Front-end Electronics for the ALICE Calorimeters

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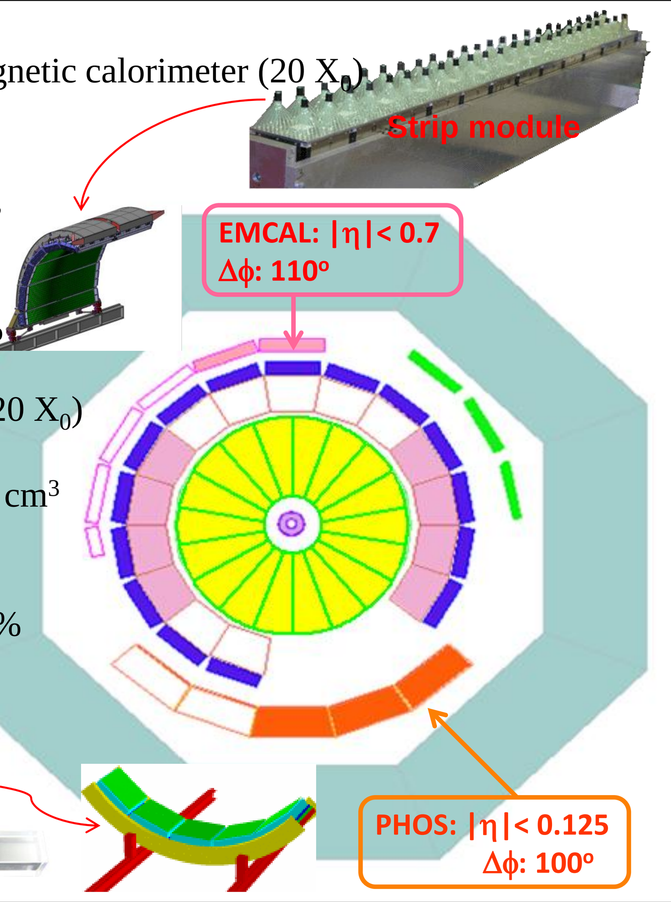
ElectroMagnetic Calorimeters at ALICE

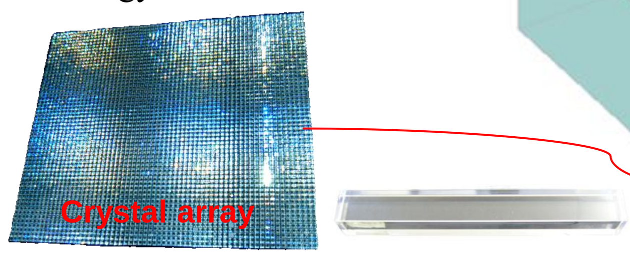
EMCAL:
large aperture Pb-Scintillator electromagnetic calorimeter (20 X_0)

- acceptance: $\Delta\varphi$=107°, |η|<0.7
- 12288 towers 6×6 cm2.
- 10 full + 2 one-third super modules,
- 24×48 towers each super module
- energy range: 0.1-250 GeV
- energy resolution: ~12%/$\sqrt{E}\oplus$1.7%

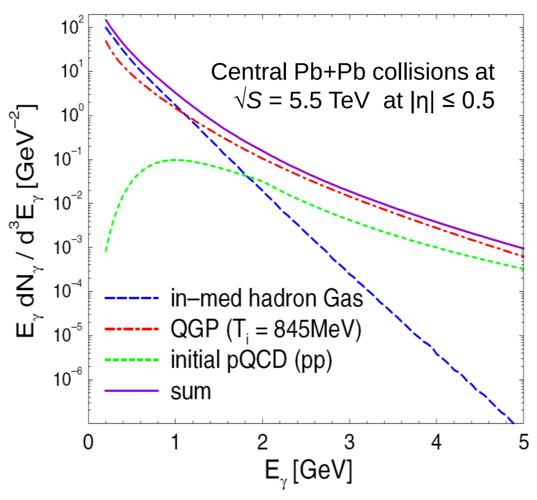
PHOS:
high-granularity photon spectrometer (20 X_0)

- acceptance: $\Delta\varphi$=100°, |η|<0.12
- 17920 $PbWO_4$ crystals 2.2×2.2×18. cm^3
- 5 modules 64×56 crystals each
- energy range: 0.1-100 GeV
- energy resolution: ~ 1.3%/$\sqrt{E}\oplus$1.3%



