Charge calibration and MC tuning of the SST

Giacomo BRUNO

UCLouvain

27 February 2010

http://cp3.phys.ucl.ac.be/

UCL

Université
catholique
de Louvain

- Detector response (in ADC) must be equalized in data to correct for instrumental effects that are absent in MC
  - procedure uses tracks from MB events
  - Physics effects are corrected too!
  - Result: $\{C^{eq}_{data}\}$
    - one per APV
    - No dimensions
    - Corrections are such that MPV for the chosen calibration sample is **300 ADC/mm**
  - These corrections are regularly uploaded to DB

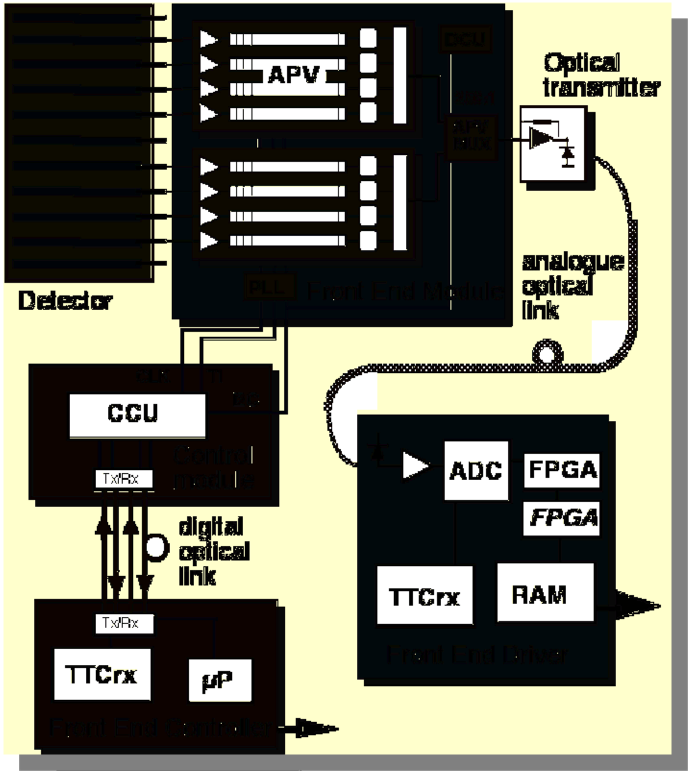
- Align equalized data (ADC) and “raw” MC (MeV) to the Bichsel prediction: MPV=f(p) [MeV] at a given pathlength
  - Procedure needs a sample of tracks with fixed pathlength
  - Result: $\{C^{bi}_{data}\}$ [MeV/ADC] and $\{C^{bi}_{MC}\}$ [no dimensions]
    - Data and MC corrections: one per η-R ring of modules
    - These corrections are computed once and for all (can be stored on DB)
    - These corrections will be used by applications that need to know the physical energy deposits (e.g. dE/dx)

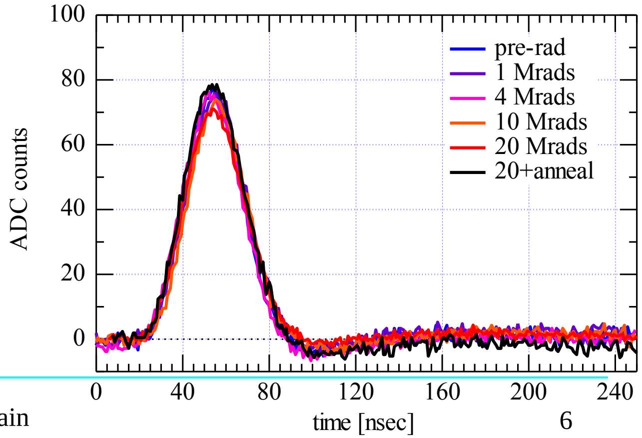
- Conversion of MC response to ADC
  - Use: MC_{raw} [MeV]* {C^{bi}_{MC} * 1/ C^{bi}_{data}} [ADC/MeV]
  - This correction guarantees that MC gives an answer in ADC that corresponds to equalized data {by definition: MPV = 300 ADC/mm on MB sample}
  - This correction is also computed once and for all, because data is always equalized to an absolute level.
  - We solve also the issue of MC productions having to handle detector instabilities over time !
    - E.g. will not need to ask ourselves with which gain corrections should we make the 2011 MC production

