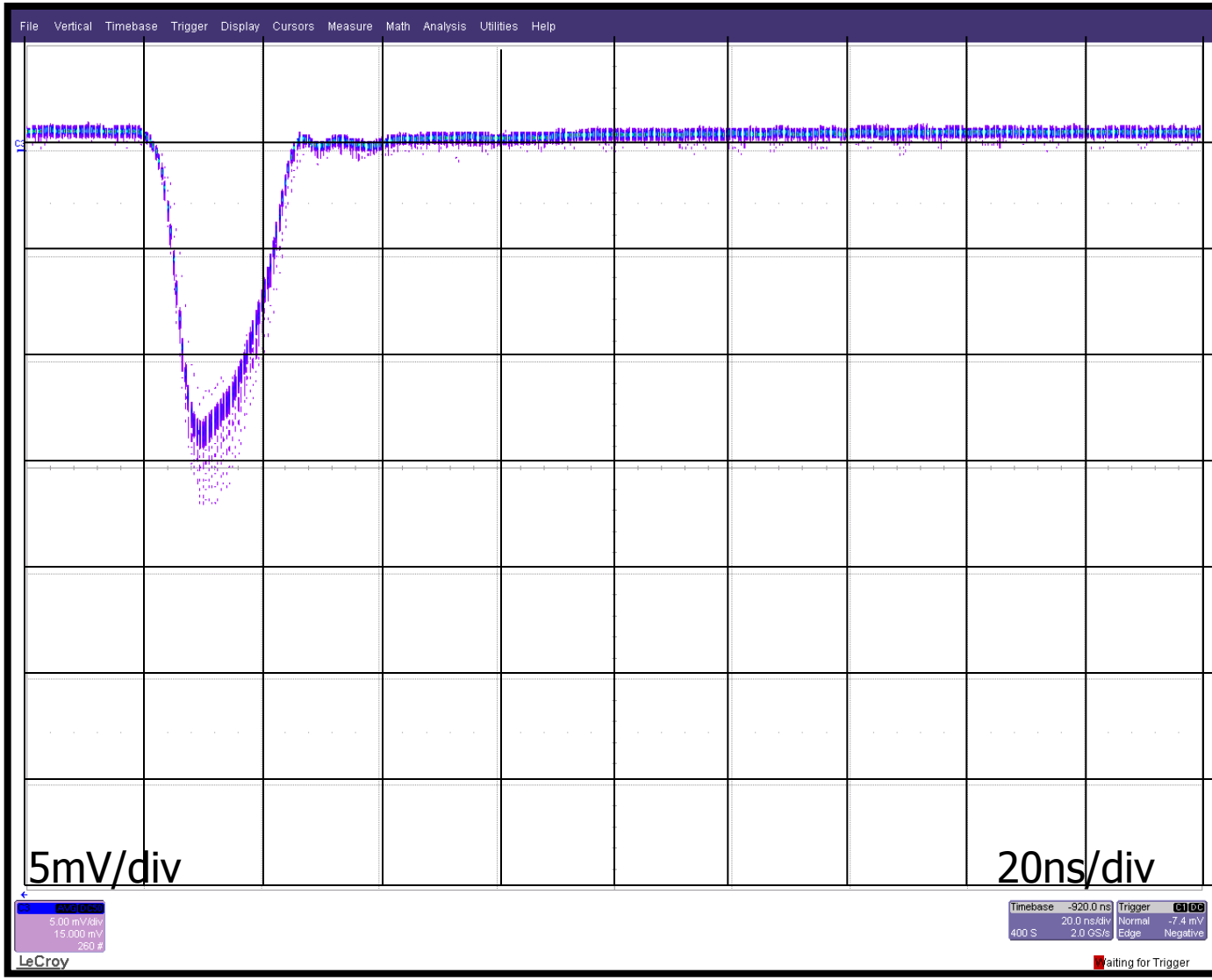
The B2 signal fits within 25 ns

Low spread in number of particles

Averaged signal integration gives 3.6 pC of charge/mip

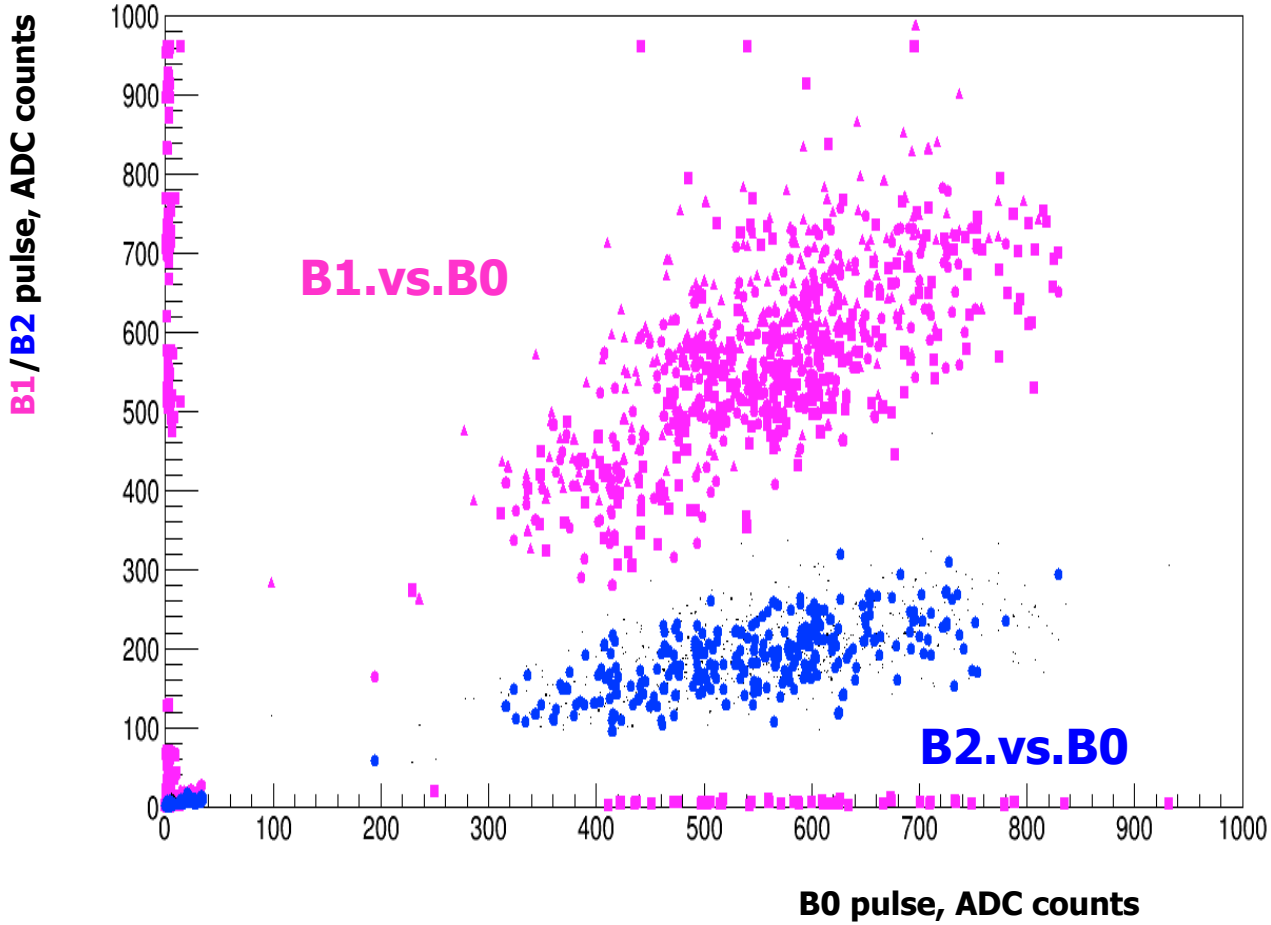
HV was set to 0.1 pC/mip

N=36→40 particles

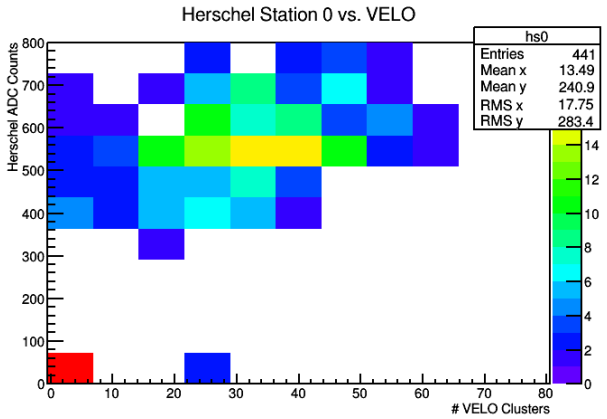


