Low – energetic Pions in the Analogue HCAL

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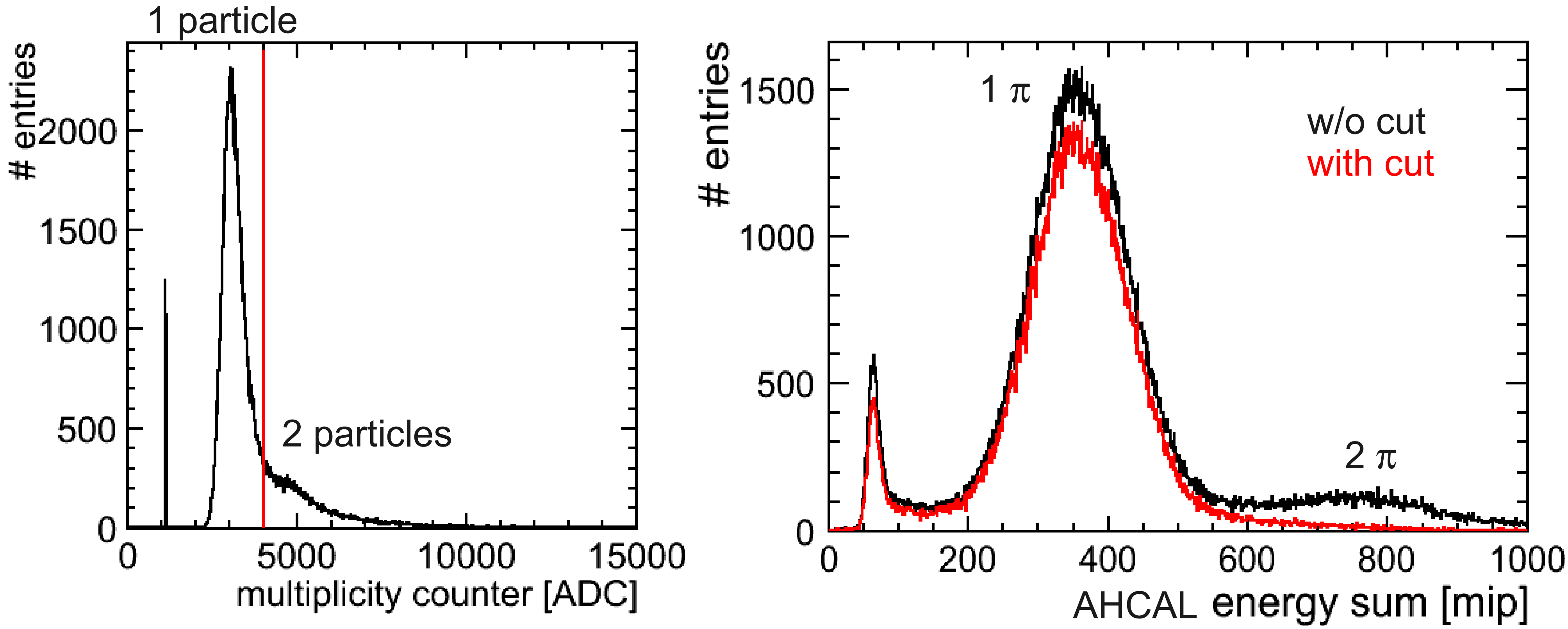
Outline

- π Data (FNAL, AHCAL stand – alone, 1 GeV – 20 GeV)
  - Rejection of multi-particle events
  - Rejection of muon events
  - π Enhancement Using Čerenkov Trigger
  - Electron Contamination
  - Check of Temperature Correction
- AHCAL Linearity
- First Comparisons Data / MC

Rejection of Multi – particle Events

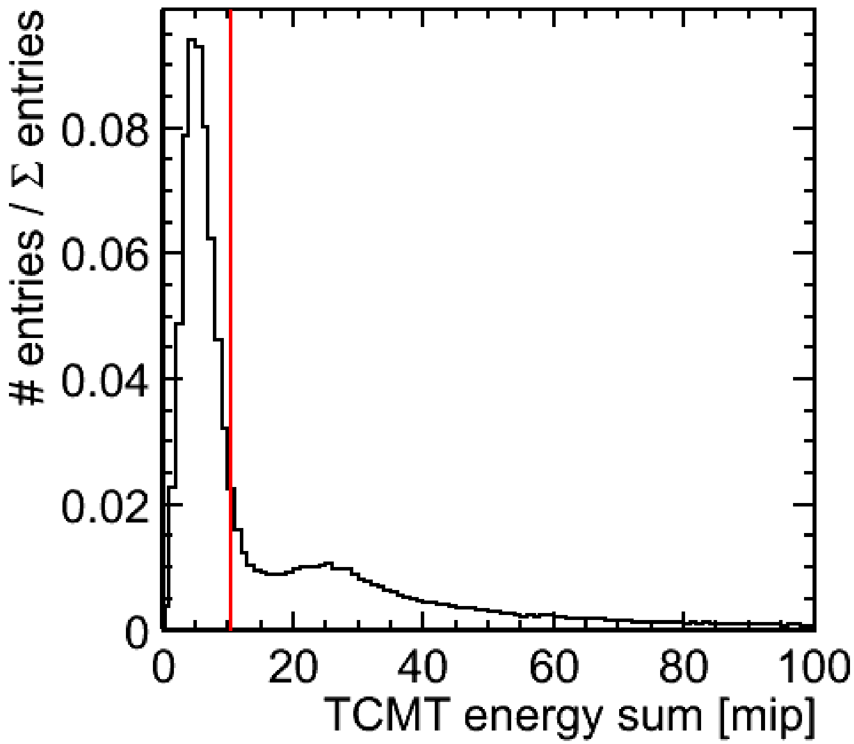
Example: π run at -10 GeV (520308)