BACK-UP SLIDES

Charge response

- Charge response in silicon strip detectors can be different from channel to channel due to a variety of reasons
  - Physics:
    - particle momentum and type
  - Instrumental:
    - Particle pathlength in silicon
      - incident angle
      - Module thickness
    - Defects/damage on silicon wafers, implants, connections
    - Sampling time (also dependent on TOF)
    - Configuration/Response of electronic and optical components (APV, Laser, fibers)
    - Zero Suppression
      - Module layout (thickness, pitch, strip dimensions)
      - Incident angles (parallel and orth. To strips)
- Deviations from linearity and absolute dE/dx scale must also be known





Charge calibration use cases

- Track reconstruction
  - Cluster building
    - Condition applied: $\sum S_i > n\sqrt{\sum N_i^2}$;[S==signal, N==Noise, n=5 (def)]
      - Whereas, the individual channel thresholds need no correction neither on S_i, nor on N_i
  - Position and error of reconstructed hits
    - Currently estimated using the charge ratio between different strips in a cluster

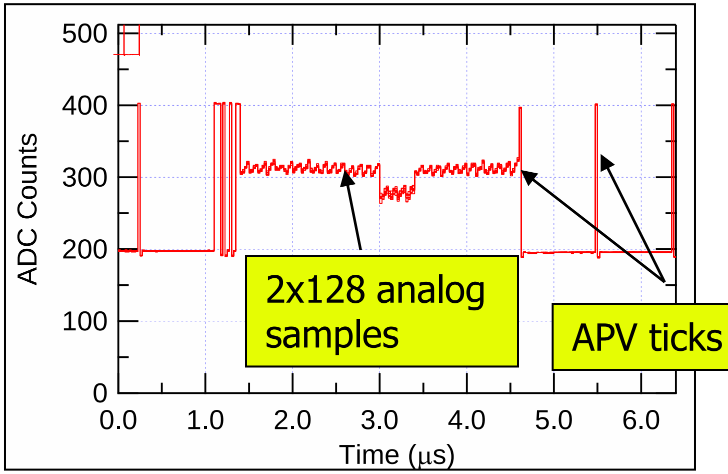
→ Equalization at the level of a single module is enough unless global parameterizations not just based on ratios are used

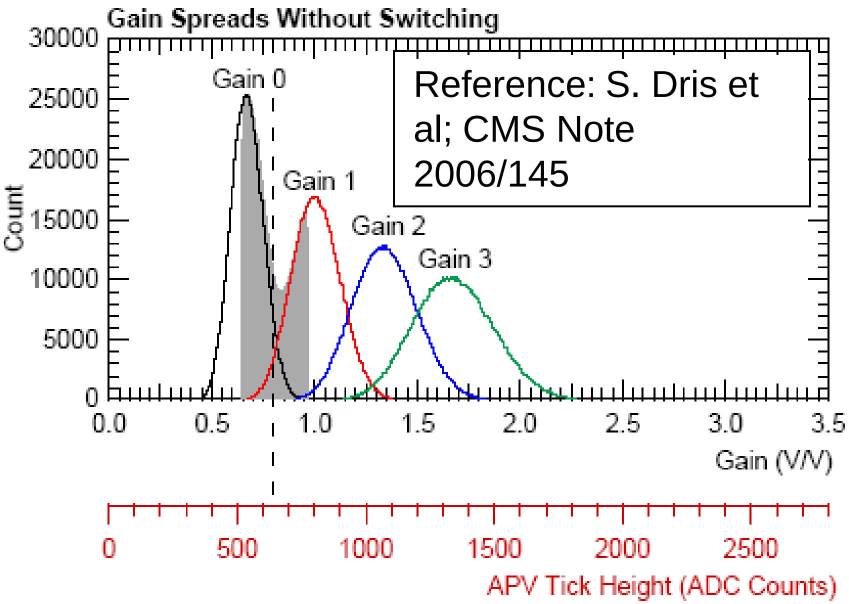
- dE/dx technique
  - Particle identification (CMS Note 2008/005)
    - Low momentum standard particles (CMS AN-2007/021)
    - High momentum hypothetical heavy stable charged particles (HSCP; CMS AN 2007/049)
  - Mass measurement
    - Heavy exotic particles