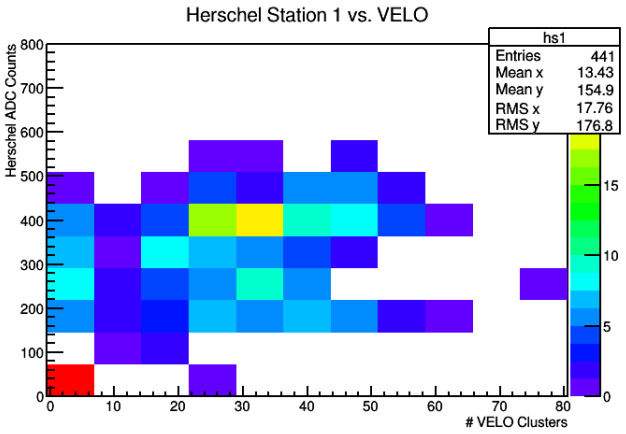
LHC Injection Tests

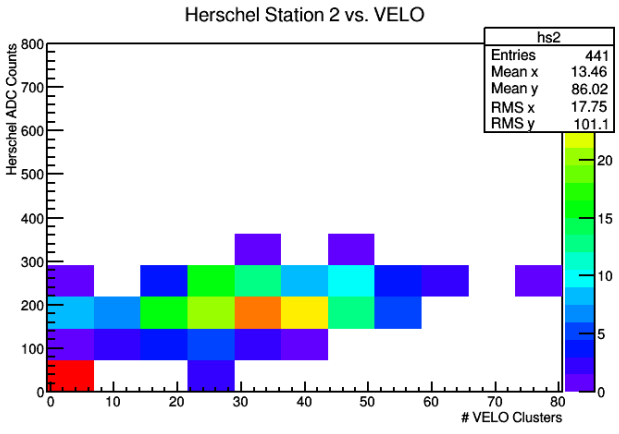
Correlation plots
between stations
B0, B1 and B2



LHC Injection Tests







Clear coincidence of multiplicity between Herschel and VELO

⇒ integration of new detector with LHCb

HERSCHEL: Increasing LHCb rapidity coverage

Summary:

Many (recent!) achievements

- **Herschel detector design finalised**
- **Performance of detector parts demonstrated**
- **Movable support designed, constructed, checked and installed**
- **New PMTs checked and divider performance shown**
- **Components assembled, calibrated and installed in tunnel**