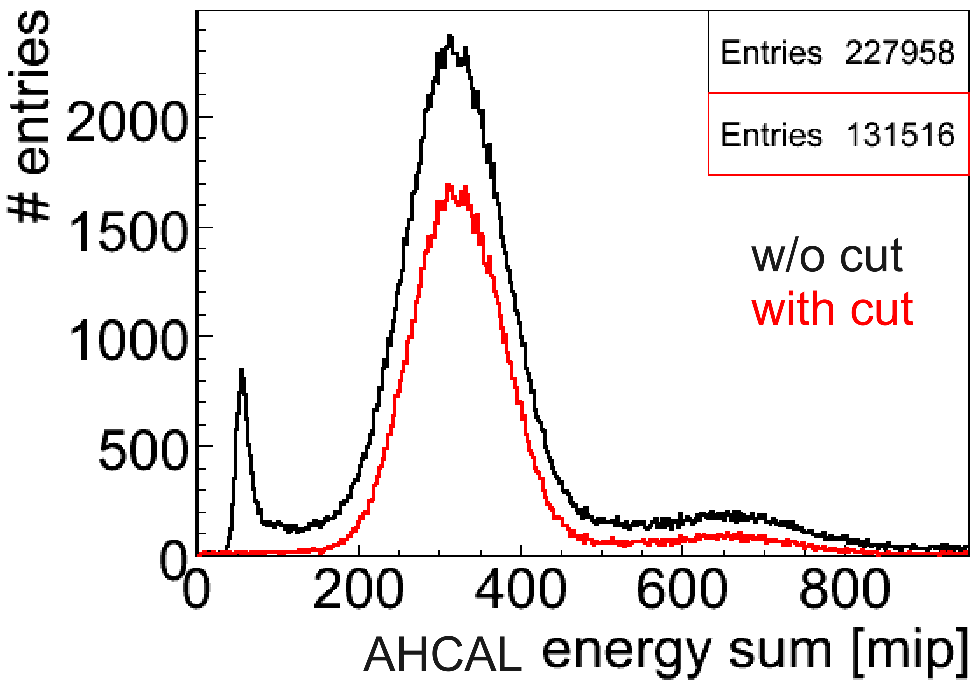


- 20x20 cm^2 scintillator (analog + digital PMT readout)
- cut: analog signal < 4000 ADC-channels → reject events with >1 particle
- reject ~ 10-30% of all beam events
- Possible improvements: optimize threshold (→ B. Lutz)

Rejection of Muon Events

Example: π run at -10 GeV (520308)



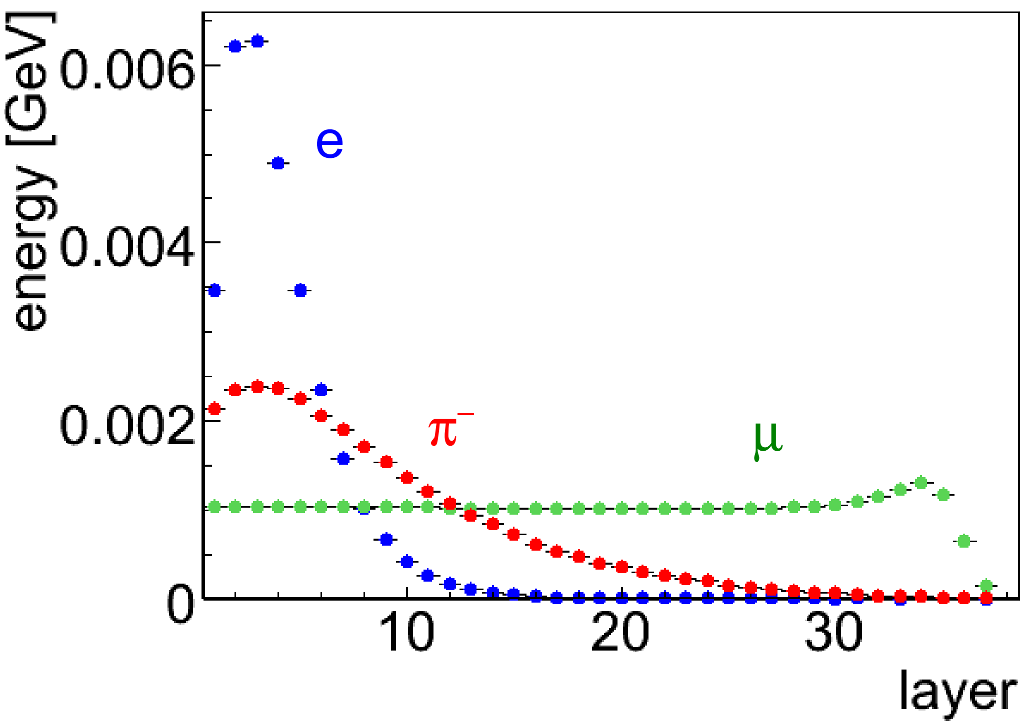


- cut: TCMT energy sum ≤ 10.5 mip → reject μ events
- reject ~ 40% of all beam events
- possible improvements: use AHCAL + TCMT information or μ finding algorithm

