Fast read-out of the COMPASS RICH CsI-MWPC chambers

D. Neyret

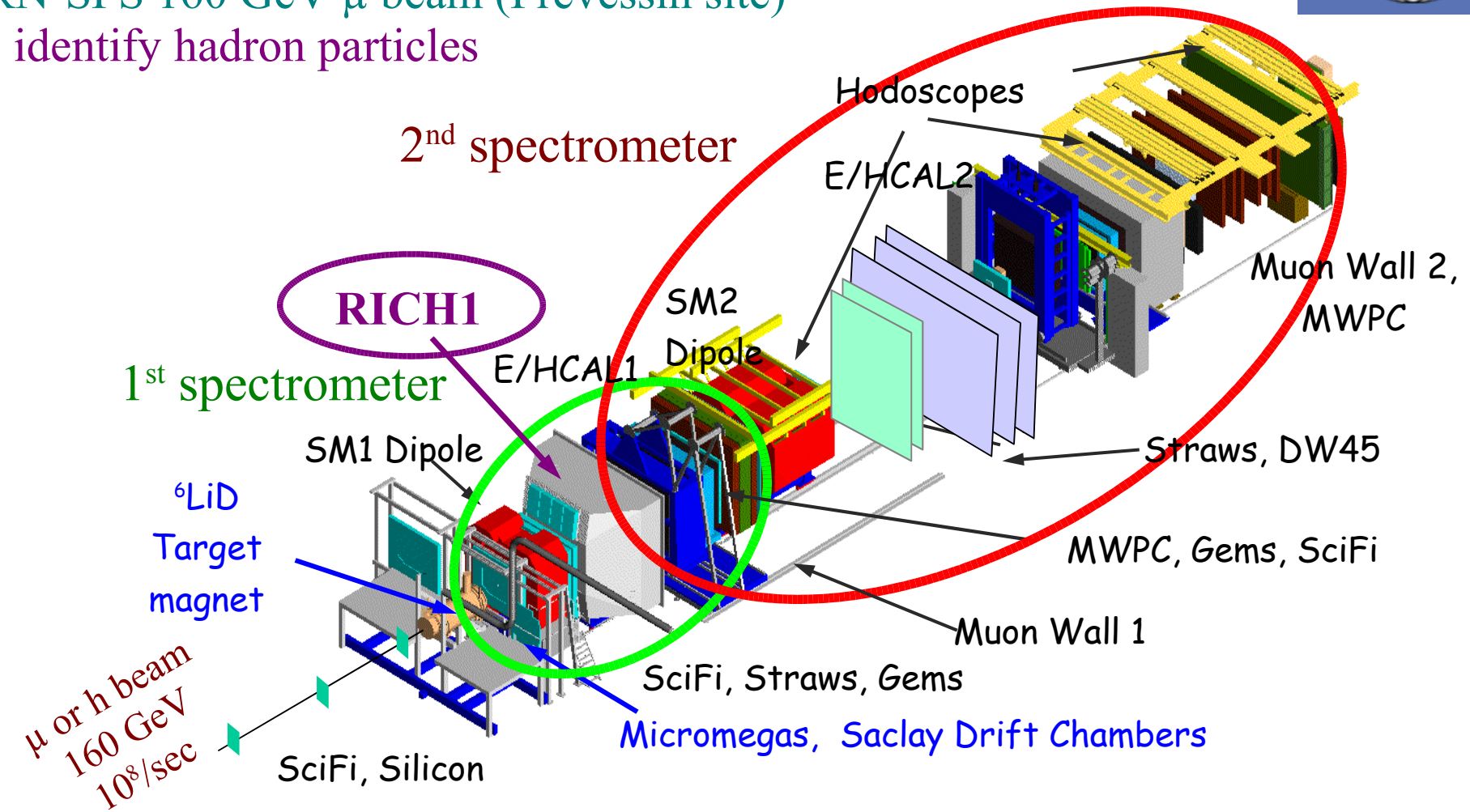
CEA-Saclay

DSM/DAPNIA/SPhN

- The COMPASS experiment and its RICH detector
- A new electronics using APV25-S1 chips
- Tests in real conditions
- Prospects

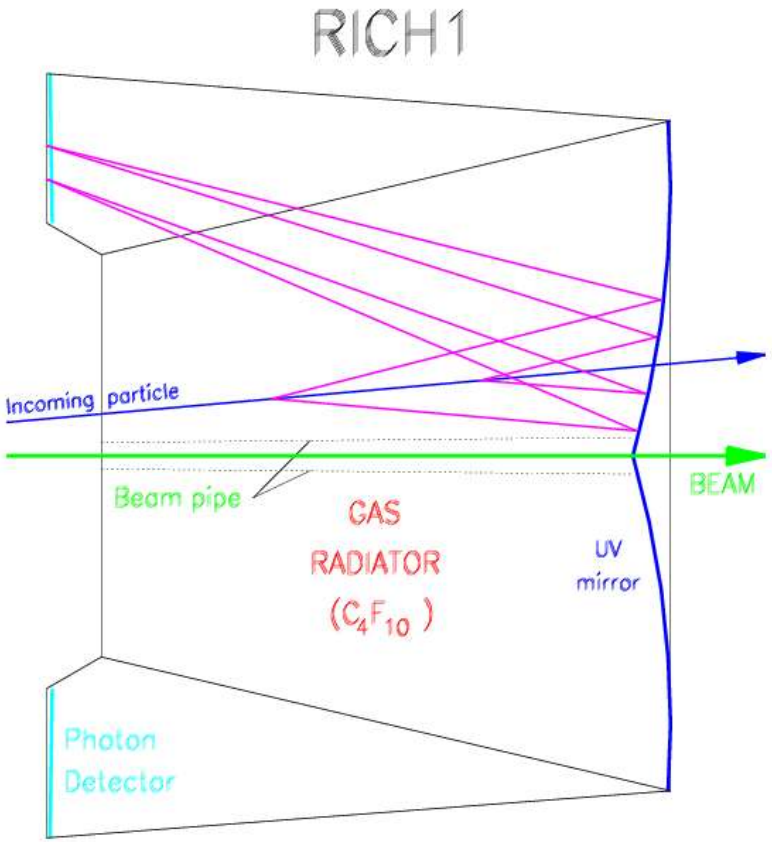
The COMPASS experiment

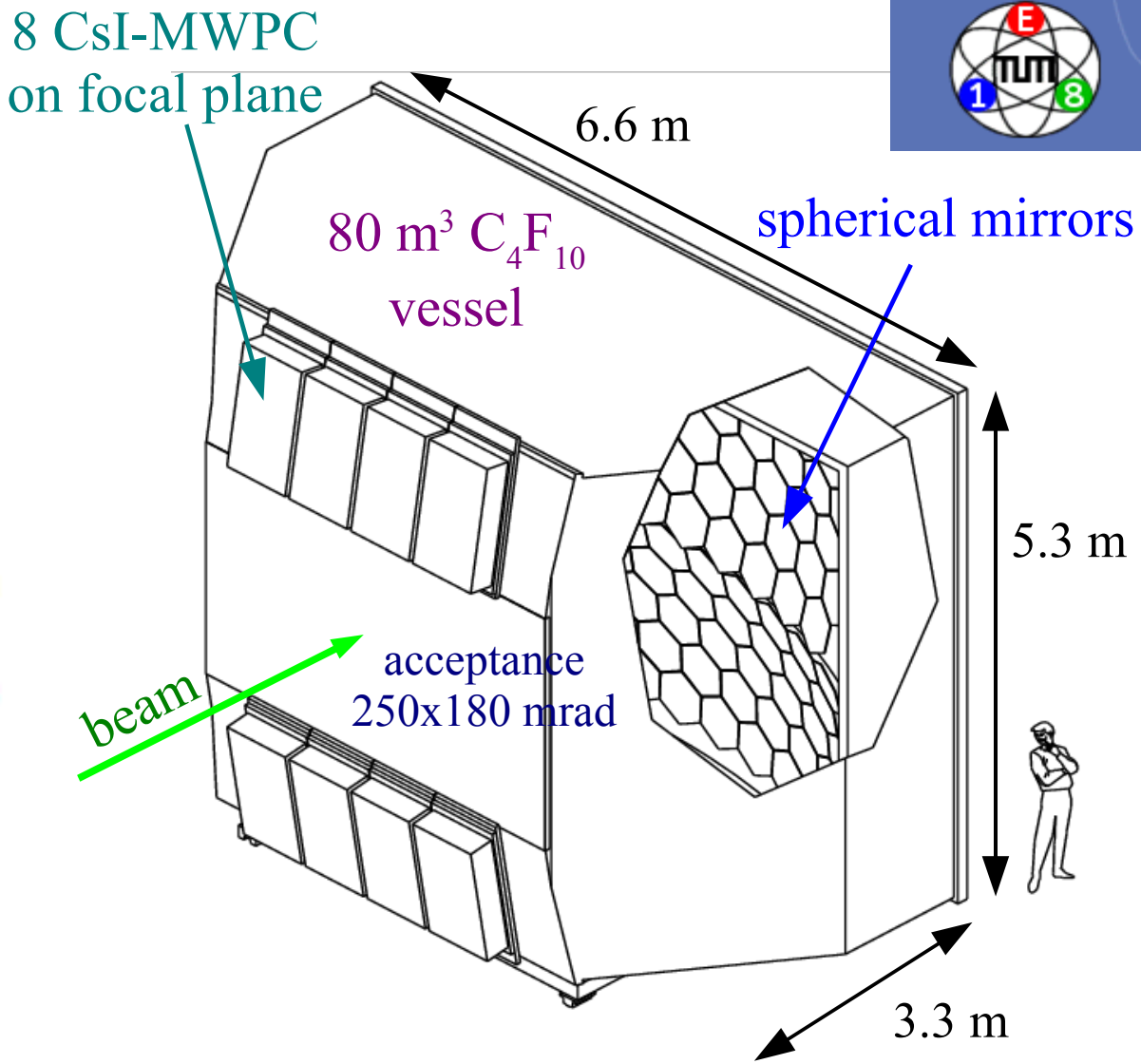
Dedicated to nucleon structure and spectroscopy studies
On CERN-SPS 160 GeV μ beam (Prévessin site)
Need to identify hadron particles



The COMPASS RICH detector

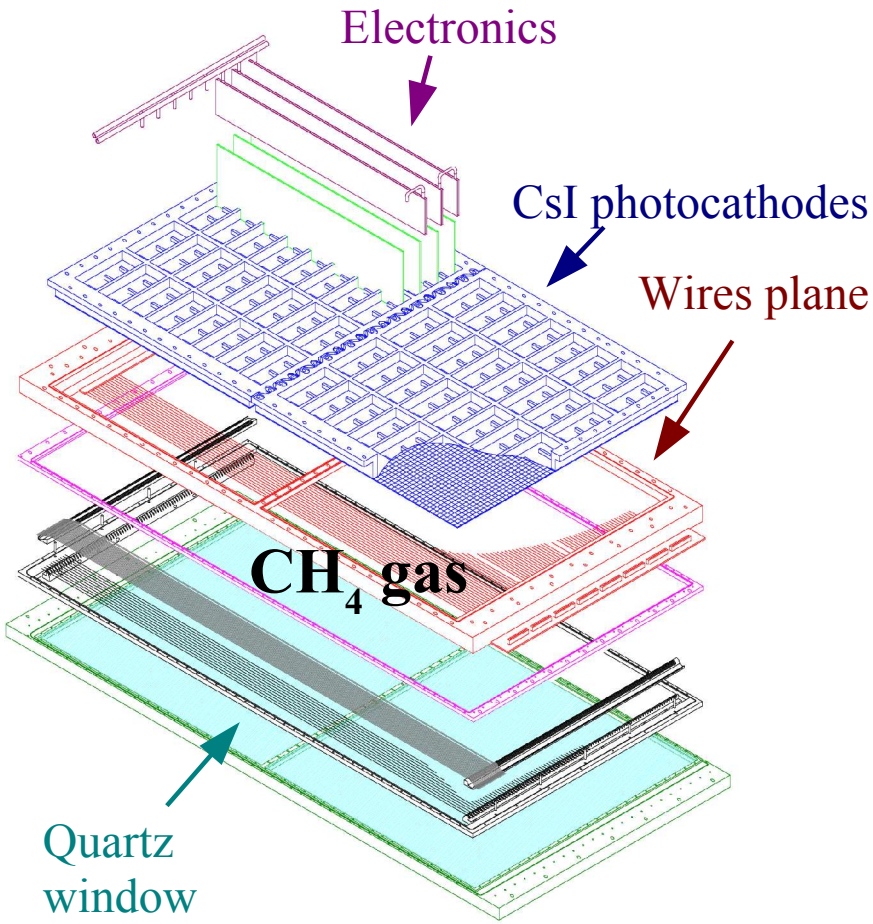
- built by INFN Trieste and ICTP COMPASS groups
- designed to identify particles between 5 to 50 GeV