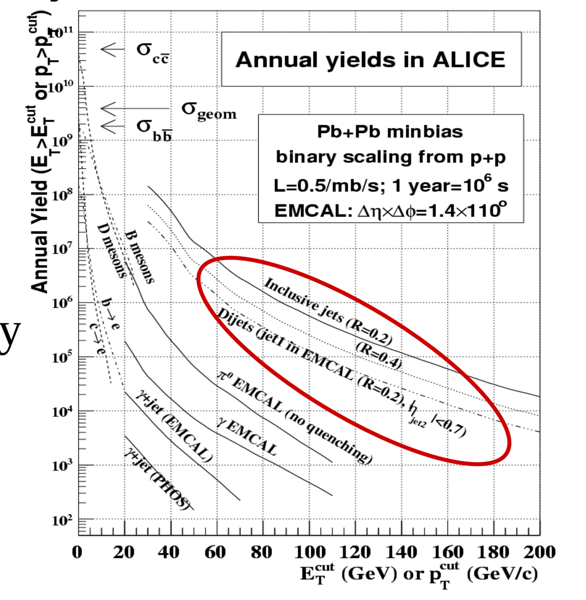


The Physics

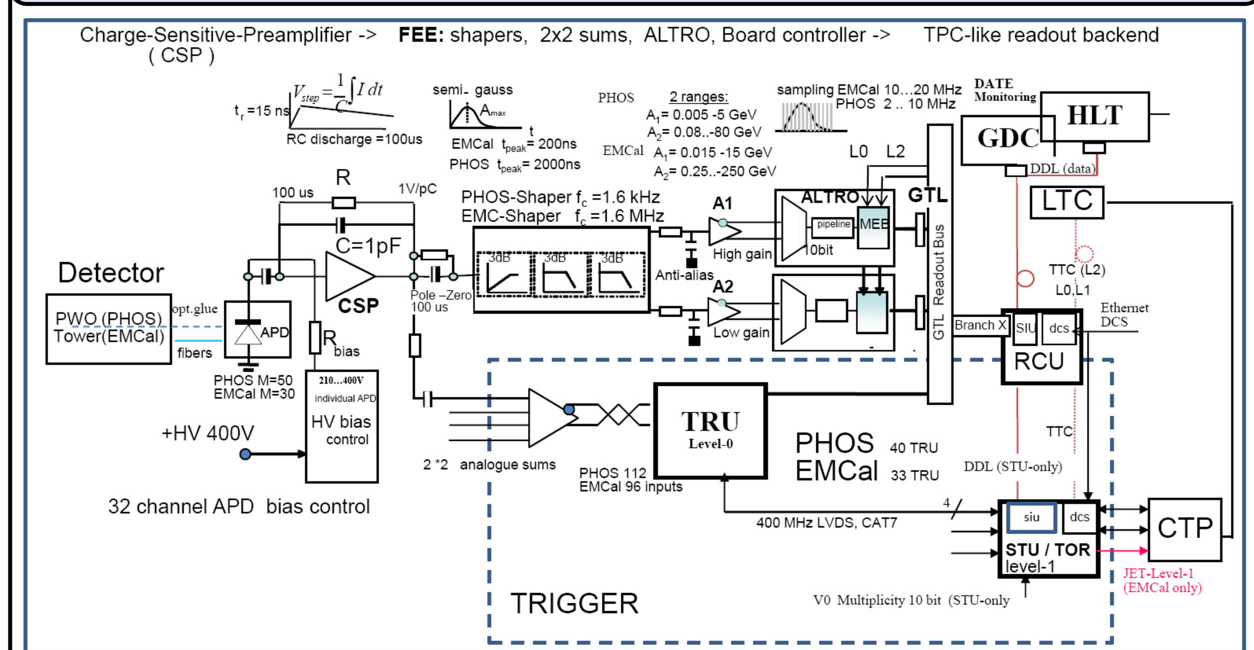


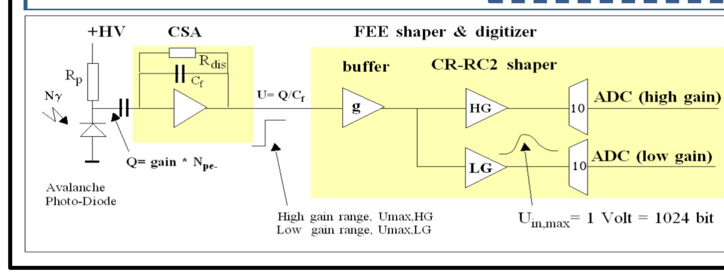
The PHOS allows several physics measurements of neutral mesons (π^0, η, ω…) and direct photon in high energy heavy ion collisions and also gamma-jet correlation.

The EMCal allows the study of jet-quenching in high energy heavy ion collisions and thus yields insights into the interactions between partons and the medium created in these collisions