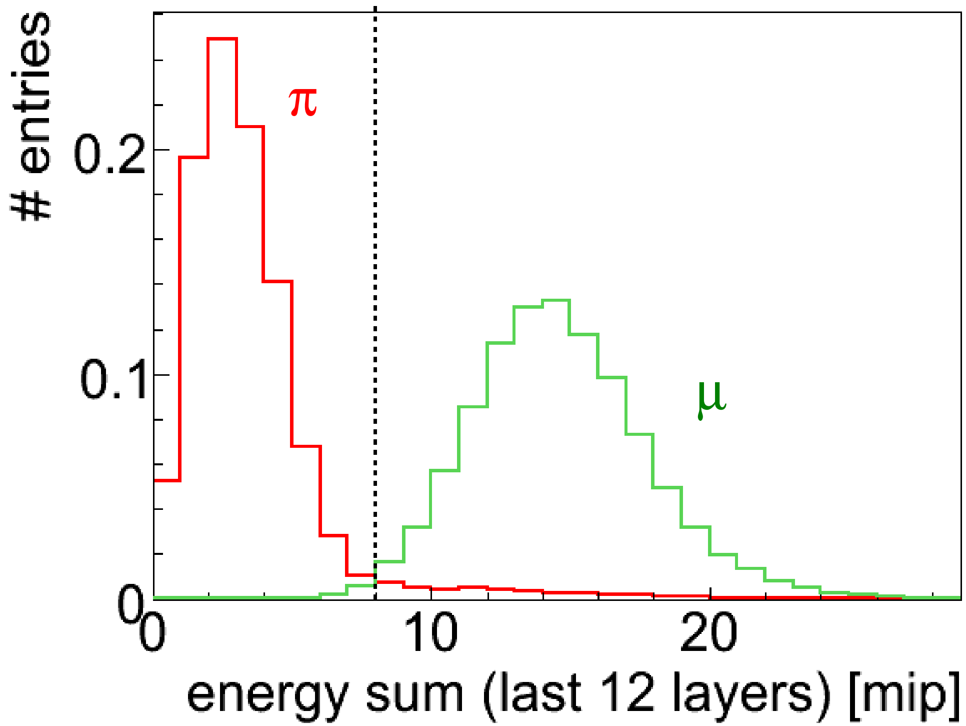
π / μ Separation At 1 GeV

Example: π – MC at -1 GeV (noise from run 580156)

pure MC



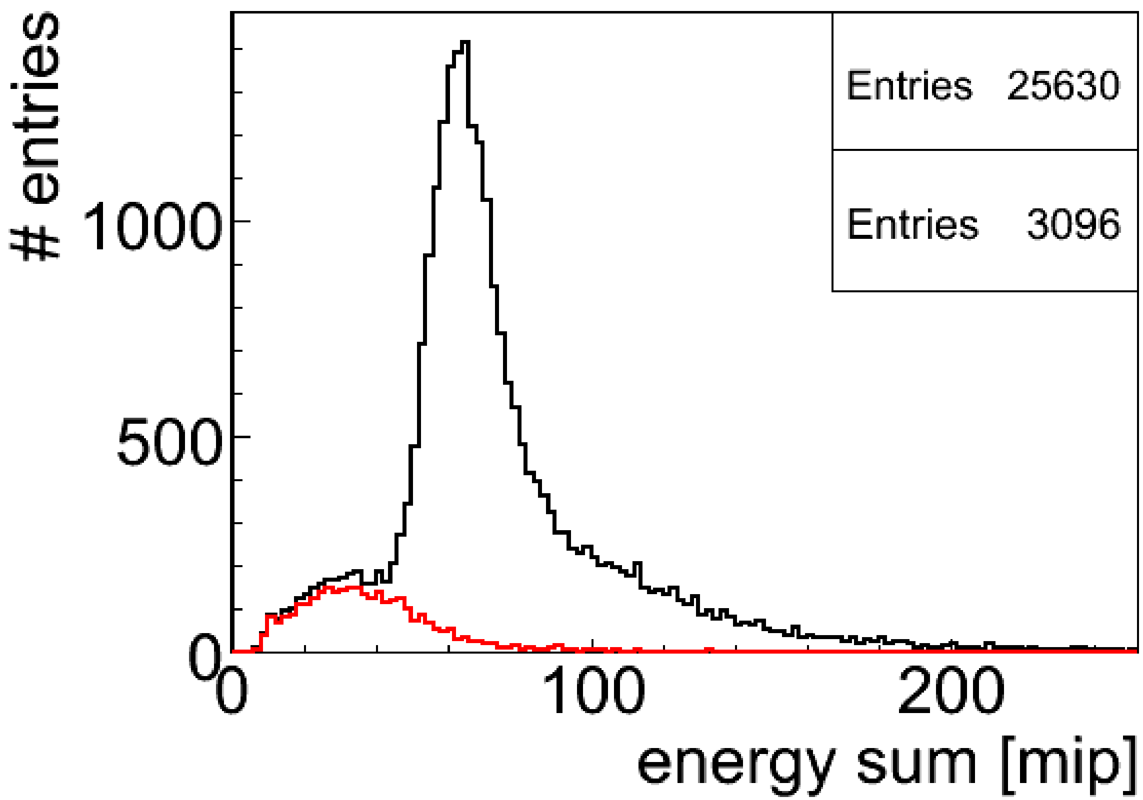
digitized MC



- TCMT cut not useable for 1 GeV μ
- separation π / μ in AHCAL: energy sum in last 12 layers
- cut: AHCAL energy sum (layers 27 – 38) < 8 mip → reject μ events