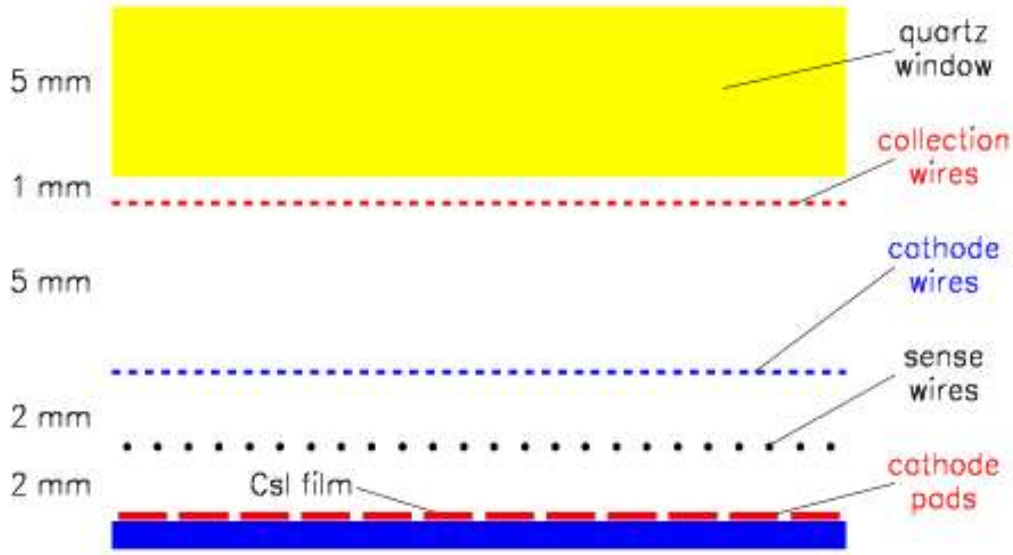




The RICH MWPCs

8 chambers with 2 photocathodes each, methane gas





photocathode: 72x72 pads of 8x8 mm²
γ detection range 160-200 nm
gas gain ~ 3.10^4 at 2000V

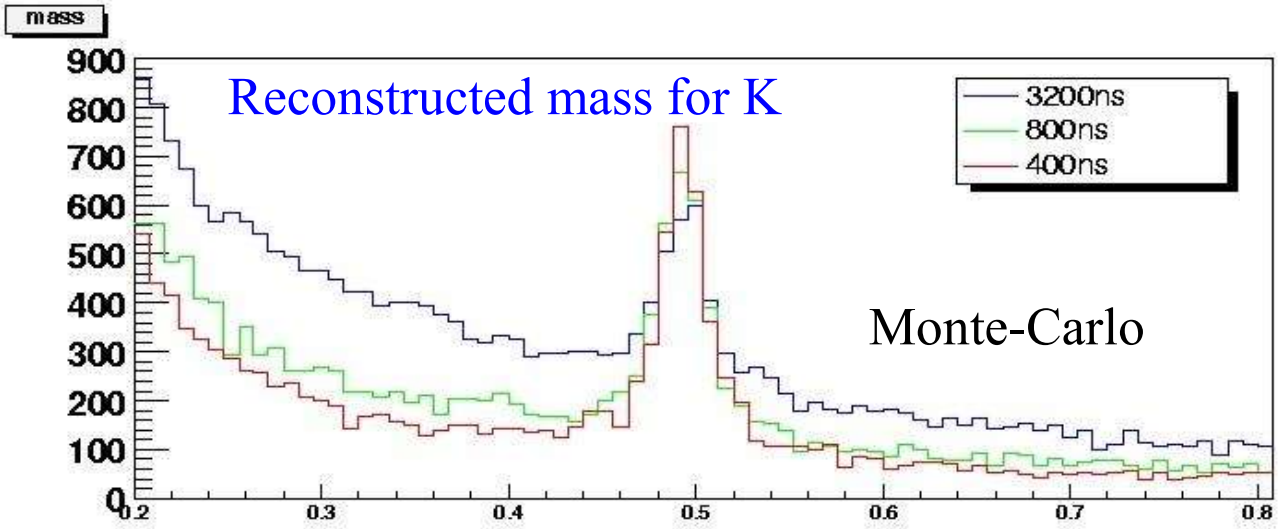
The RICH MWPC read-out

Present electronics based on Gassiplex amplifier

- electronics noise ~1000 e^-
- but large integration time (~3 μs, compared to up to 1 Mhz hit rate in central region)
- long dead time needed by amplifier to restore the base line (~5 μs)

Features to improve

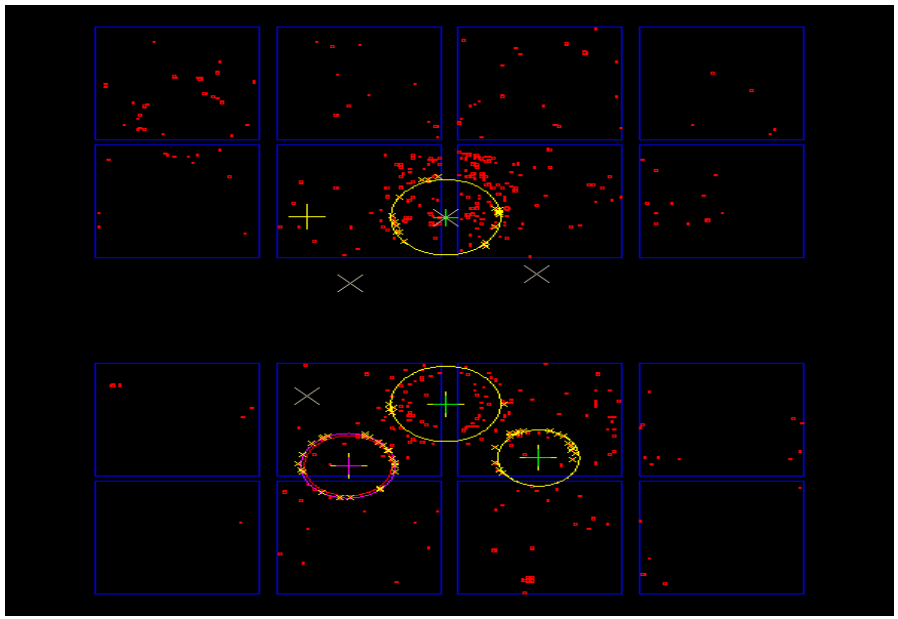
- signal over background improvement by reducing integration gate
- dead time reduction to stand higher trigger rate (up to 100 kHz)



Upgrade of the COMPASS RICH

2 complementary projects:

- replace MWPC by MaPMT in the central region (cf. A. Ferrero's talk)
- replace read-out electronics by a new one using APV25-S1 amplifier in external region



The APV25-S1 chip read-out

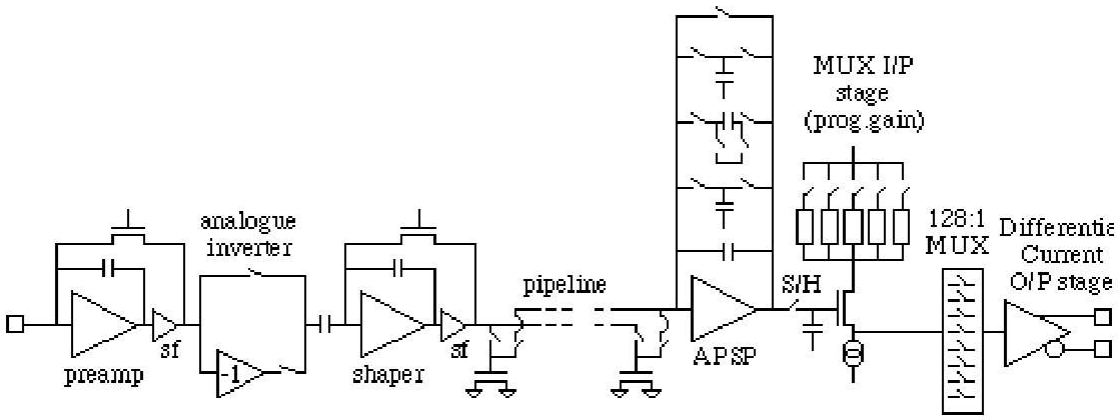
Principle: to use APV25-S1 chips to amplify, sample and multiplex analog signals, which are then read by ADCs

Main characteristics of the APV25-S1:

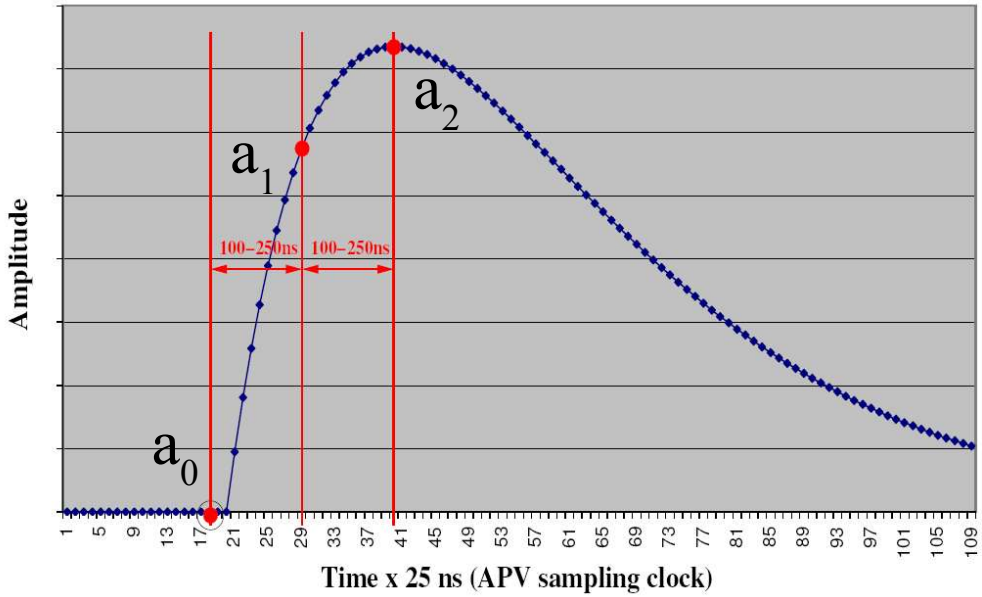
- 128 channels / chip, low cost
- fast analog signal pre-amplifier, shaper and multiplexer, adjustable time constants
- 40 MHz sampling on 192 cells analog pipeline
- designed for CMS silicon microstrip tracker
- already used on other COMPASS detectors (GEM, Silicon tracking detectors)