Front-end Electronics Overview

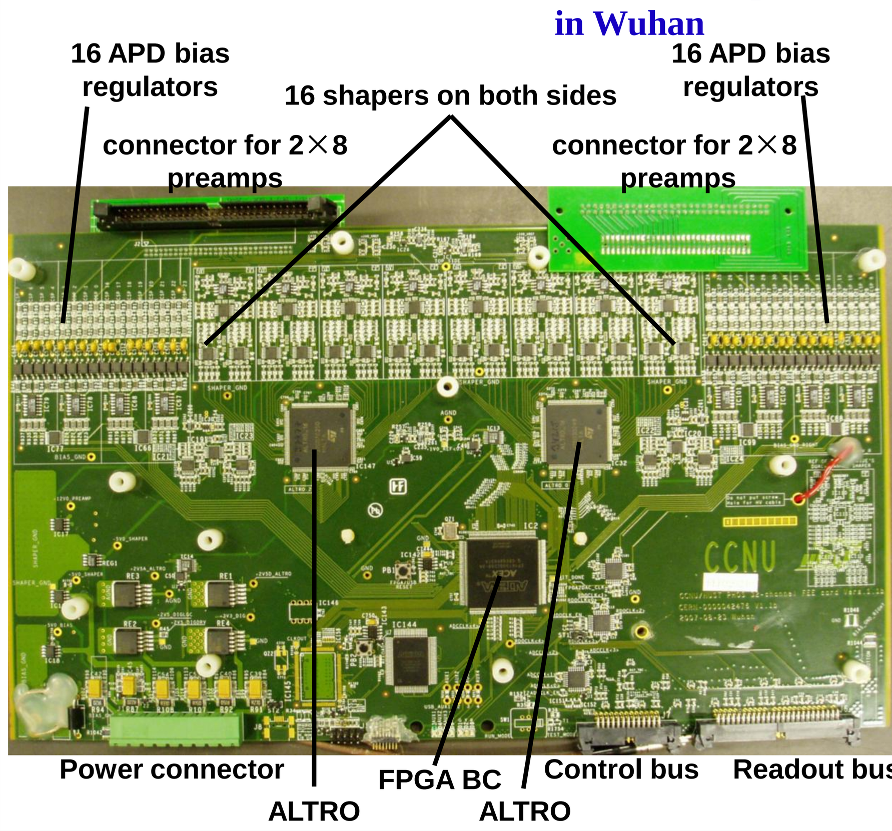




The FEE measures the particle energy of each channel very precisely over a linearity range via dual gain shapers.

FEE Cards

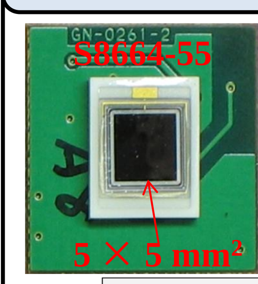
32 channel Front-end Electronics cards, mass production and test for PHOS in Wuhan



Hardware properties:

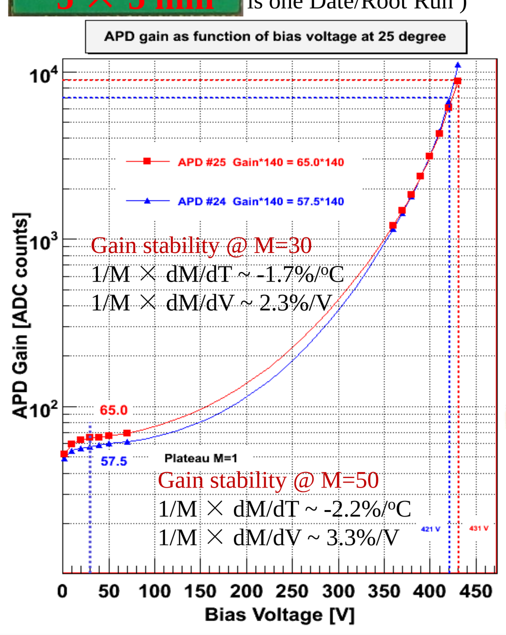
- 32 ch. dual gain shapers, 64 readout channels
- RMS noise: ~3.2 MeV
- 14 bit dyn. energy range
- 32 HV regulators, 10 bit for APD bias
- Fast OR (2 × 2 crystals) for trigger
- 10 bit ADCs (ALTRO) 10 MHz
- Board controller firmware in FPGA
- GTL readout and control bus
- DAQ readout and DCS via RCU
- 5.5 watt, 349 × 210 mm^2

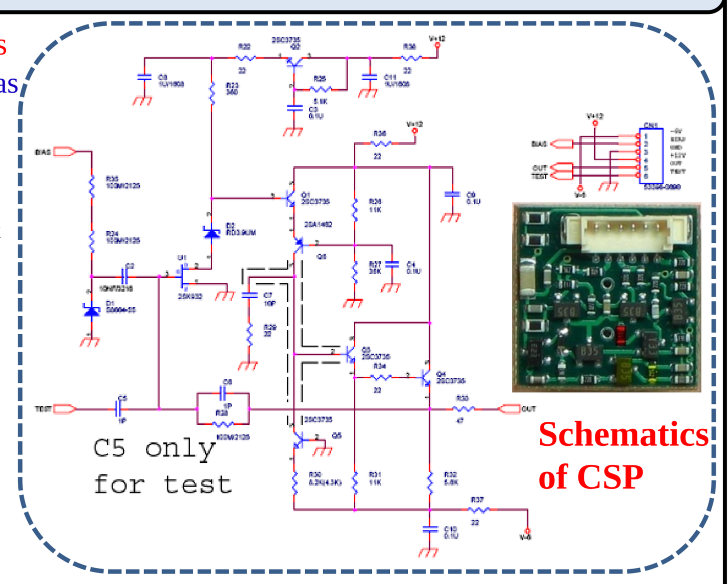
APD pre-Calibration & CSP

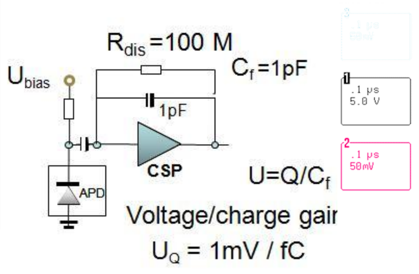


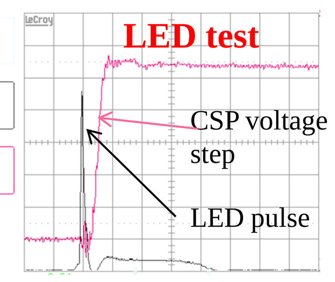
APD gain M depends on: manufacturing, bias voltage, temperature