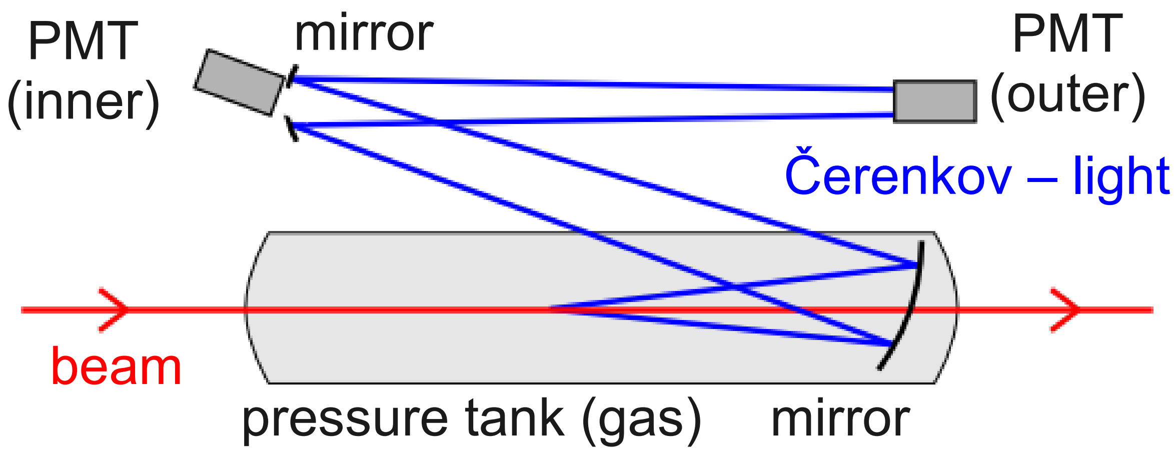
Muon Rejection At 1 GeV

Example: π run at -1 GeV (580156)

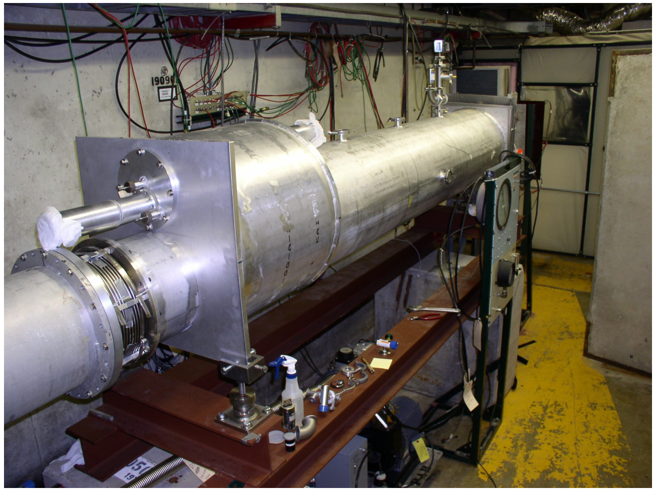


- cut: AHCAL energy sum (layers 27 – 38) < 8 mip
  && TCMT energy sum ≤ 10.5 mip → reject μ events
- reject ~85% of all beam events
- possible improvement: use μ finding algorithm

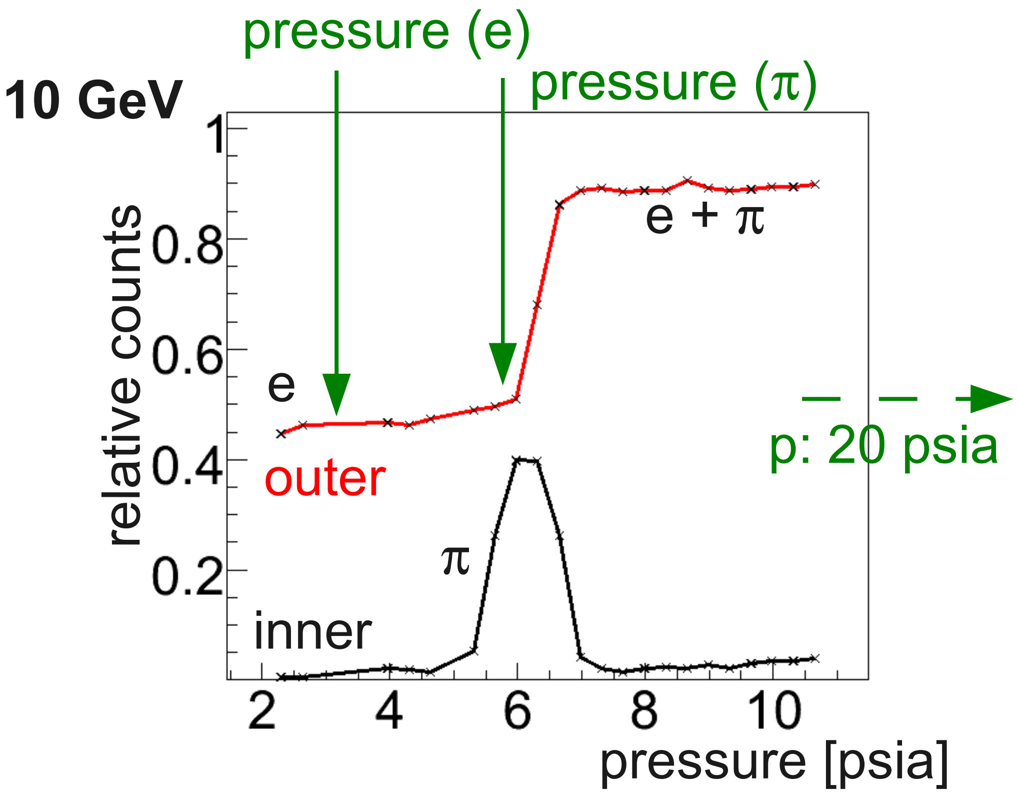
Differential Čerenkov – Counter



Triggering on Čerenkov:
enhance π / e / p content
e.g. π content (10 GeV):
~50 % → ~90 %