Joint project between TUM Munich and CEA Saclay COMPASS groups

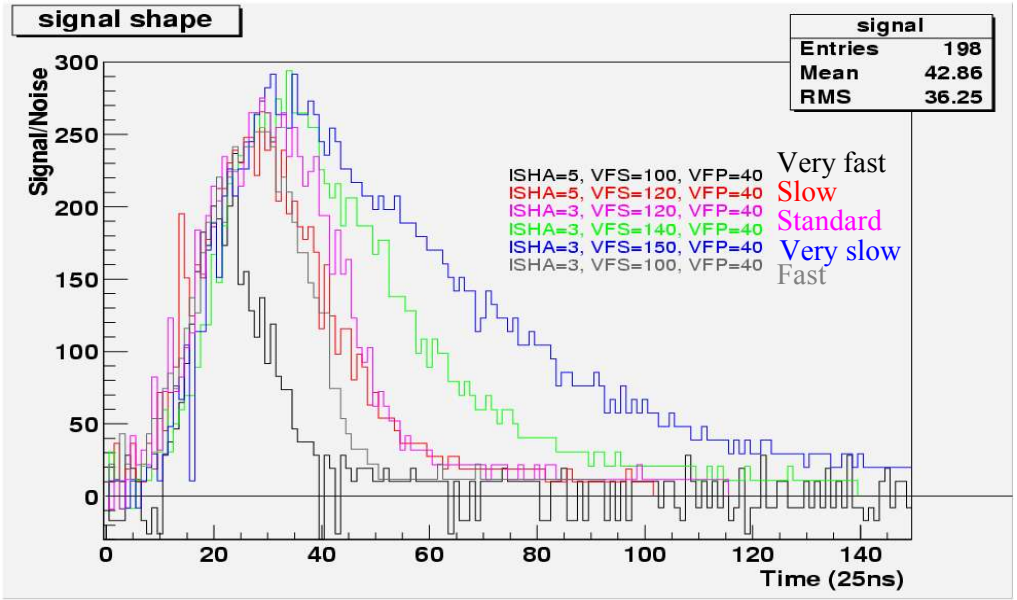
APV25 functional schematic



Characteristics of the read-out



3 samples read for each hit to get informations on signal shape and timing



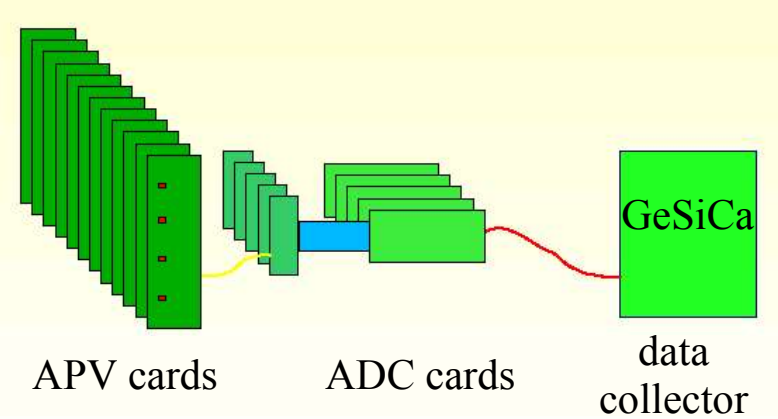
Signal shapes for different sets of APV parameters
peaking time from 50 to 500 ns
gate time 400 to 2 µs

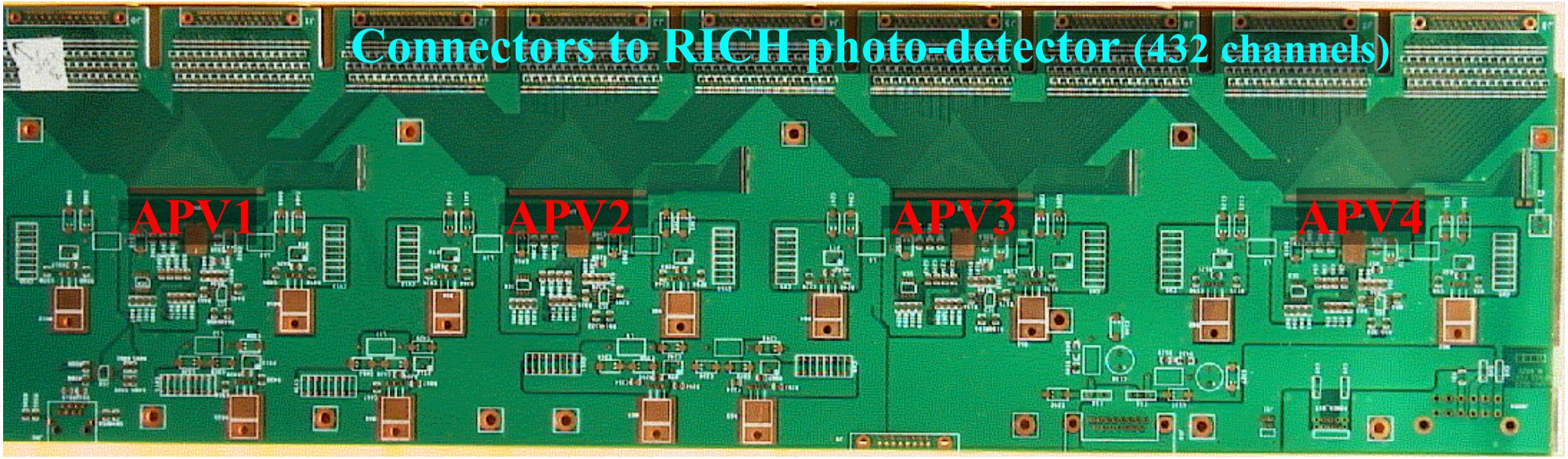
Low dead time up to 80 kHz

Tests in real conditions

12 front-end cards (432 ch. each) built to equip a whole photocathode in RICH central region

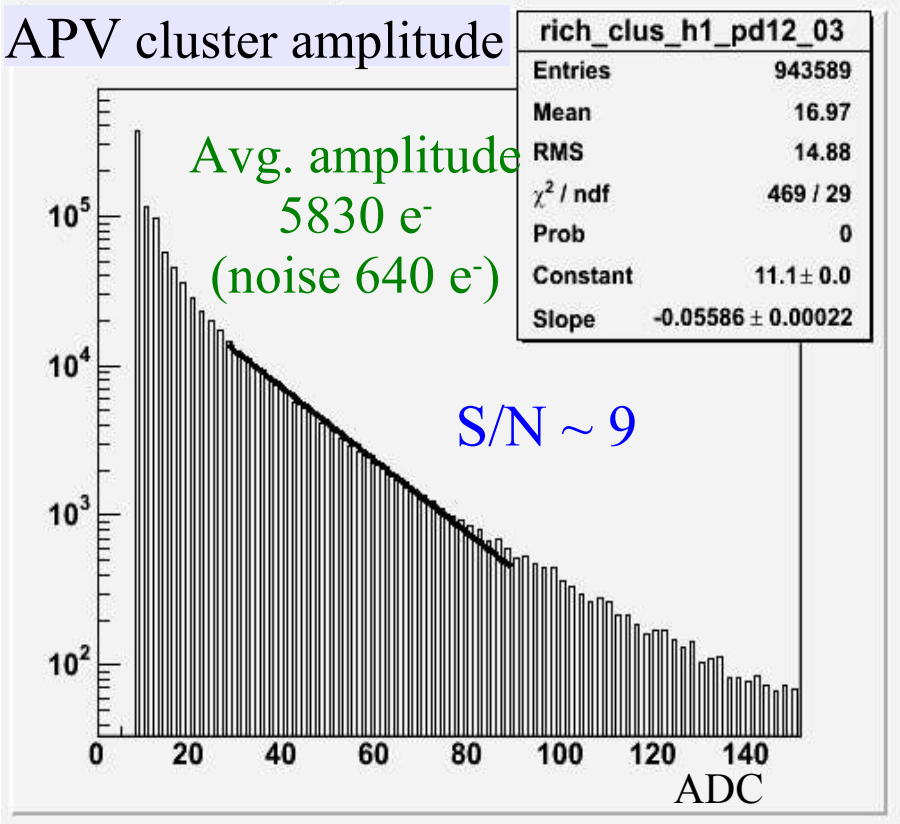
Tested with μ beam in ~ nominal conditions



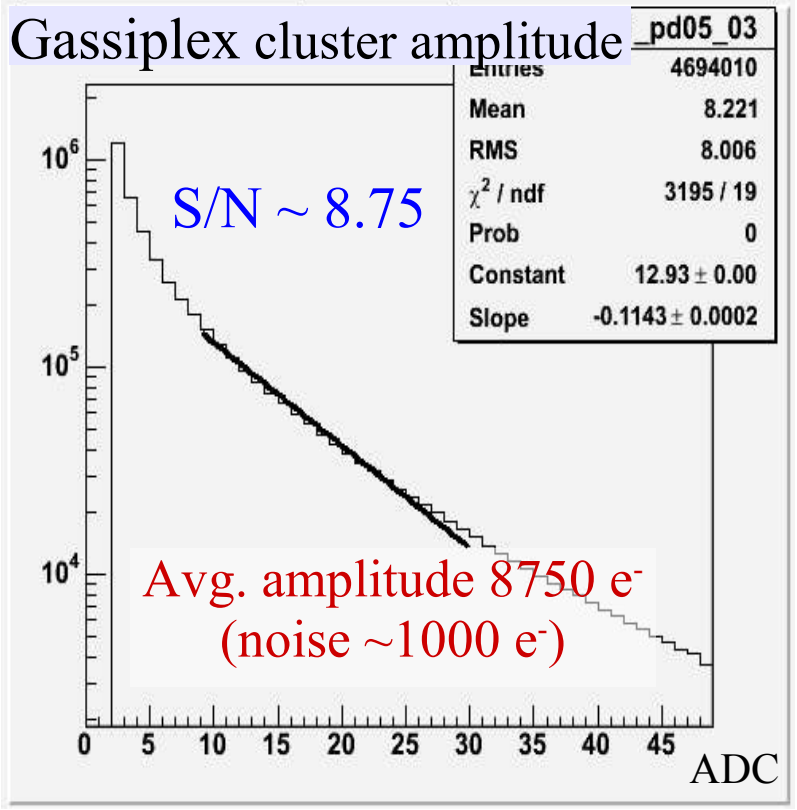


Amplitude spectrum

APV cluster amplitude



Gassiplex cluster amplitude



Higher ballistic deficit due to shorter integration time

As expected by simulation

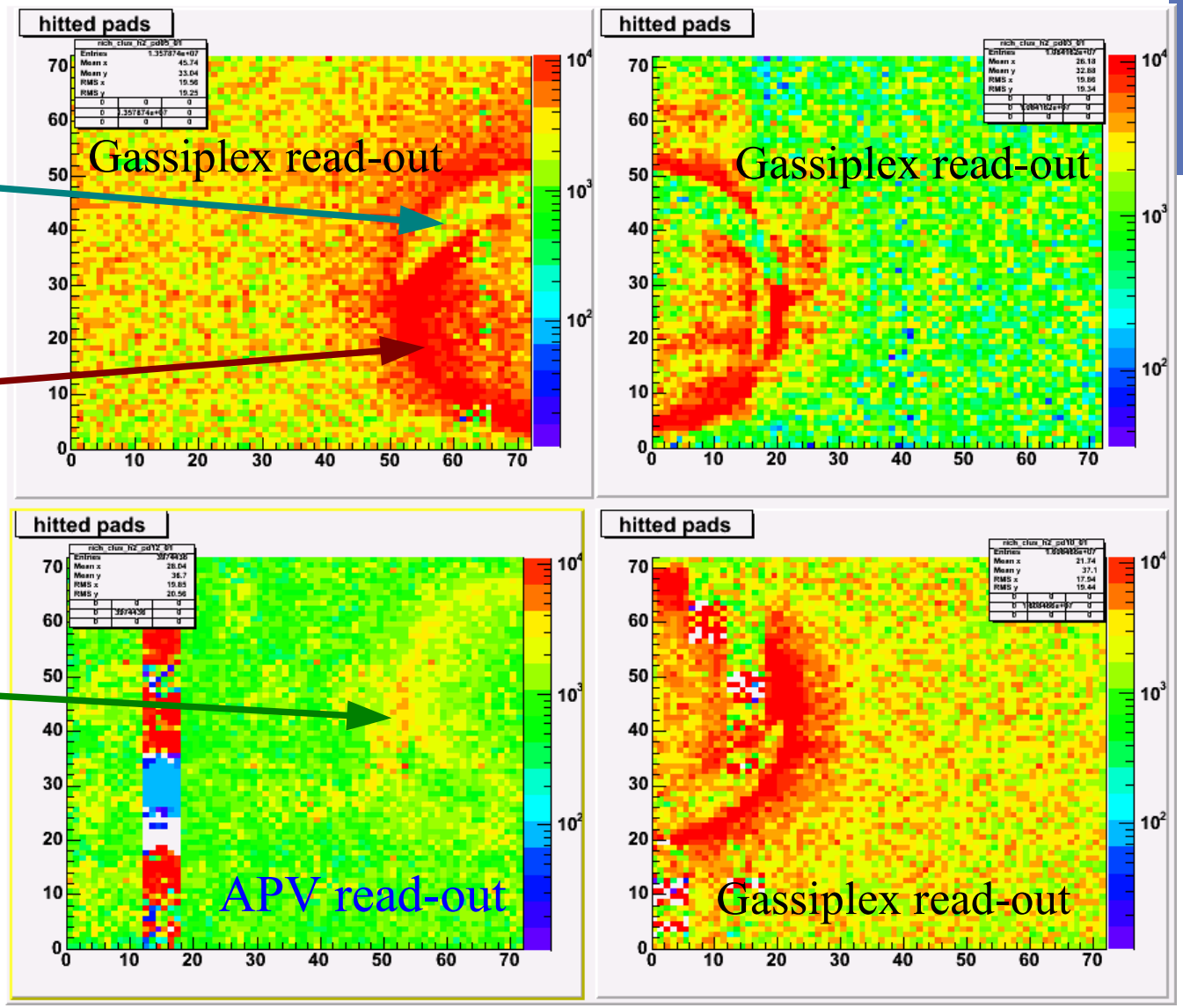
Deficit compensated by lower threshold (better noise figure)