Gain calibration of each APD with LED (each point is one Date/Root Run)

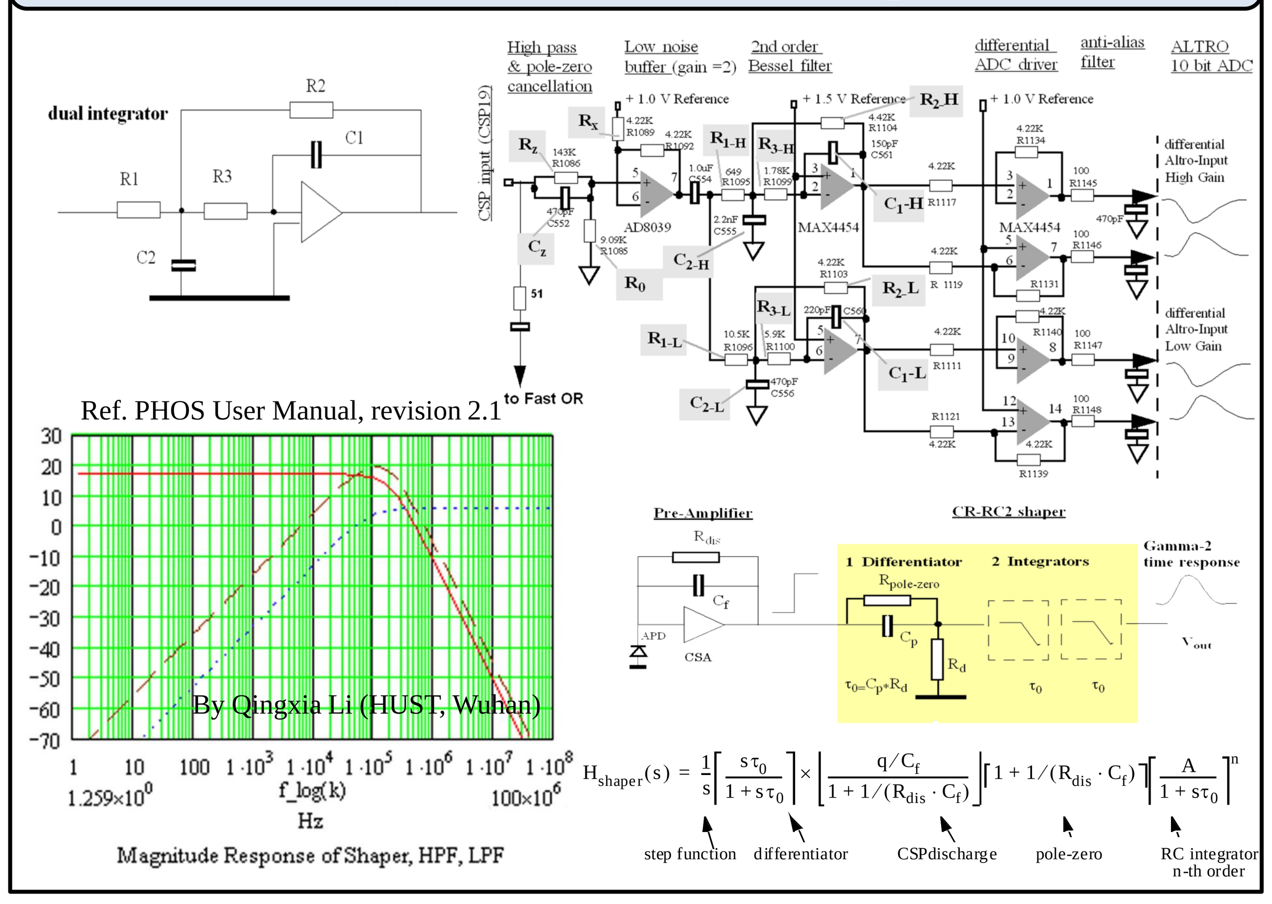






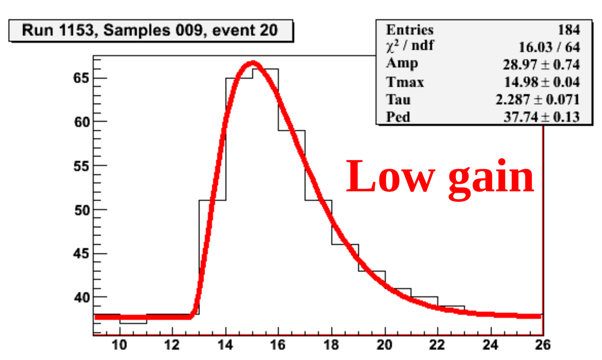


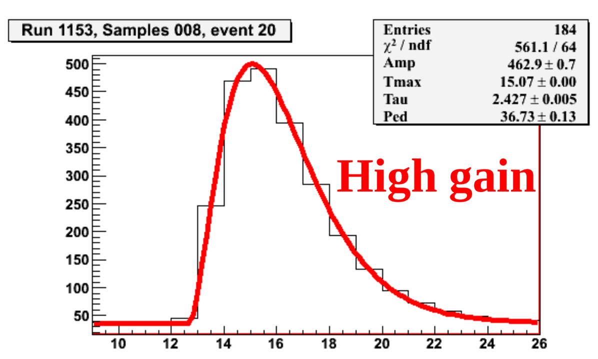
High/Low Gain Shaper



Shaper Readout

- a single APD channel is measured by two 10 bit ADC's
- high/low gain ratio between both channels is 16/1
- combined measurement corresponds to 14 bit dynamic range