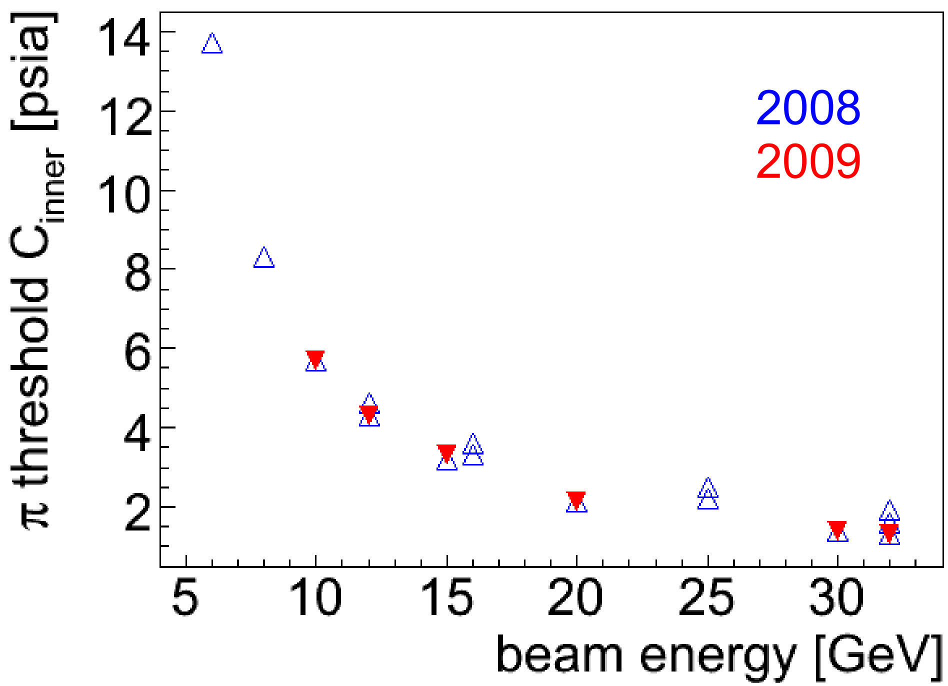
Differential Čerenkov – counter
at Fermilab MTBF



Čerenkov Operating Pressure (π Data)

π (6 – 32 GeV): tag π

Trigger: 10x10 && C_{inner}



π (1 – 4 GeV): veto e

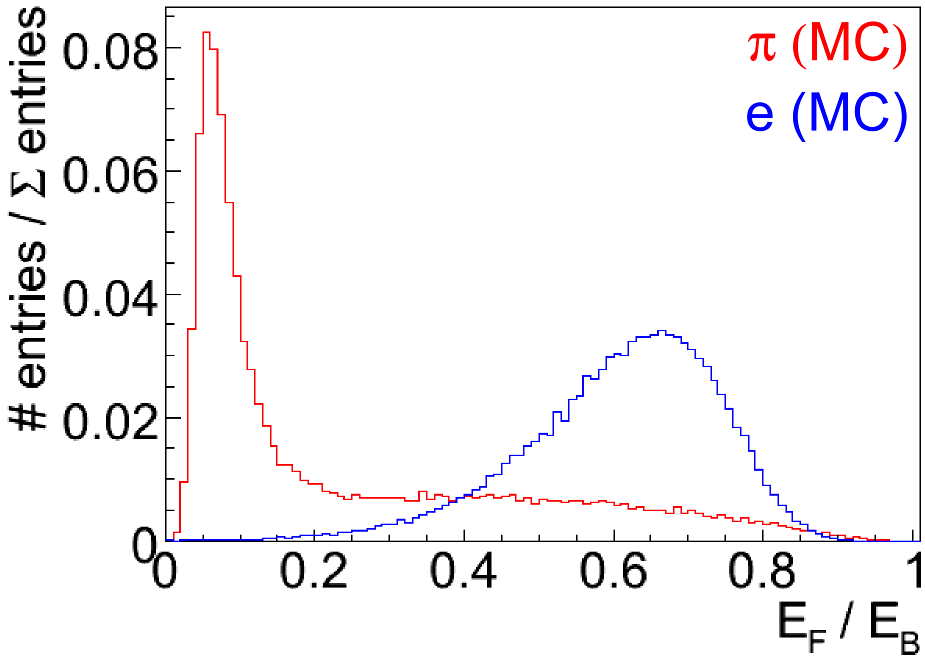
Trigger: 10x10 && ! C_{inner} && ! C_{outer}

2008: maximise e detection / rejection efficiency
→ operate at 20 psia

2009: minimise material (gas), multiple scattering and generation of knock – on electrons in Čerenkov to maximise π rate
→ operate at 2 psia

DAQ rate @ 2 psia ~factor 1.6 larger than DAQ rate @ 20 psia, π content?

e / π Separation At Low Energies



π – MC at 4 GeV

E_F = energy sum layers 1 – 5

E_B = energy sum layers 1 – 38

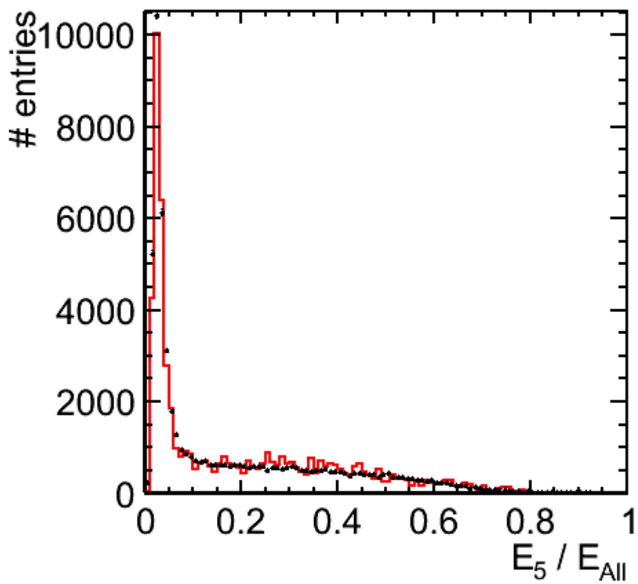
- Best variable to separate e from π at 1 – 20 GeV:

$$\frac{\textbf{energy sum (layers 1 – 5)}}{\textbf{energy sum (layers 1 – 38)}}$$