2D profiles of the RICH central chambers

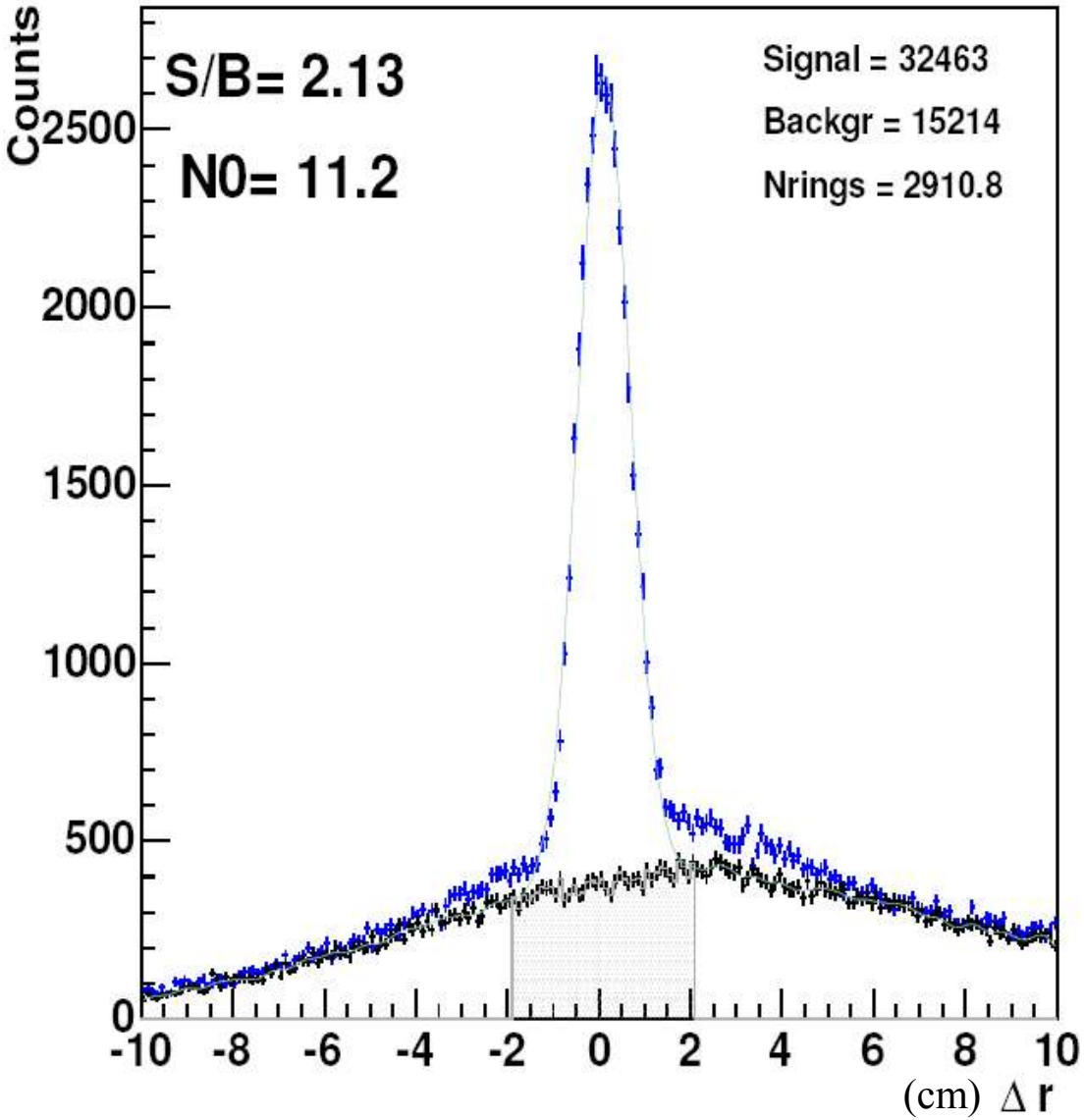
Halo mask
("lunettes")

Beam halo

Reduced occupancy from beam halo



Ring reconstruction with APV



$$\Delta r = r_{hit} - r_{\pi}$$

where r_{π} is the radius expected if the particle is a pion (ring center given by tracking system)

Cuts:

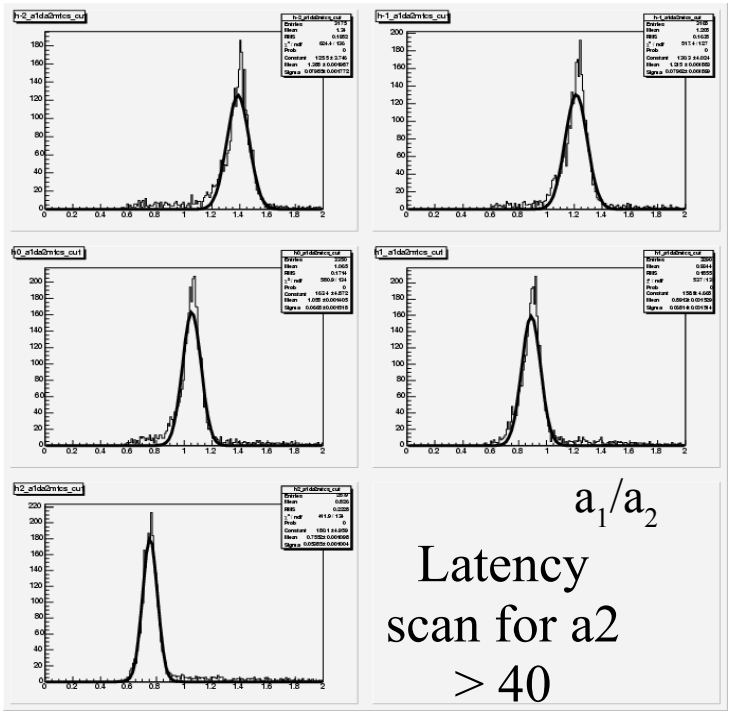
- $a_2 > a_1$
- $a_2 > a_0$
- $a_{cluster} > 2400\ e^-$ (~ 3 σ)