2nd order Gamma2 fit:

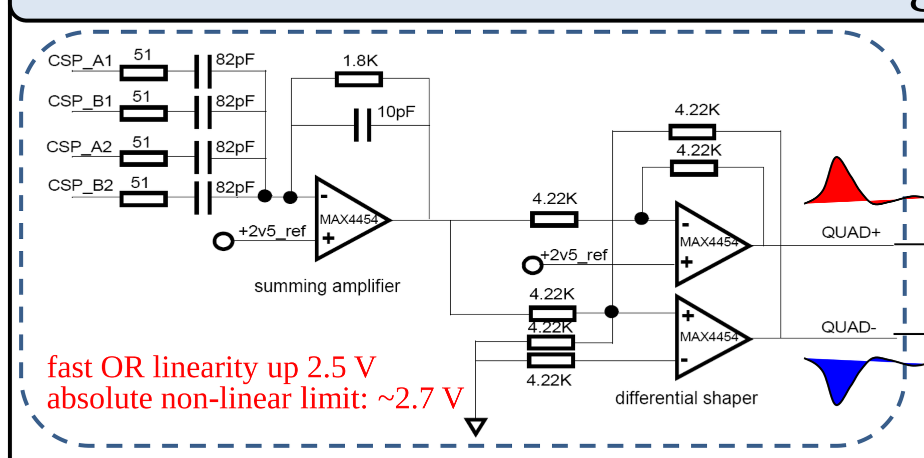
$$\mathrm{Vout}(t) = \left[\frac{4Q \cdot A^2}{C_f}\right] \cdot \left[\frac{t - t_0}{\tau}\right]^2 \cdot e^{-2\frac{t-t_0}{\tau}}$$

Q = input charge on APD
C_f = 1 pF
τ = 1000 ns (PHOS) or 100 ns (EMCal)
A = CSP gain

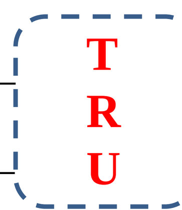
PHOS:
energy ranges 0.005 GeV~5 GeV / 0.08 GeV~80 GeV for APD gain M=50