- TFractionFitter (ROOT): Fit of sum of MC distributions to data histogram
  - Input: histograms (data, π – MC, e – MC)
  - Output: fractions of π and e MC that describe the data best

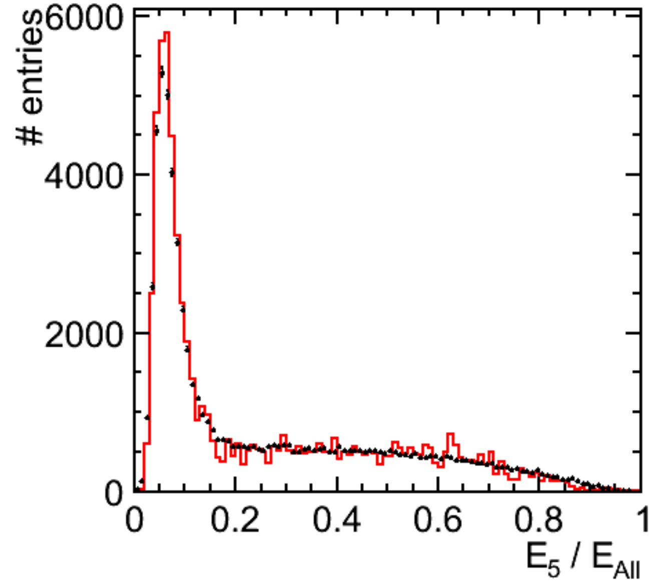
Electron Contamination

10 GeV



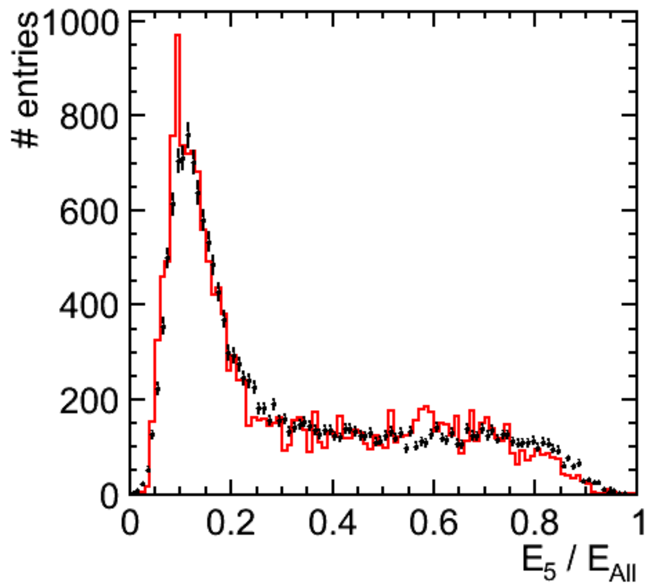
data
MC: 100% π
+ 0% e

4 GeV



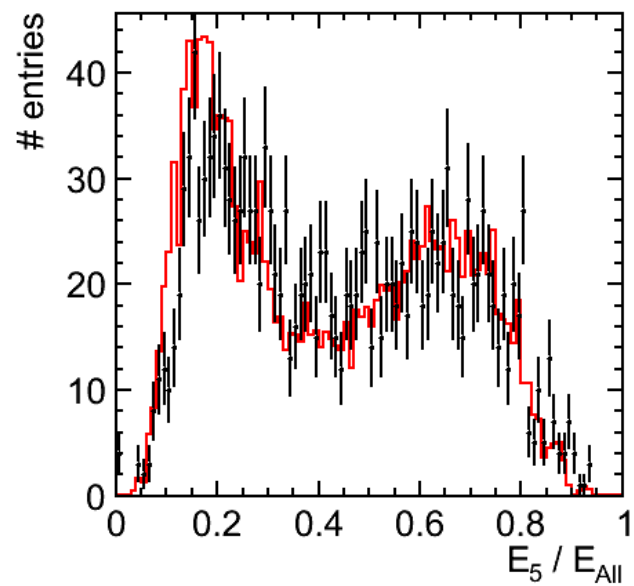
data
MC: 99% π
+ 1% e

2 GeV



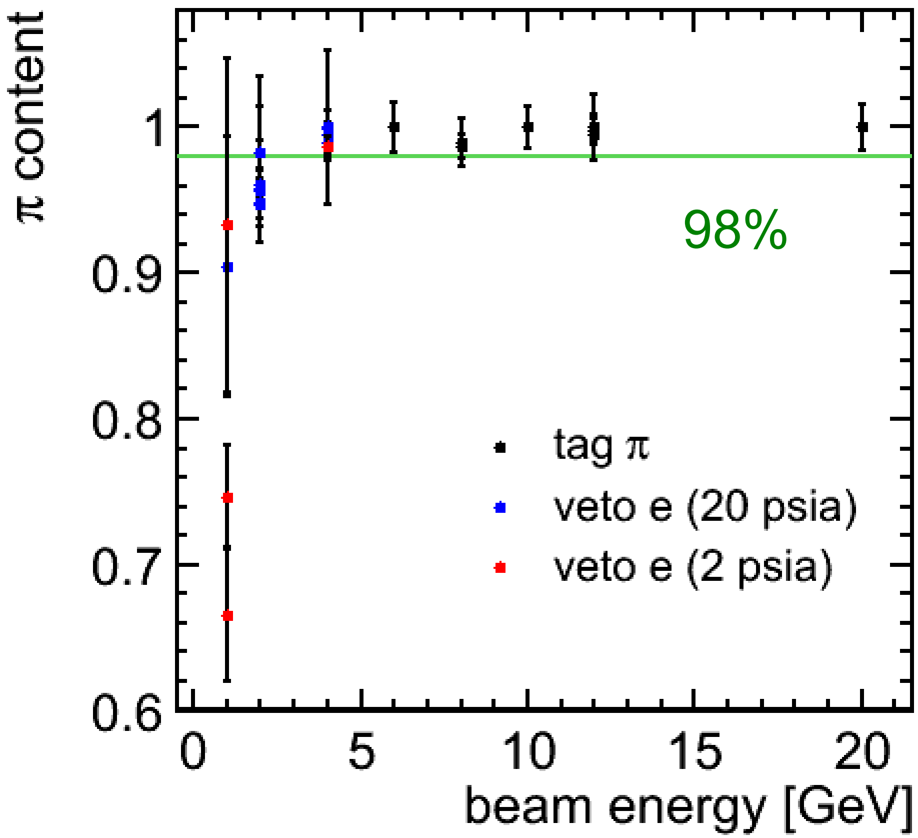
data
MC: 96% π