Number of clusters = 11.2
similar to Gassiplex

S/B =2.13 compared to
0.35 with Gassiplex

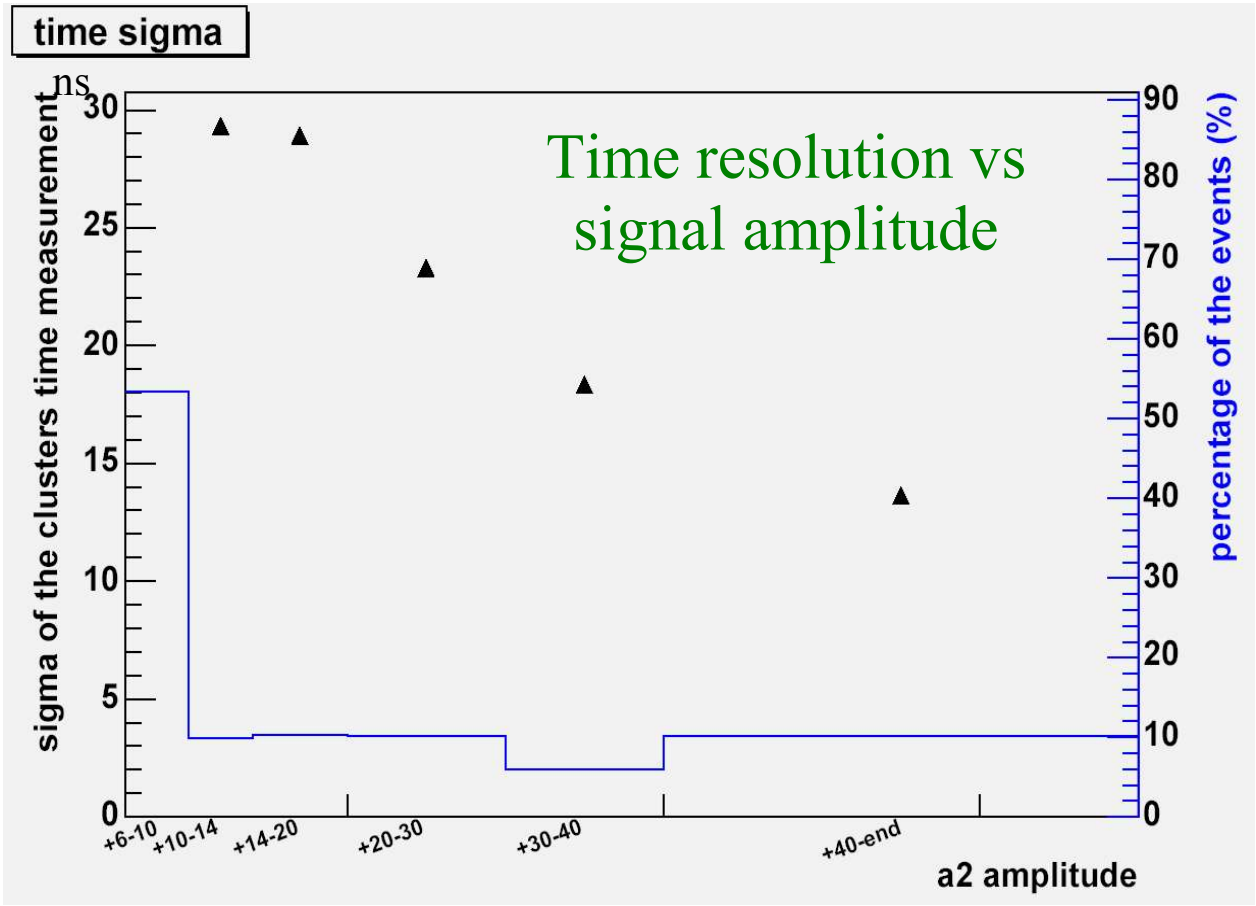
Time measurement resolution

Time measurement with a_1/a_2 ratio

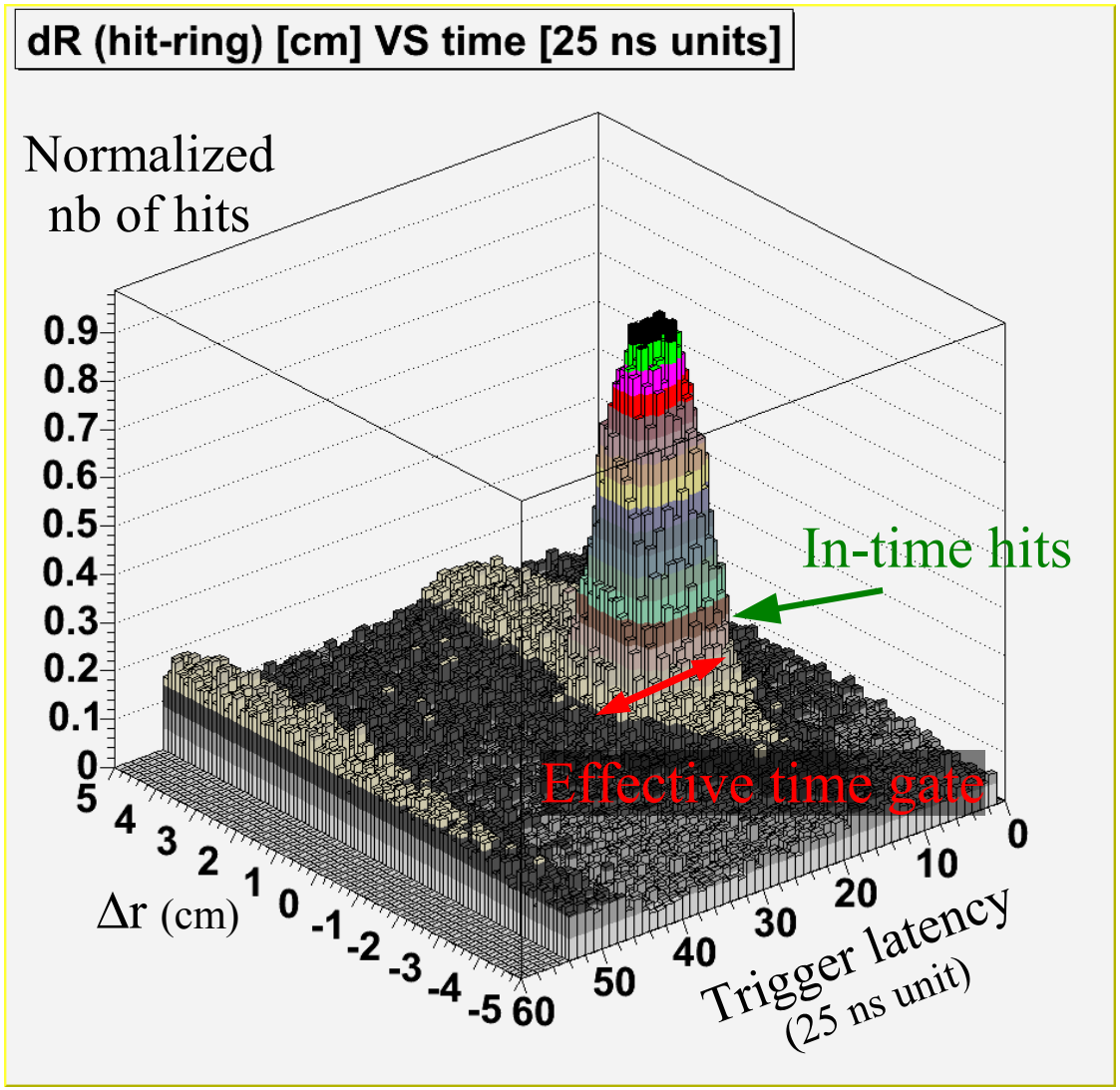


a_1/a_2

Latency scan for a2 > 40



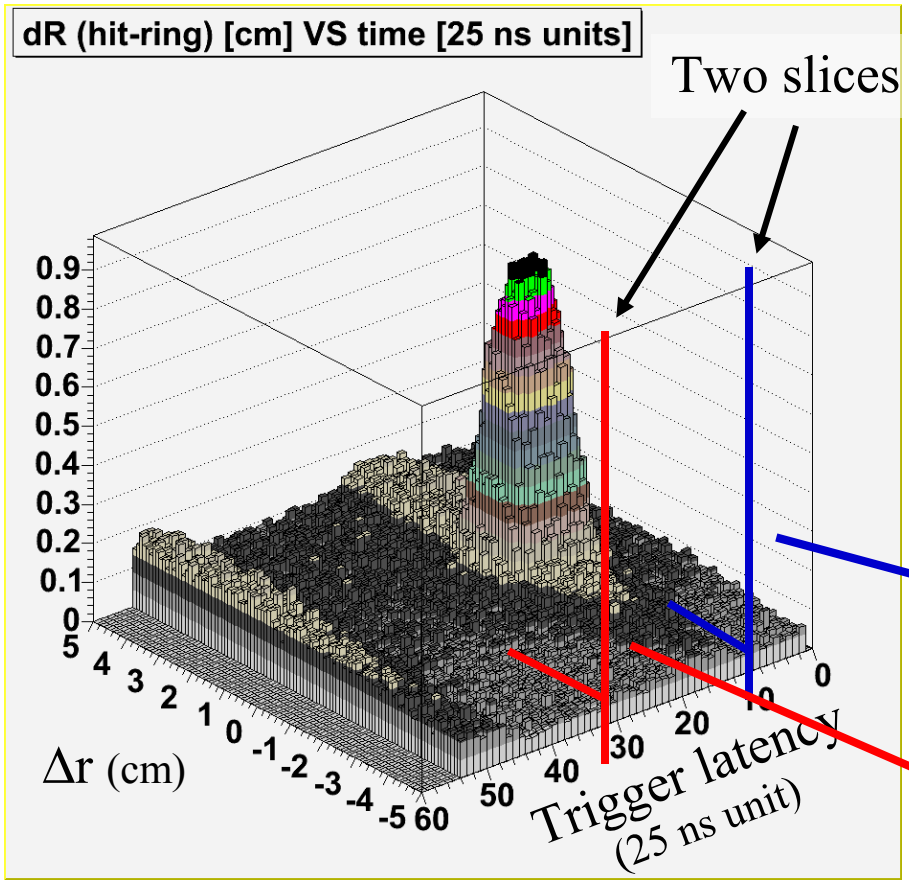
Effective time gate

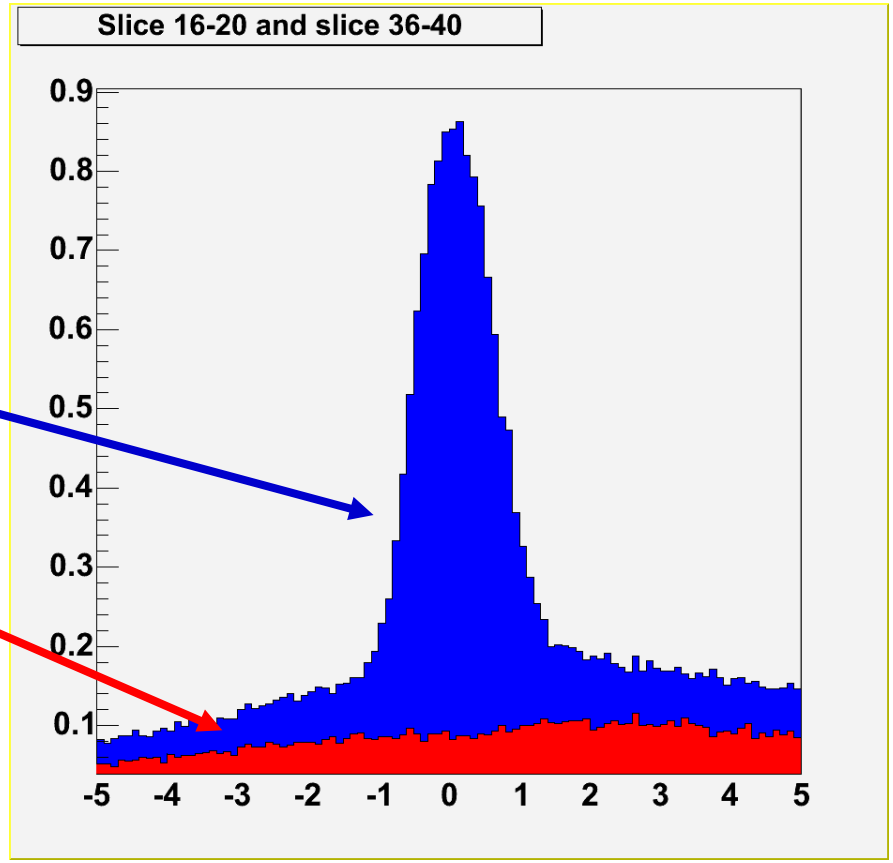


Normalization by the number of rings

Measured effective time gate
- full width: 375 ns
- at half maximum: 250 ns

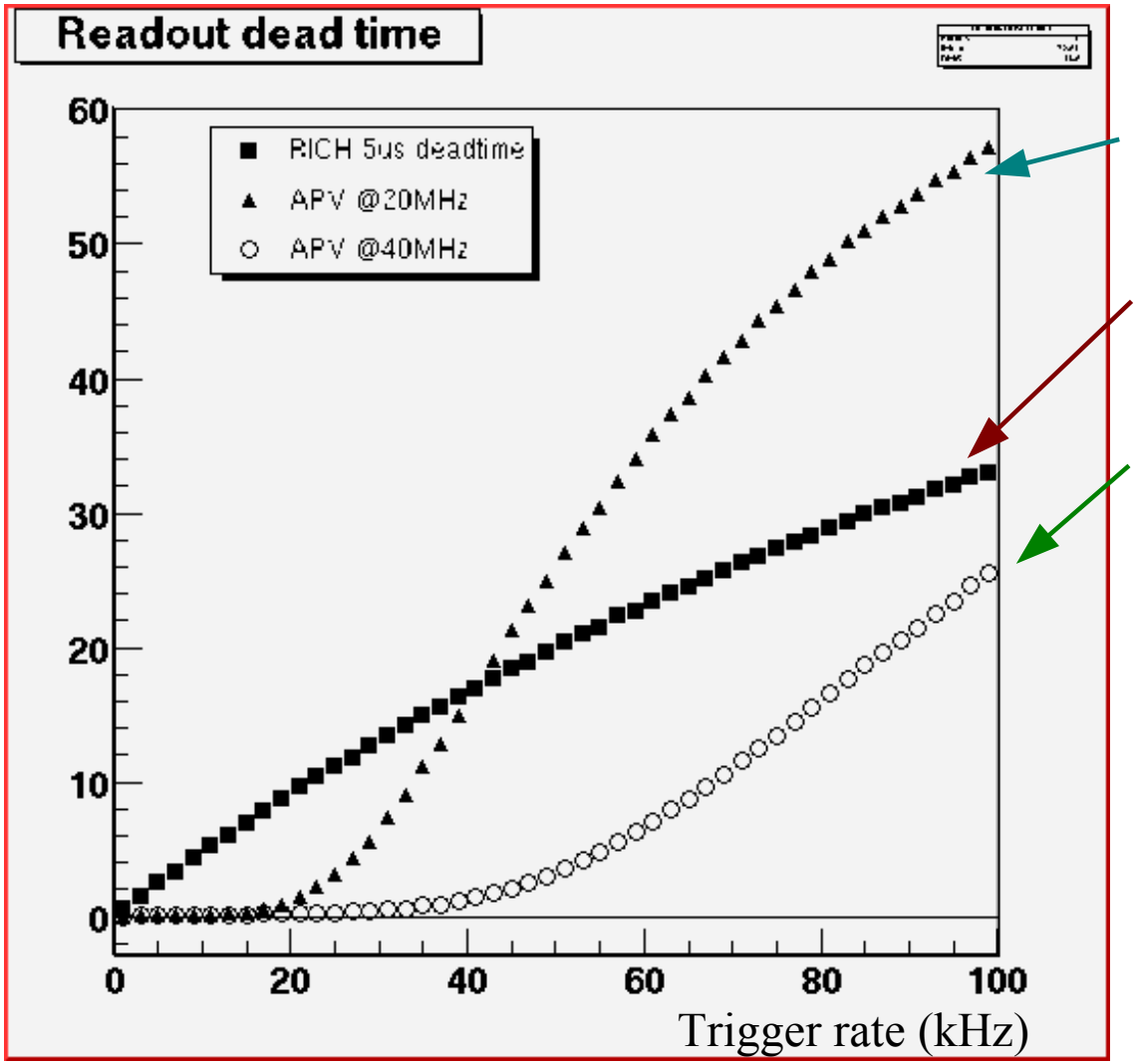
Signal – background comparison





50% background hits are in time

Dead-time improvement



APV 20 Mhz read-out

Old Gassiplex electronics

APV 40 Mhz read-out

Almost no dead time up to
40 kHz trigger rate
Low dead time up to 80 kHz

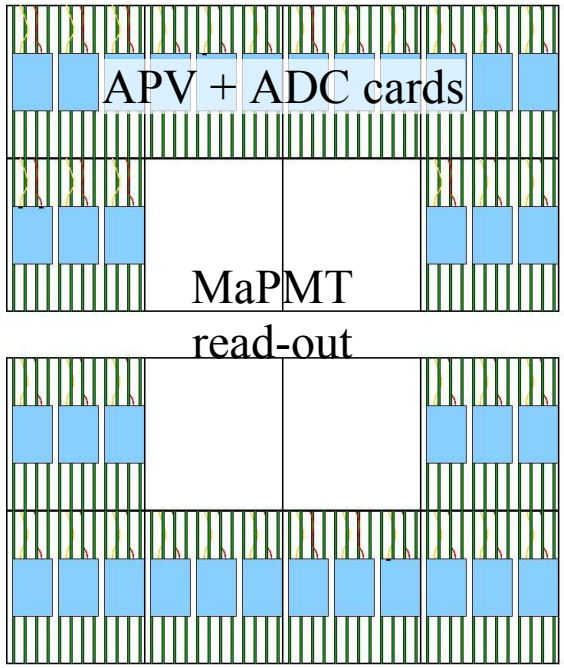
Conclusions

Project to read gaseous CsI-MWPC photo-detector with fast electronics

More efficient than classical slow electronics:

- Same signal / noise ratio
- Small effective time gate (< 375 ns)
- Time resolution < 30 ns for 50% of the clusters
- Low dead time
- Highly integrated and cost effective

This electronics will be installed on COMPASS RICH detector for the 2006 data taking period (~62000 channels)