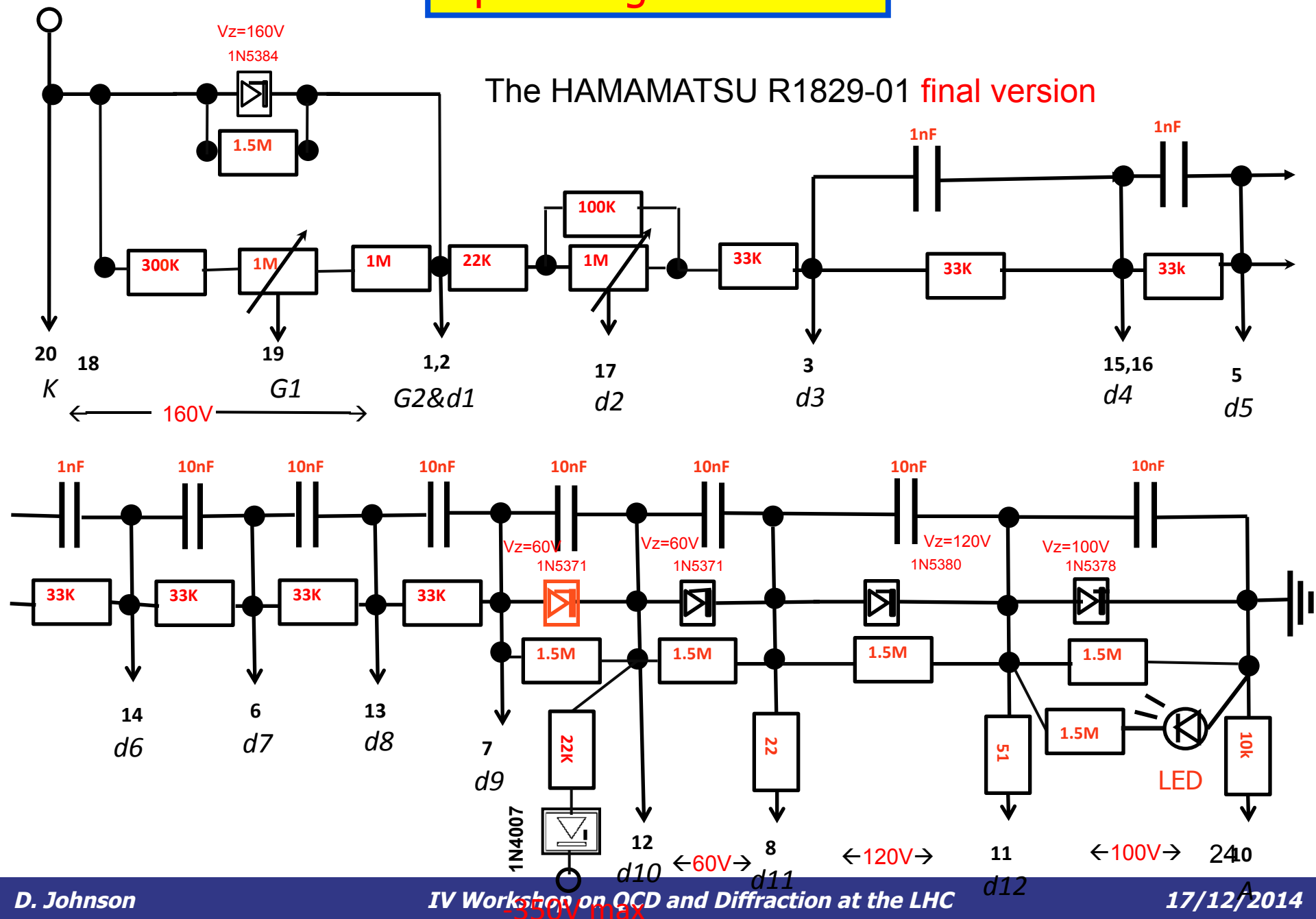
- **First run with TED show low noise level ⇒ well grounded**
- **Baseline solution with FE readout exists and checked**
- **Further progress with FE proceeding** (promising solution exists)

Looking with optimism towards fast-approaching Run 2!

Additional material

HV -1.5kV max

Optimising the Divider



The HAMAMATSU R1829-01 final version