+ 4% e

1 GeV



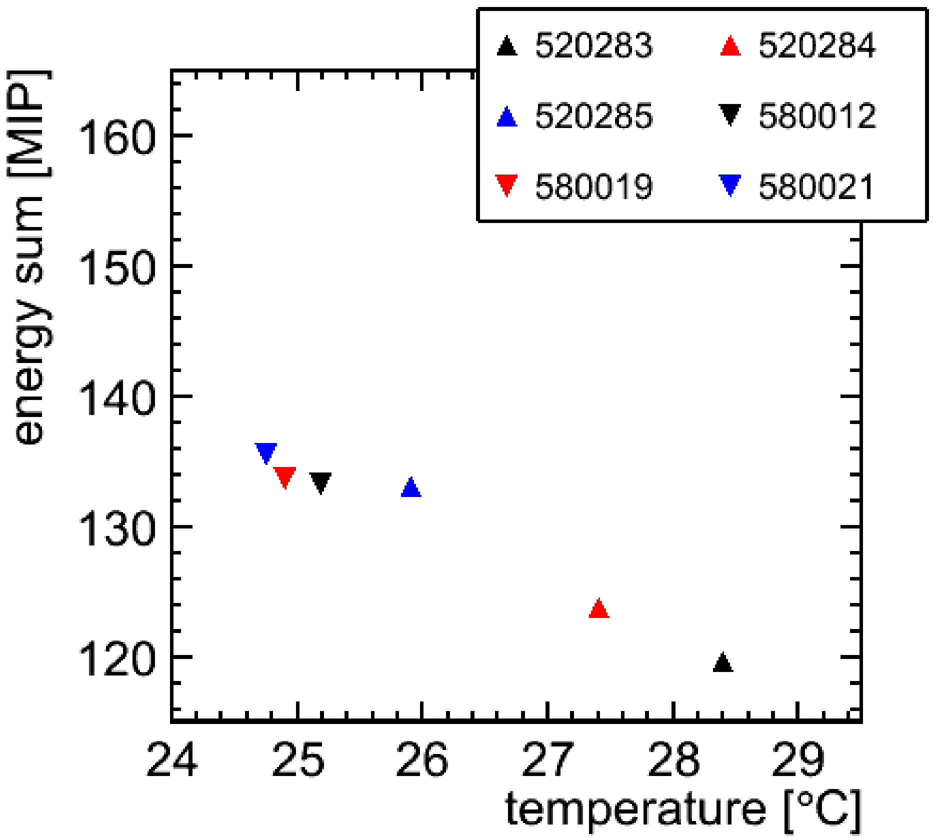
data
MC: 75% π
+ 25% e

Results For FNAL Data

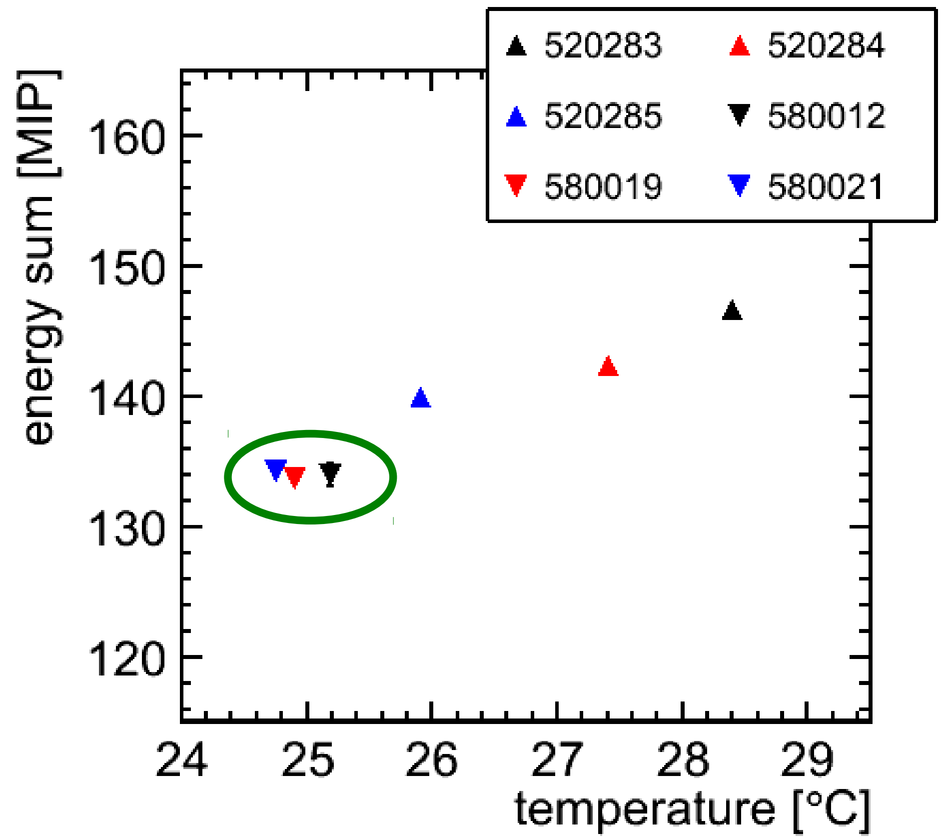


- AHCAL stand – alone running (2008, 2009)
- cuts for rejecting multi – particle and muon events applied
- > 2 GeV: e contamination neglibigle
- errors purely statistical → should be asymmetric (π content = 1 is upper limit)
- e veto: operating Čerenkov at 2 psia yields comparable purity at ~1.6 times higher DAQ rate