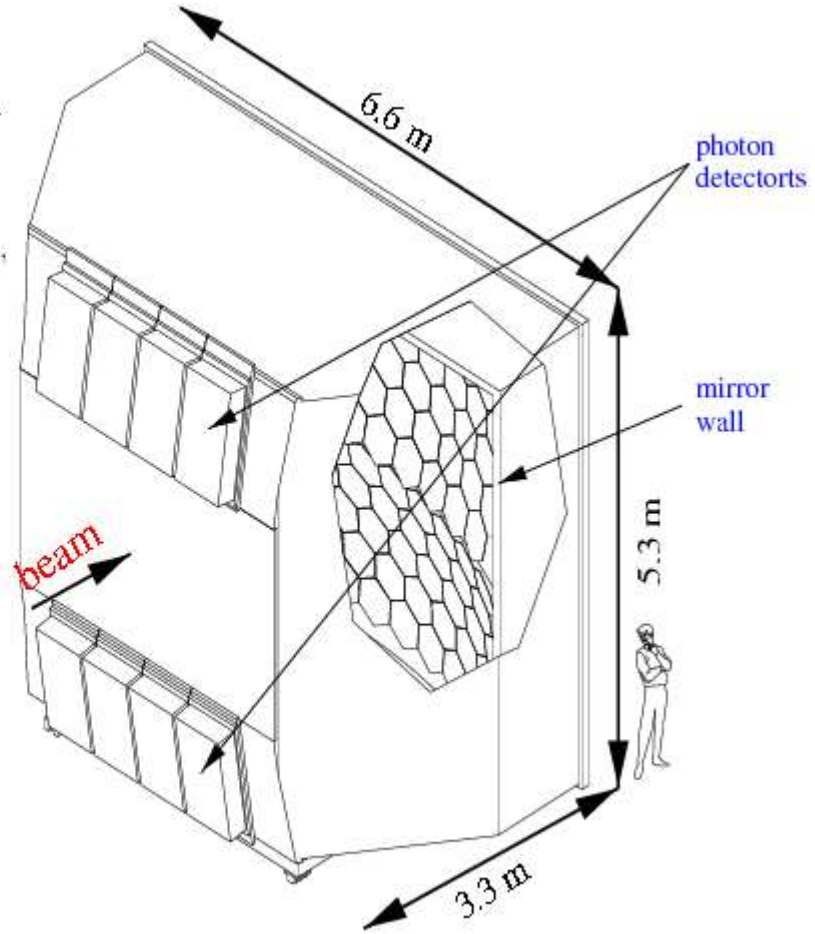


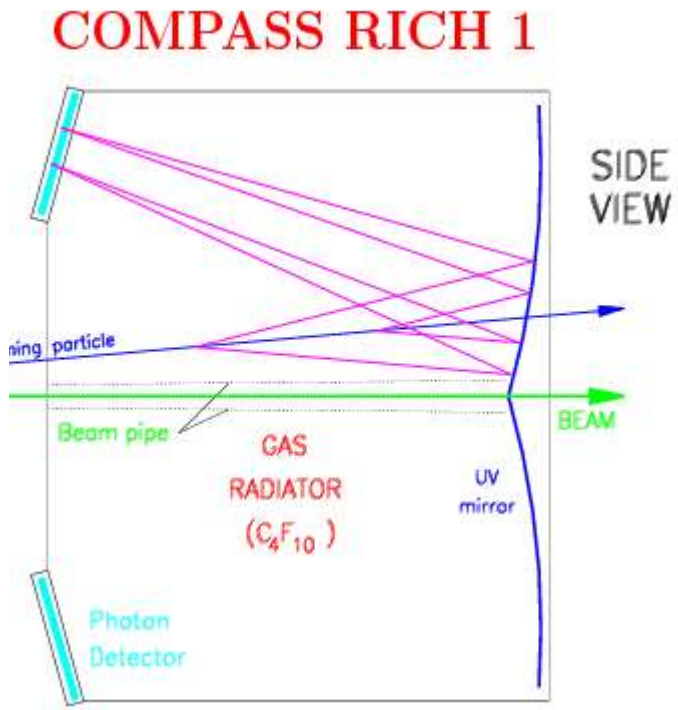
The COMPASS RICH detector

Spares

RICH

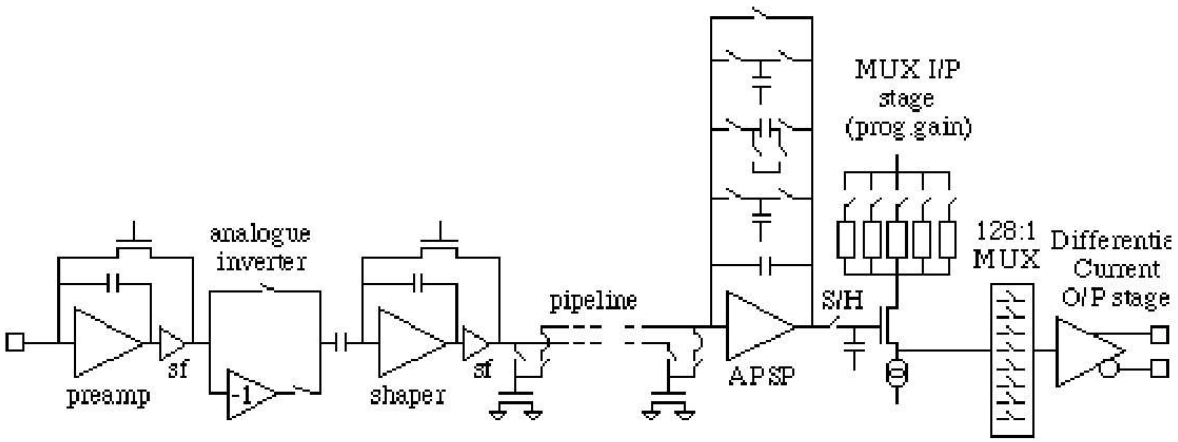
- **radiator :** C_4F_{10} , length: $\sim$ 3 m
- **mirrors :**
  spherical, focal length: 3.3 m,
  reflectance $>$ 80% for $\lambda > 165$ nm,
  total surface: (5.3 * 4) m^2
- **photon detectors: MWPC's with CsI photocathodes,**
  out of spectrometer acceptance,
  total active surface: 5.3 m^2
- **read-out electronics :**
  analog read-out
  (mainly for good efficiency),
  83 K channels in total,
  av. expected occupancy: $\sim$ 5 % ,
  total maximum data flux:
  2.5 GB / sec in spill





APV chip

APV25 functional schematic



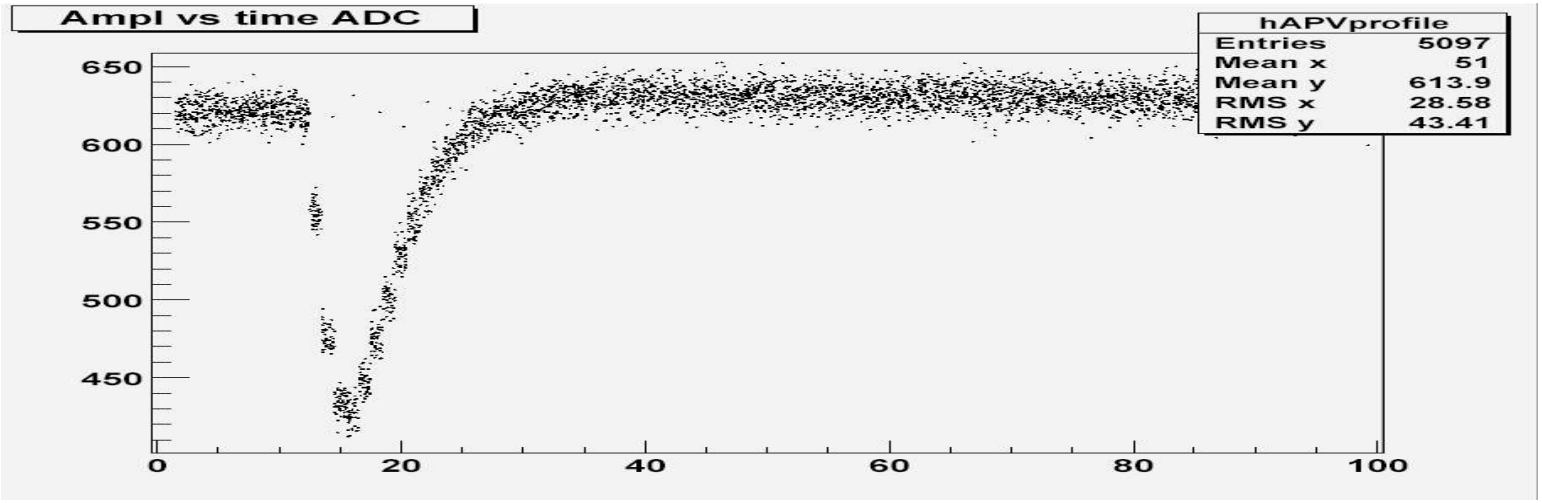
APV configurable parameters :

- VFP – preamplifier feedback voltage bias defines falling edge of the signal after preamplifier
- ISHA – shaper input FET current bias defines the rise time of the shaper
- VFS – shaper feedback voltage bias defines the falling edge of the signal
- MODE: single sample or triple samples(Silicon&GEM)

Standard APV settings: VFP = 30, ISHA = 30 , VFS = 60

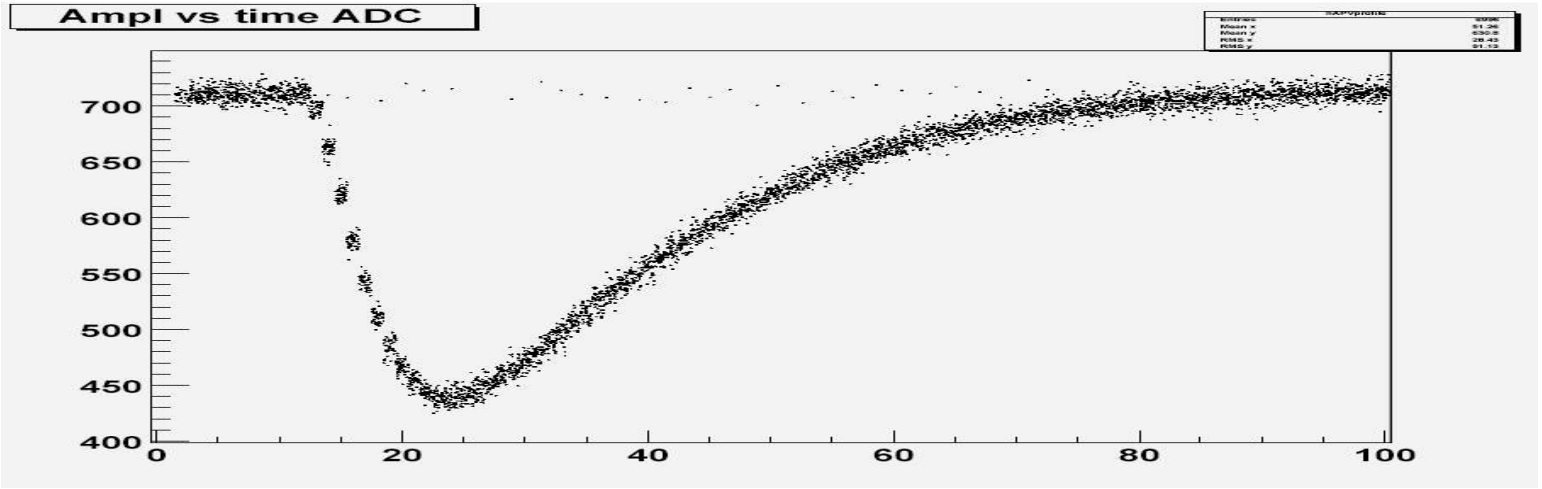
RICH APV settings : VFP = 40, ISHA = 5, VFS = 170