→ Global calibration across modules is necessary

Calibration signals: tickmarks

- “Tickmark” signals
  - can be produced by each APV
  - Tick height is full digitizer (FED) dynamic range
    - ±5% variation from APV to APV (M. Raymond, *et al.*, CERN/LHCC/2005-038, pp. 453-457, 2005)
- Response equalization is performed to some extent in the hardware configuration
  - Feed tick mark signal produced by each APV into FED.
  - see response in terms of ADC counts.
  - Choose the one in four available values that brings the response closest to a reference value.
    - One discrete parameter (Laser Driver gain: 0,1,2,3) can be set in the AOH (one per APV pair)
    - Distribution is non gaussian after hardware gain optimization
  - Intrinsic precision of the method ~ 15%
    - **Plus contributions from all effects to which the method is insensitive**





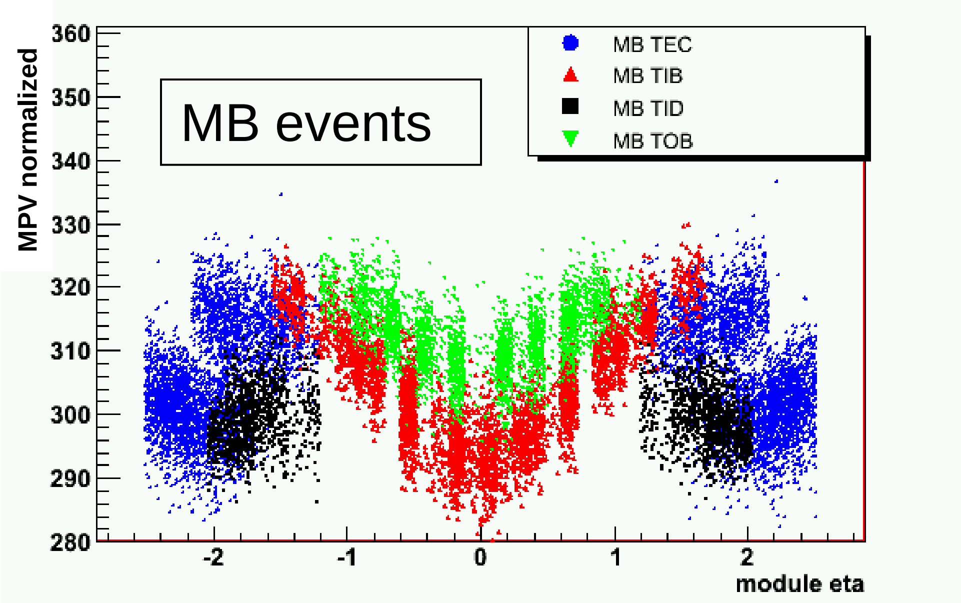
Reference: S. Dris et al; CMS Note 2006/145