EMCal:
energy ranges 0.015 GeV~15 GeV / 0.25 GeV~250 GeV for APD gain M=30

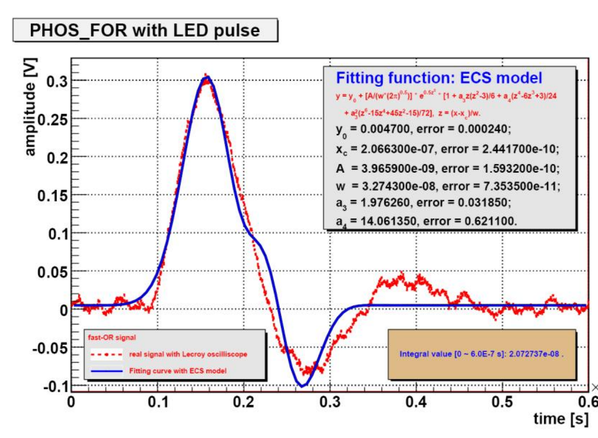
fast-OR Differential Signal

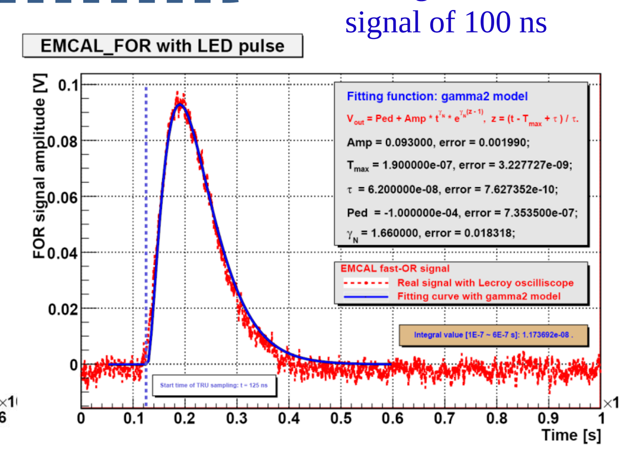


40 cm cable to TRU

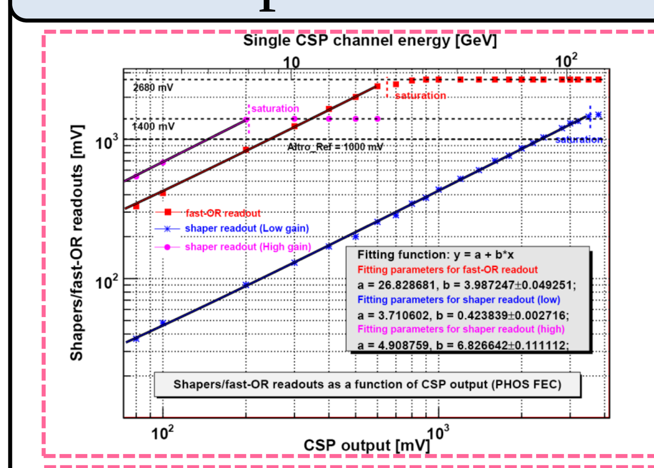


analogue 2×2 CSP signal of 100 ns

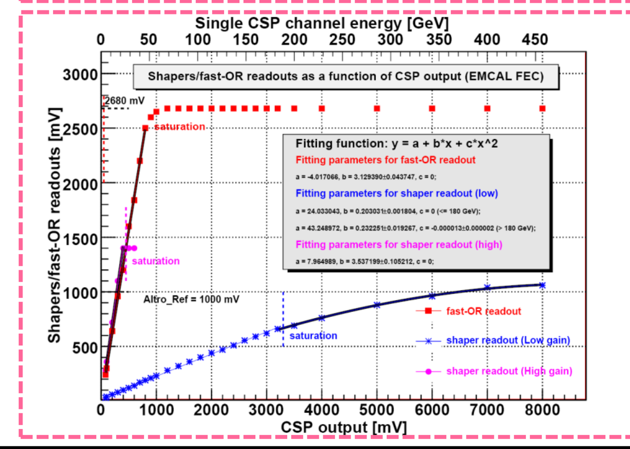




Shaper/fast-OR Readout Linearity

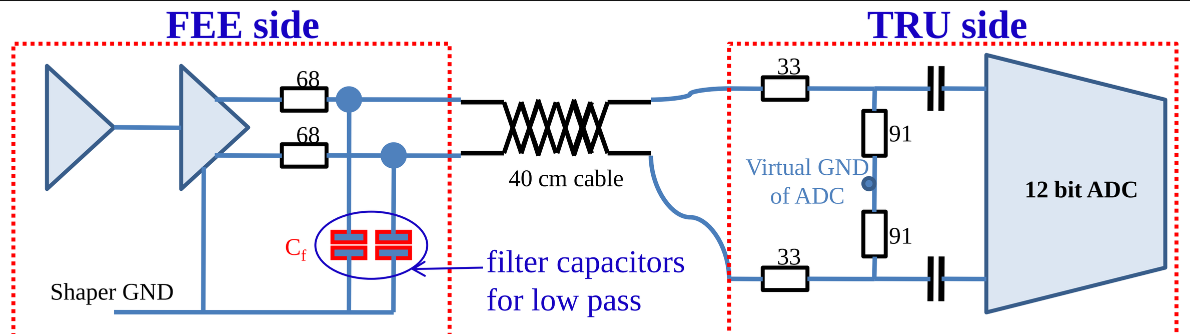


- fast OR saturation at 2.5 - 2.74V differential
- fast OR / LG = ratio 9.403
- CSP gain = 29.2 uV/MeV (for M=50)
- LG shaper gain = 0.427
- HG shaper gain = 6.85
- Linear range:
- fast OR saturation @2.5V:
- LG value ~ 260mV
- CSP value = 0.609 V
- Saturation Energy = 20.86 GeV
- Non linear range:
- fast OR @ 2.68V
- LG value ~ 380 mV
- CSP value = 0.890 V
- Saturation Energy = 30.48 GeV

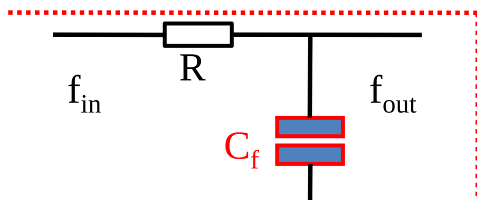


- fast OR saturation at 2.5 - 2.74V differential
- fast OR / LG = ratio 13.784
- CSP gain = 17.5 uV/MeV (for M=30)
- LG shaper gain = 0.229
- HG shaper gain = 3.66
- Linear range:
- fast OR saturation @2.5V:
- LG value ~ 180 mV
- CSP value = 0.792 V
- Saturation Energy = 45.25 GeV
- Non linear range:
- fast OR @ 2.68V
- LG value ~ 250 mV
- CSP value = 1.091 V
- Saturation Energy = 62.8 GeV