APV Signal shape with Delta input signal



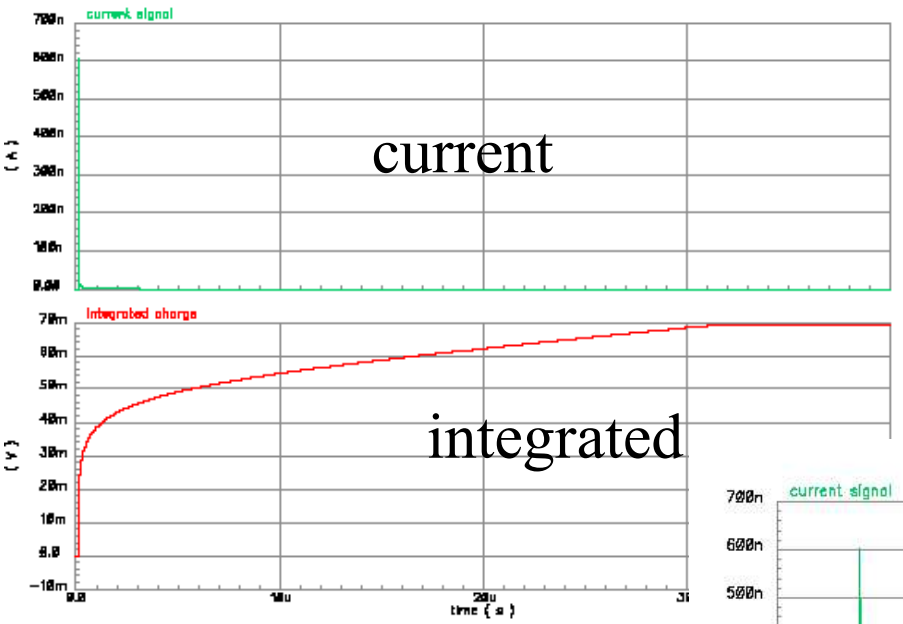
Standard settings

x 25ns



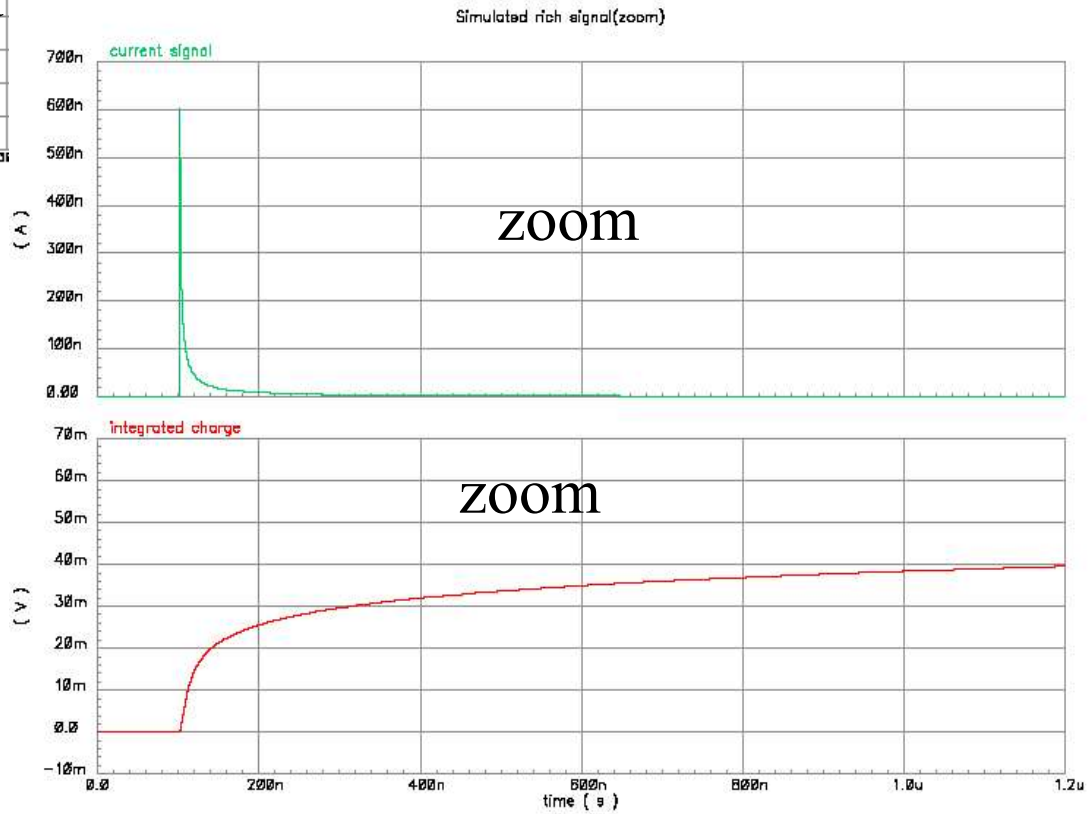
RICH settings

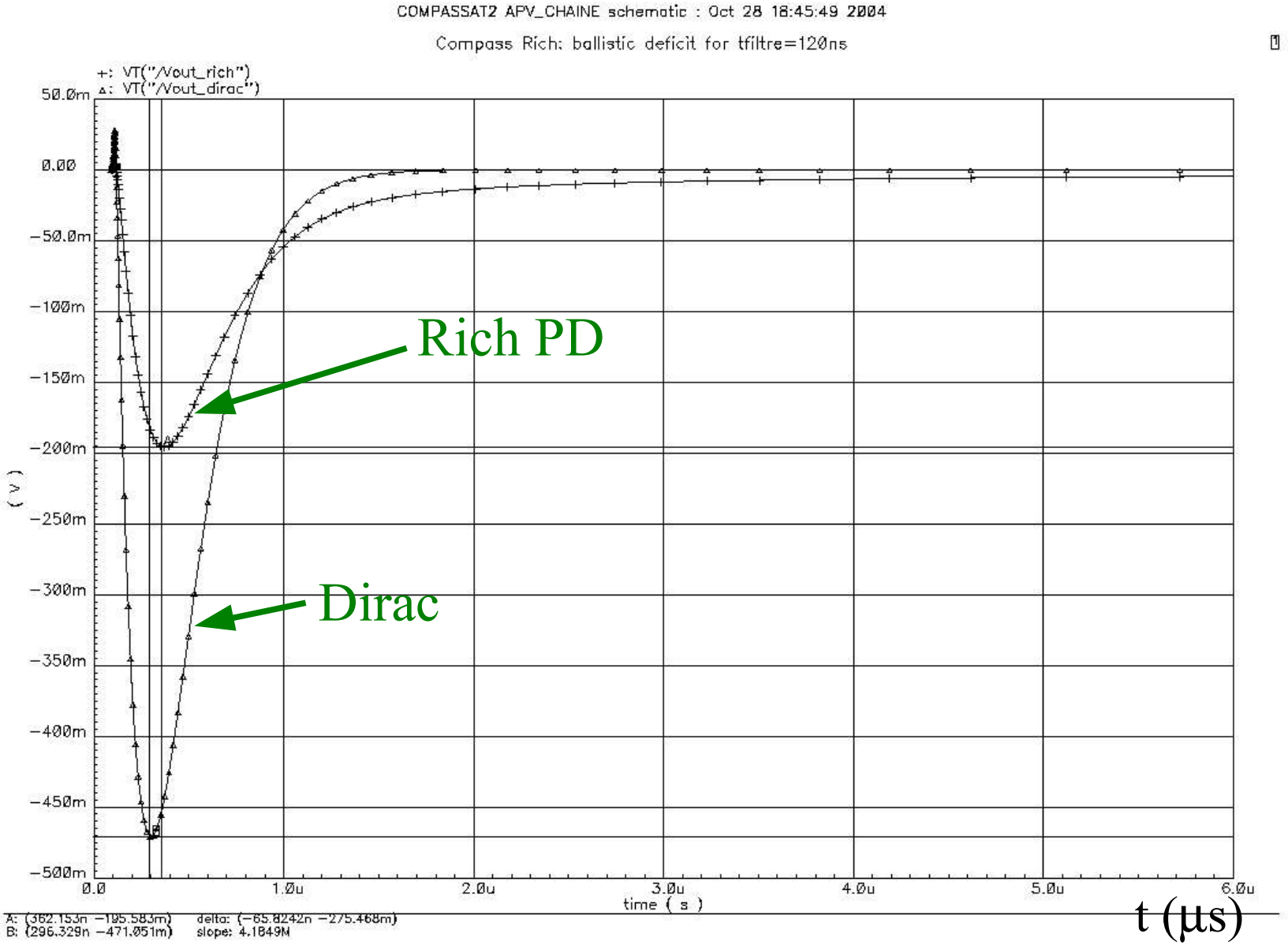
x 25ns



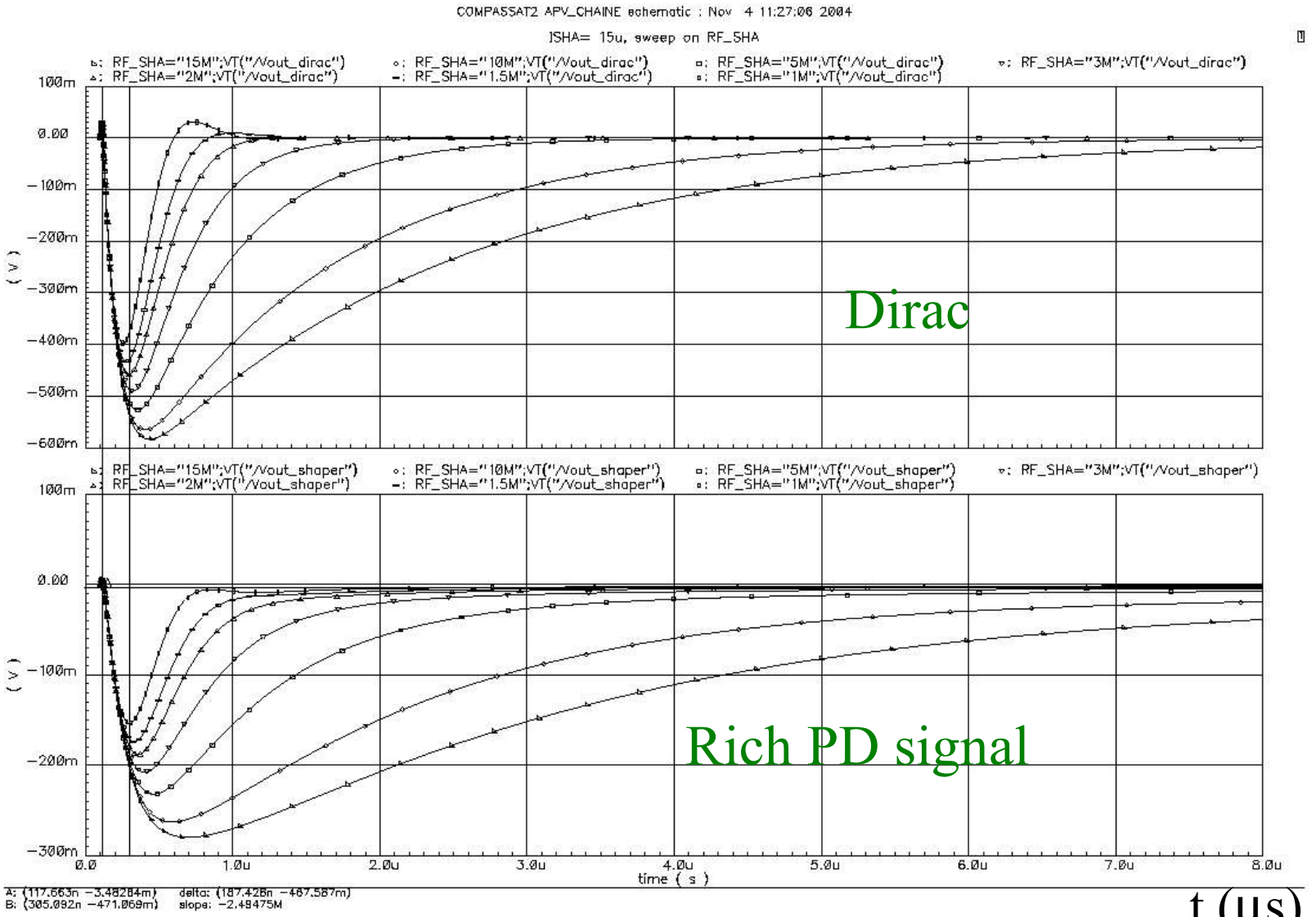
Results on simulations (by E. Delagnes)

Rich PD signal used in simulation
(P. Pagano dipl. thesis)