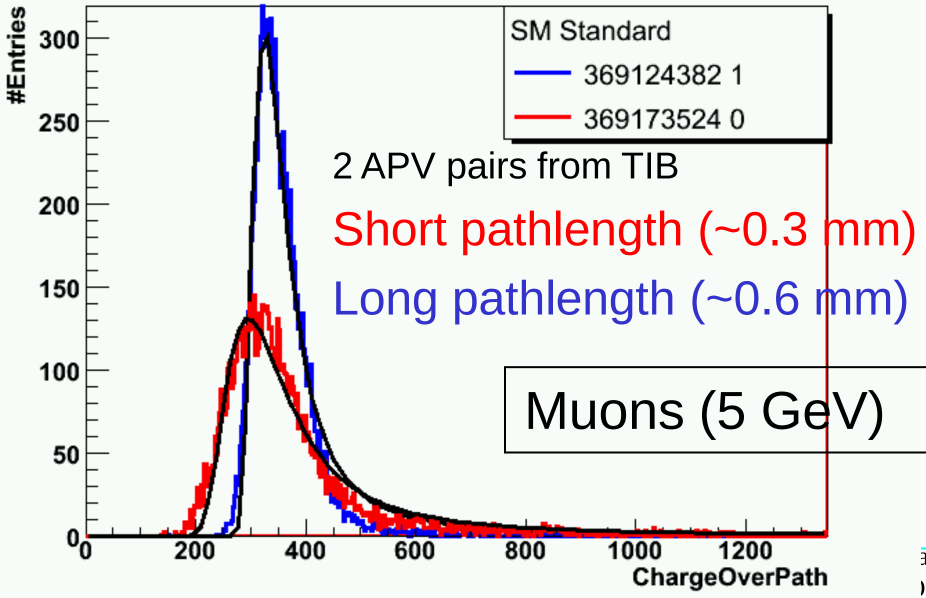
Calibration with particles

- Goal
  - Correct for residual miscalibration of tick mark method (±5% + any effect on amplification chain before AOH)
  - In addition, absolute mass scale determination and linearity crucial for special particle id (e.g. Heavy Stable Charged Particles)
- Method:
  - Take all clusters associated to tracks (cosmics or MB)
  - Normalize charge to thickness traversed
  - Produce a charge distribution for each APV pair
  - Fit to a Landau and use Most Probable Value (**MPV**) to compute the correction

Normalized MPV distributions

- Large MPV variation (more than 10%)
  - Clear correlation with pathlength through modules
    - Explained by dependence of MPV on pathlength
      - MPV ~ Ax +B lnx [PDG]
    - FWHM / MPV = [15%, 50%]
  - MB give wider dispersion than monoenergetic muons at fixed η
    - Explained by different spectrum/typical pathlength (due to stronger bending) for modules at different R

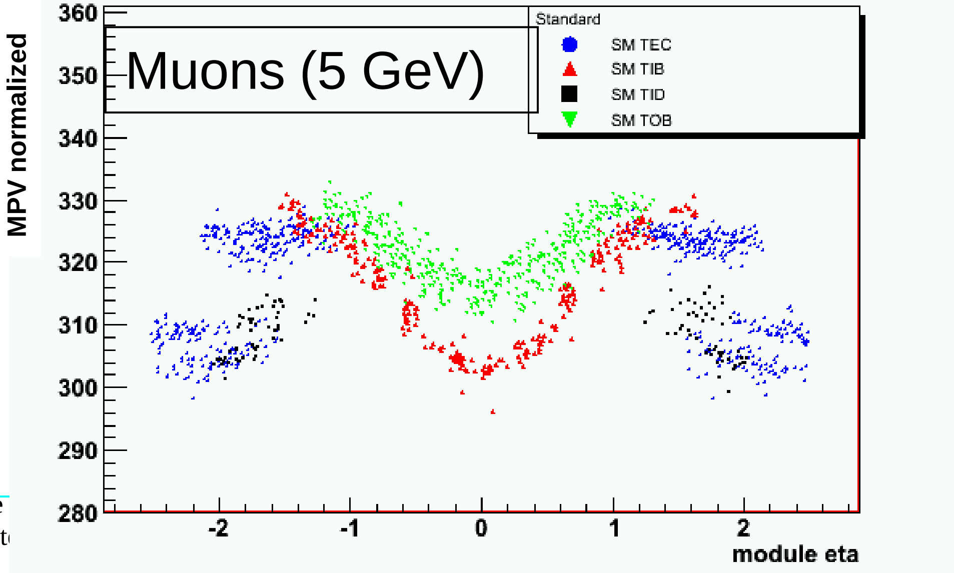

MB events


2 APV pairs from TIB

Short pathlength (~0.3 mm)

Long pathlength (~0.6 mm)

Muons (5 GeV)

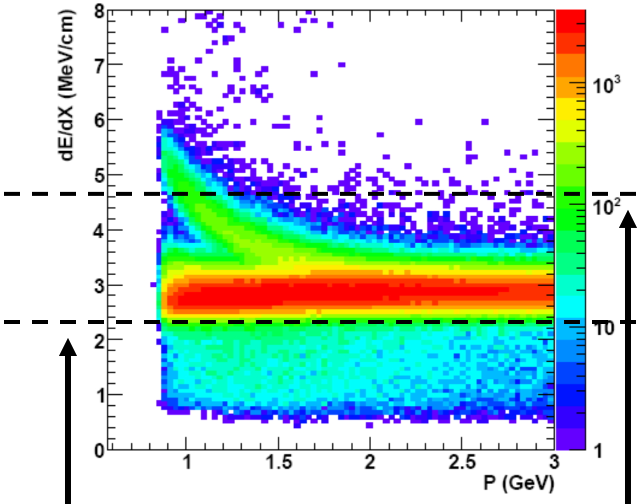

Muons (5 GeV)