Noise filtering for fast-OR



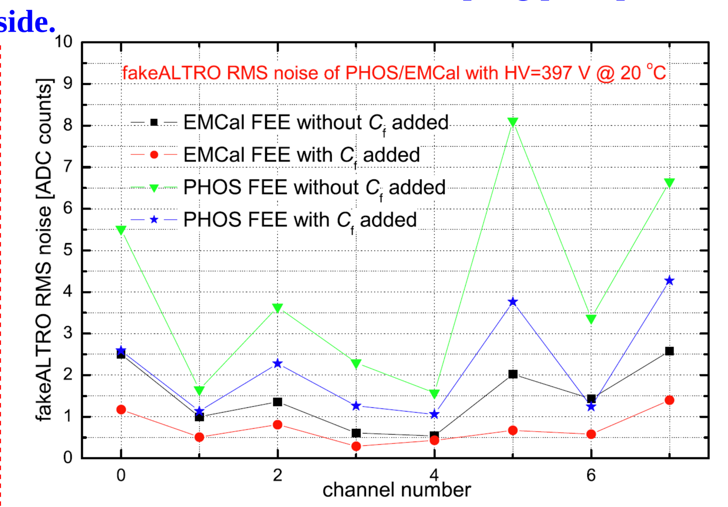
Low pass filter capacitors are added to filter a 10 MHz ALTRO sampling pickup noise for fast-OR channels on the FEE side.



at f_0 and above 3 dB attenuation per frequency octave:

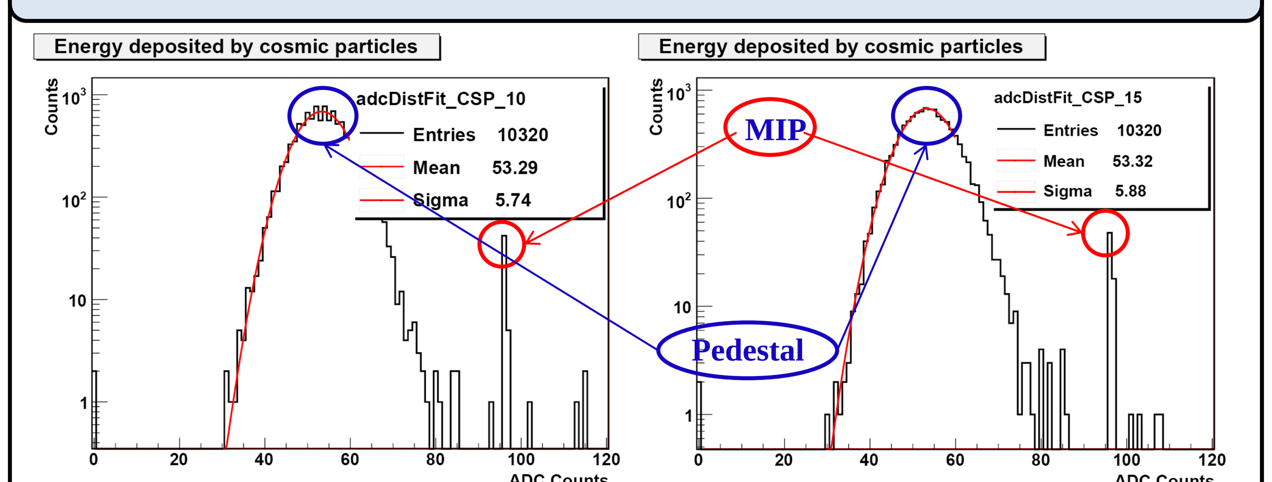
$$f_0 = \frac{1}{2\pi RC_f}, R = 68\Omega$$