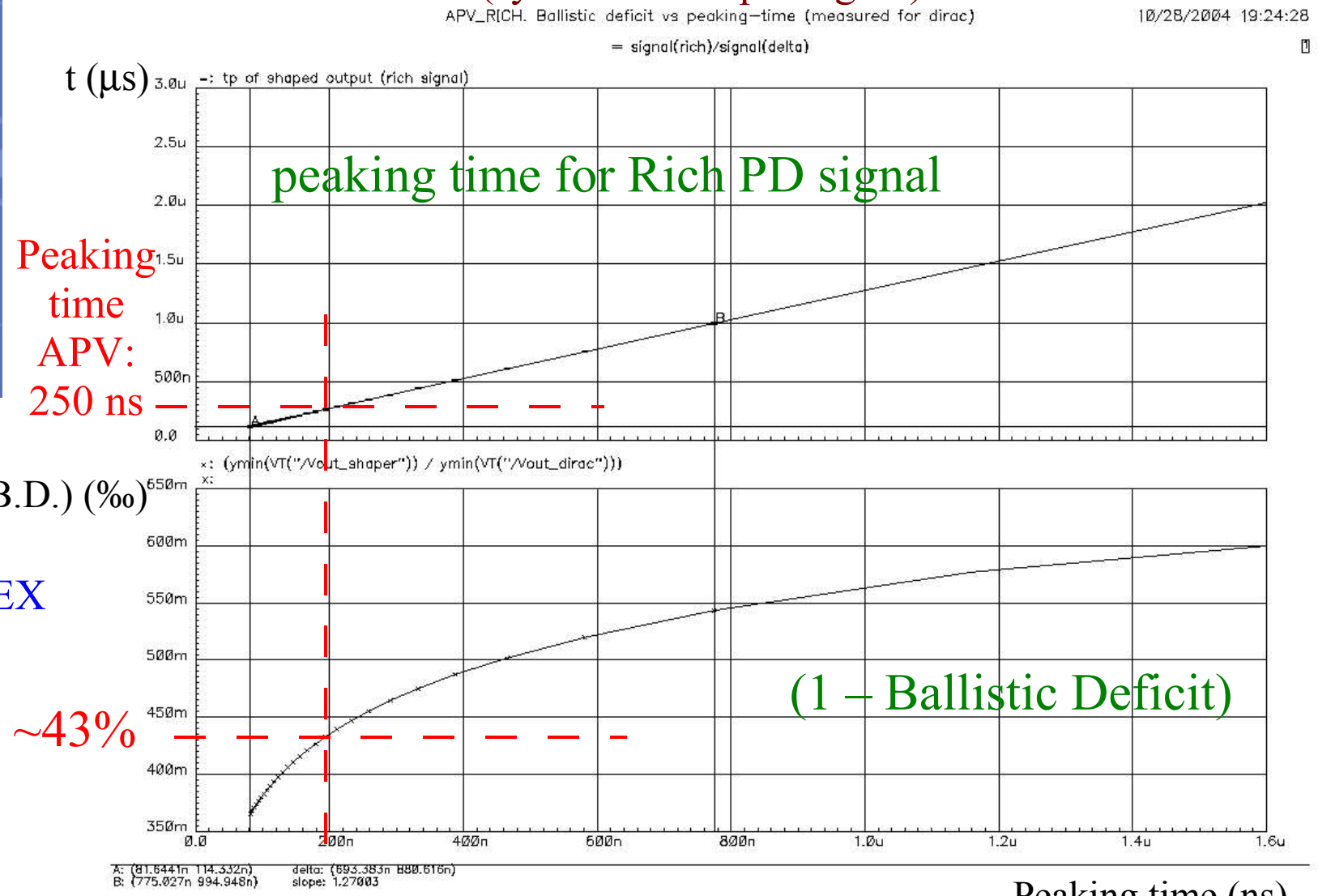

COMPASSAT2 APV_CHAINE schematic : Oct 28 18:45:49 2004
Compass Rich: ballistic deficit for tfiltre=120ns
+: VT("/Vout_rich")
Δ: VT("/Vout_dirac")
50.0m
0.00
-50.0m
-100m
-150m
-200m
-250m
-300m
-350m
-400m
-450m
-500m
(V)
Rich PD
Dirac
0.0
1.0u
2.0u
3.0u
4.0u
5.0u
6.0u
time (s)
t (μs)
A: (362.153n -195.583m)
B: (296.329n -471.051m)
delta: (-65.8242n -275.468m)
slope: 4.1849M

APV output for several set-up



Ballistic deficit vs peaking time

(symetrical output signal)

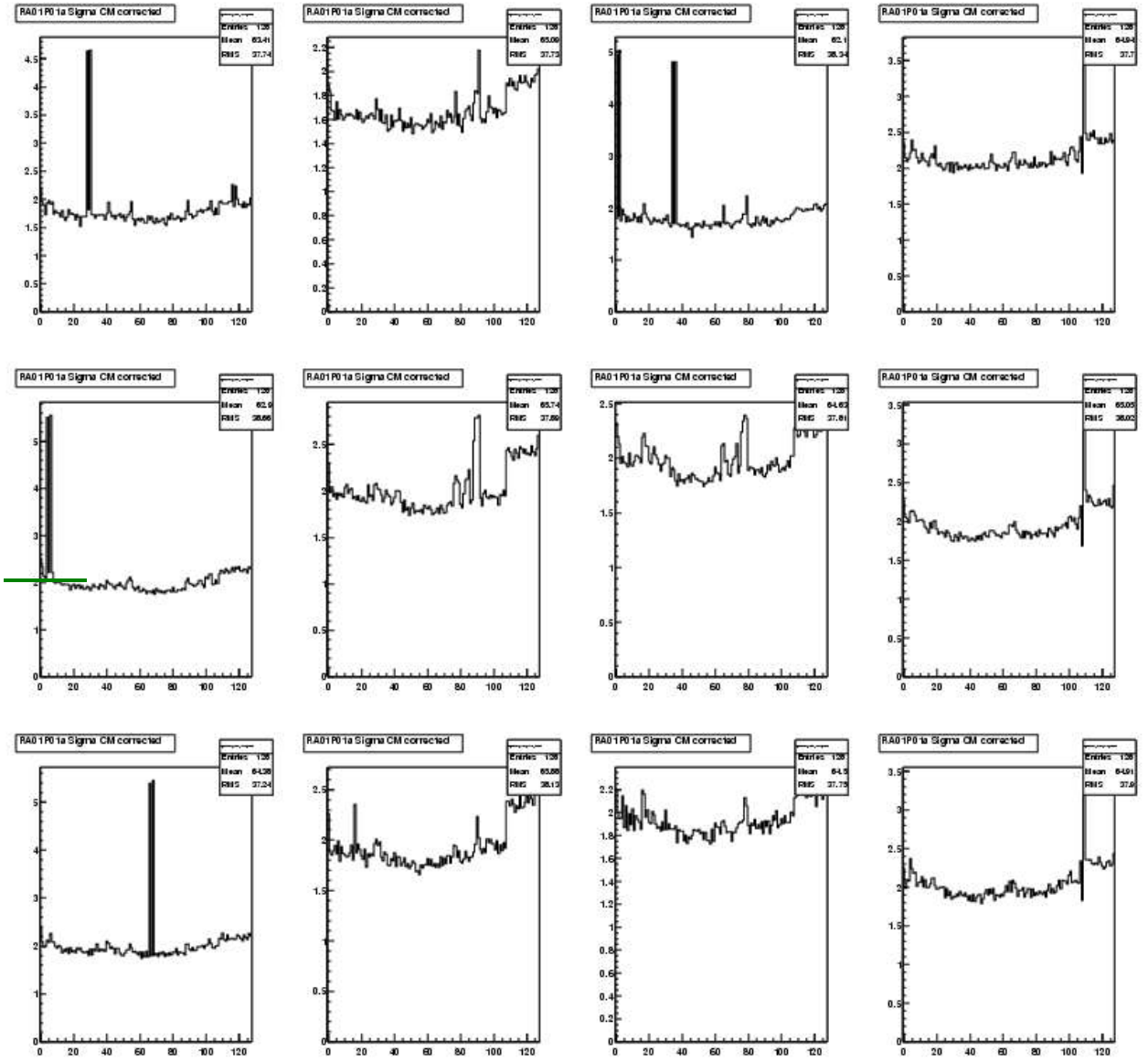


Test on Rich with beam

- Muon beam at low and high intensity with CH_2 target
- 1 central photocathode fully equipped with 12 front-end cards and 4 ADC cards
- For each APV setting: pedestals + timing scan + data in time
- Gassiplex electronics enabled during the tests
- Analysis with reconstructed events

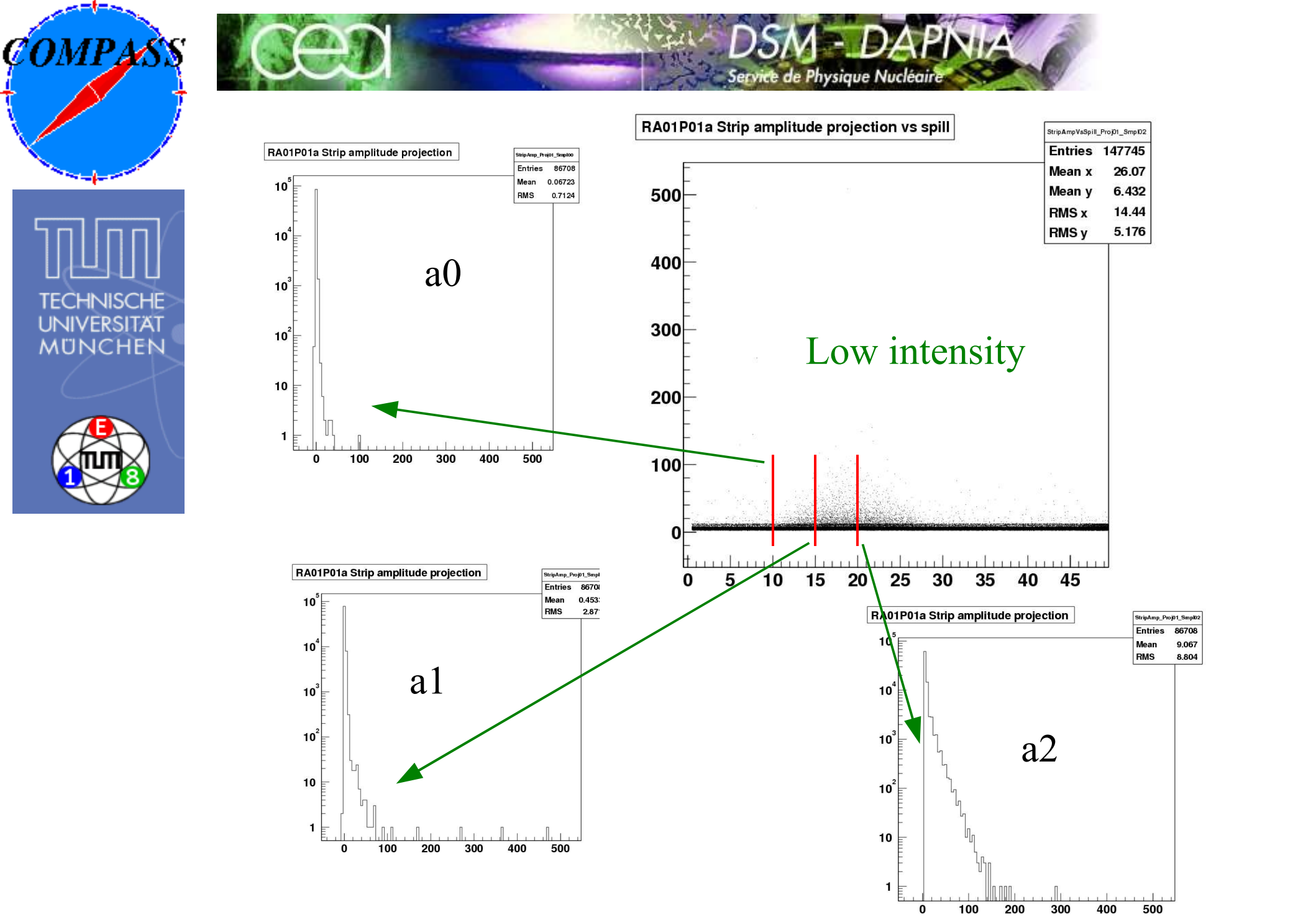
Noise measurement

σ_{noise}



640 e^-

Better noise figure compared to source tests


RA01P01a Strip amplitude projection
Entries 86708
Mean 0.06723
RMS 0.7124
a0
RA01P01a Strip amplitude projection vs spill
Entries 147745
Mean x 26.07
Mean y 6.432
RMS x 14.44
RMS y 5.176
Low intensity
RA01P01a Strip amplitude projection
a1
RA01P01a Strip amplitude projection
Entries 86708
Mean 9.067
RMS 8.804
a2