Charge calibration

- Must choose a conventional calibration point
  - Equal response guaranteed only at this point
    - Definition of equal response: “MPV of normalised charge distribution is equal to Reference Value”
    - Landau width at calibration point will vary significantly (FWHM / MPV) ≈ [15%,50%]), depending on
      - Geometrical location of the module (pathlength)
      - chosen particle type/momentum (pathlength and specific ionization)
  - Away from calibration point:
    - Normalized MPV and Width will change with respect to Ref. Value
    - In addition, for 2 modules in different [η, R] “rings” they will shift differently
    - Reasons:
      - Particle type (different specific ionization)
      - Particle momentum (different pathlength and specific ionization)
- Scenario ‘A’ (CMS start-up)
  - Use all tracks with p>1 GeV from MB events
    - O(1 M) events are enough
      - 1 day of MB data taking at 10 Hz and 14 TeV

Particle identification

- Assumption
  - All dE/dx meaurements (normalised cluster charge) of a given track come from a single Landau distribution that only depends on the particle m and p (measured).
- Identification principle
  - estimate the MPV with the ~10 dE/dx measurements.
- Method
  - Obtain dependence of dE/dx estimator and dispersion vs p
  - Protons and, hopefully, kaons will be distinguishable in specific p intervals.
  - HSCP will feature a striking pattern.
  - Identify particles on a simple cut basis (p dependent)
- Limitations
  - dE/dx measurements do not come from the same Landau
    - ~5% variation on MPV from calibration (MB p spectrum)
    - ~10% variation in points far from the calibration point (MIPs), due to different shift of MPV with pathlength and specific ionization
    - Measurements with longer pathlength must be given higher weight (they come from thinner and almost Gaussian shaped Landau distributions)
  - Cut-off of 255 ADC counts
    - ~5% on MPV in high pathlength region (calibration fit bias)
    - Landau tail shape affected differently
    - Critical for HSCP id (non-bent tracks → small cluster size)



255 ADC counts for pathlength = 1 mm

255 ADC counts for pathlength = 0.5 mm

Calibration Scenario ‘B’

- Calibration point
  - Align normalized MPVs for tracks of relatively high p, say [10-15] GeV
    - Can be any (isolated) track and later even identified muons (combined Tk-Mu muon id needed)
- Features

  + insensitive to p spectrum variations (5% effect)

  + high p SM tracks give well defined point
    - straight tracks: can define an “intrinsic” pathlength for each module
    - Lots of overlapping effects from MB eliminated

  + can fully exploit a likelihood based method (high-p SM-particle incompatibility) in HSCP search (see next slide)
    - Potentially more powerful than currently investigated methods
      - Makes full use of all information available (Landau MPV, shape...)
    - Will soon investigate its potential

  Statistics?:
    - Step 1: intercalibrate with MB events all modules in a given [η, R] “ring”
      - φ symmetry: same geometrical data, same illuminating spectrum.
      - 1 M events are enough (1 day of MB data taking at 10 Hz)
    - Step 2: Intercalibrate rings using monoenergetic muons
      - O(100) Charge distributions to populate (instead of 33k)
      - ~10 k high p tracks needed

More advanced Particle Identification

- HSCP search
  - Scenario ‘B’ calibration
  - Obtain normalized charge distributions vs pathlength
    - Possibly as a function of cluster size/pitch (if strong dependence exists – to be investigated)
  - For each dE/dx measurement of an HSCP candidate compute probability from corresponding charge distribution
  - Build likelihood from all measurements
  - Apply muon-incompatibility cut
- Low p particle identification
  - Same as above.
  - In addition, need pure samples of protons and/or kaons
    - Obtain charge distributions as a function of pathlength for different βγ values
  - Build likelihood from all measurement to test different mass hypothesis

Outlook

- Particle Physics aims at pushing forward our fundamental comprehension of the Universe we live in

- It prepares the ground for far-future Applied Science

- It already pushes applied science beyond its frontiers