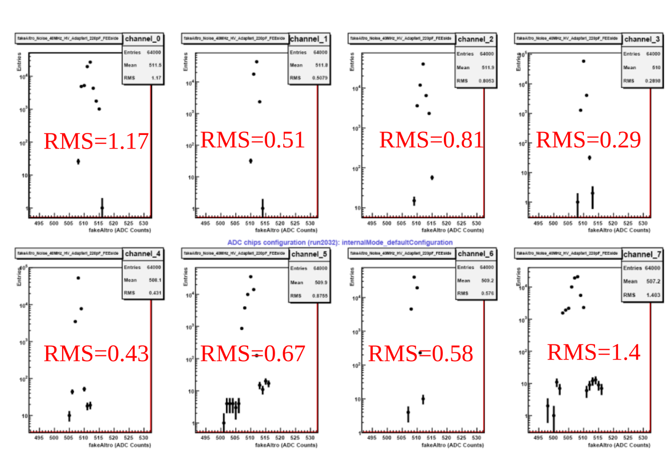
f_0 = 10 MHz for C_f = 220 pF



The noise filters make MIP survive over noise in fakeALTRO

MIP and S/N ratio





MIP ~ 43 ADC counts at room temperature

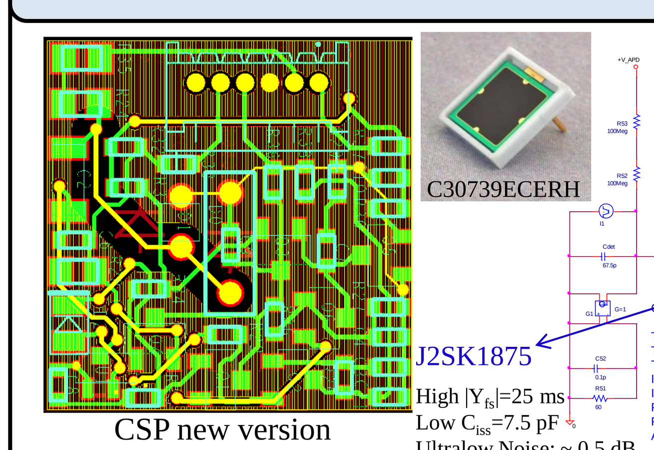
PHOS FEE digital resolution: 5 MeV/ADC

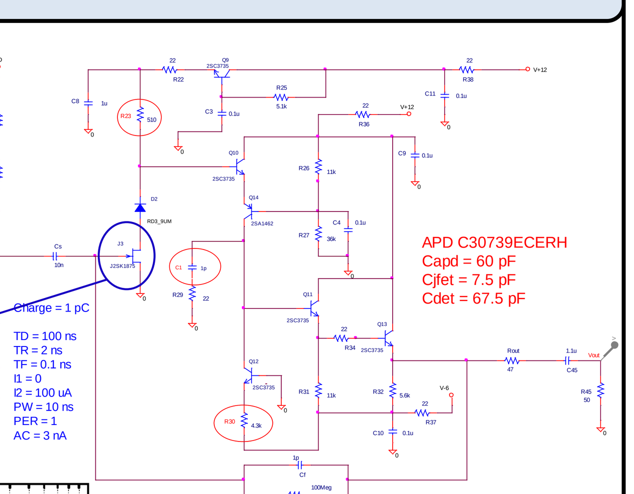
MIP ~ 215 MeV with noise level of 30 MeV per channel at room temperature

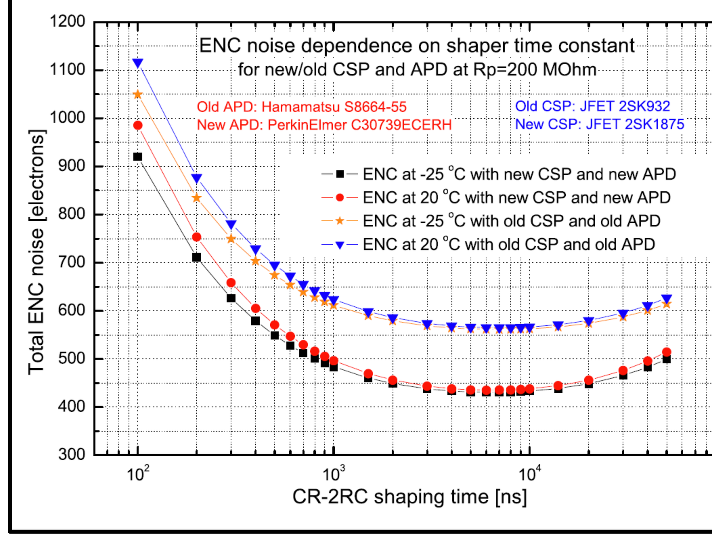
Signal to Noise Ratio at room temperature: ~ 7

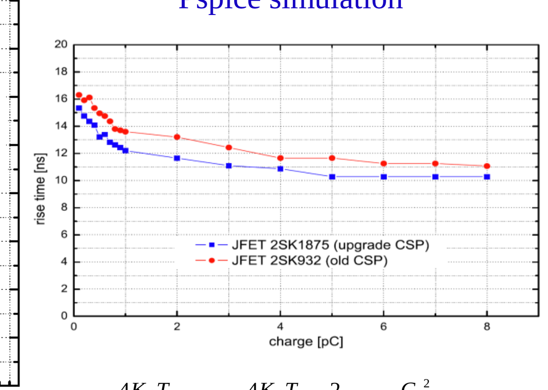
EMCal FEE fast-OR maximum RMS noise level : ~ 1.4 ADC counts, corresponding to peak-to-peak noise ~150 MeV

CSP & APD new version









$$ENC^2 = \frac{4K \cdot T}{q^2 \cdot R_p} \cdot F_p \cdot \tau + \frac{4K \cdot T}{q^2} \cdot \frac{2}{3 \cdot g_m} \cdot F_s \cdot \frac{C_d^2}{\tau} + C_d^2 \cdot const$$

Summary & Acknowledgements

The ALICE calorimeters PHOS and EMCal are based on Avalanche Photo-Diode photosensors with Charge-Sensitive Preamplifiers for readout of the scintillating elements. The amplified signals are read out via 32-channel shaper/digitizer electronics (FEE) with 14-bit effective dynamic range. The electronics is based on configurable 2nd order shapers of different gain with 2 ALTRO chips per channel. Each APD channel is equipped with an individual 10-bit APD gain-adjustment and 2x2 channel clusters generate a 100 ns shaped analogue sums output (Fast OR) for the associated Trigger Region Units (TRU). The front-end electronics cards for PHOS are in mass production and tested in Huazhong Normal University (CCNU), Wuhan.

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