Temperature Correction: 4 GeV π Data



w/o temperature correction



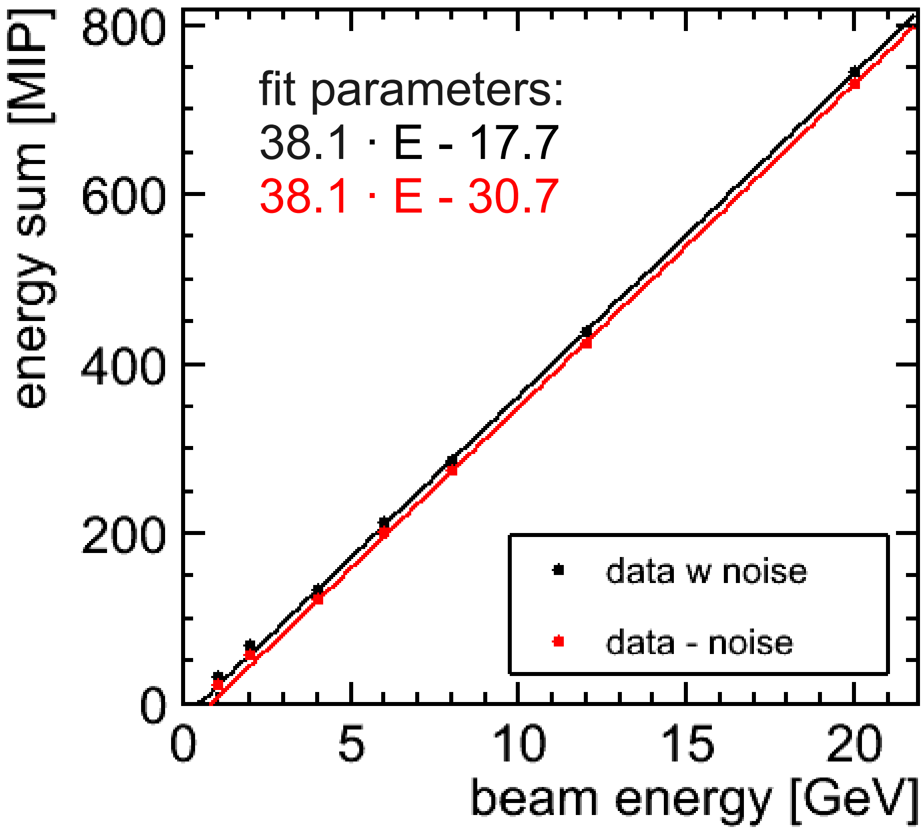
after temperature correction

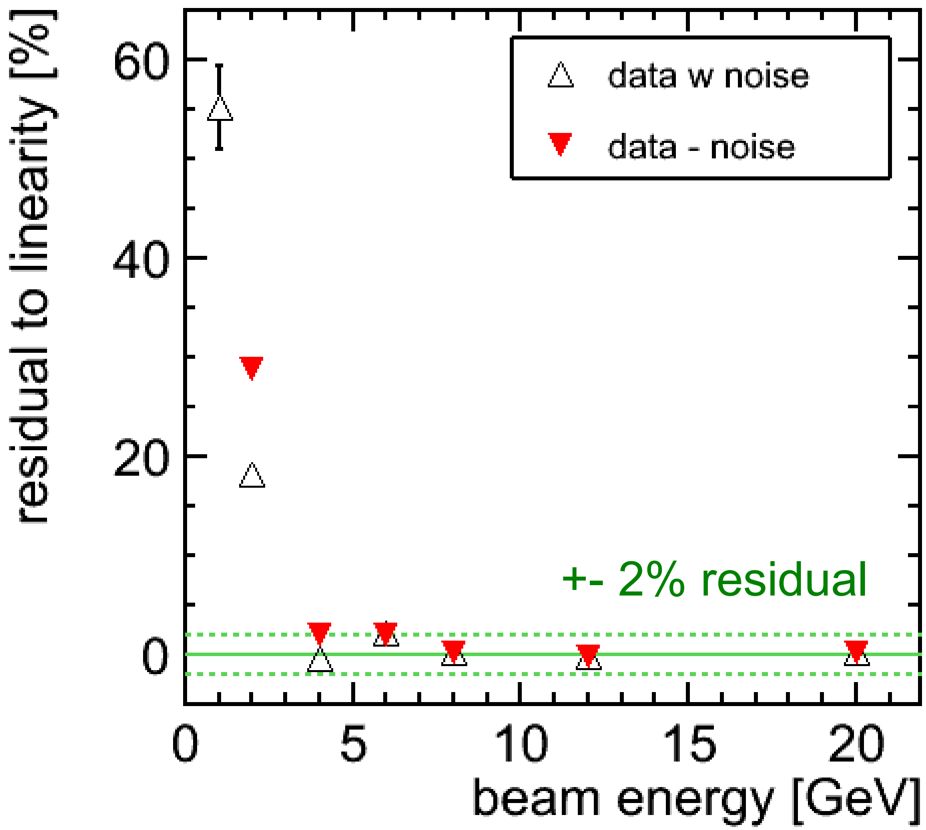
→ merge runs for analysis:
580012 + 580019 + 580021

→ similar picture for other energies

Linearity

residual = (data – line) / line

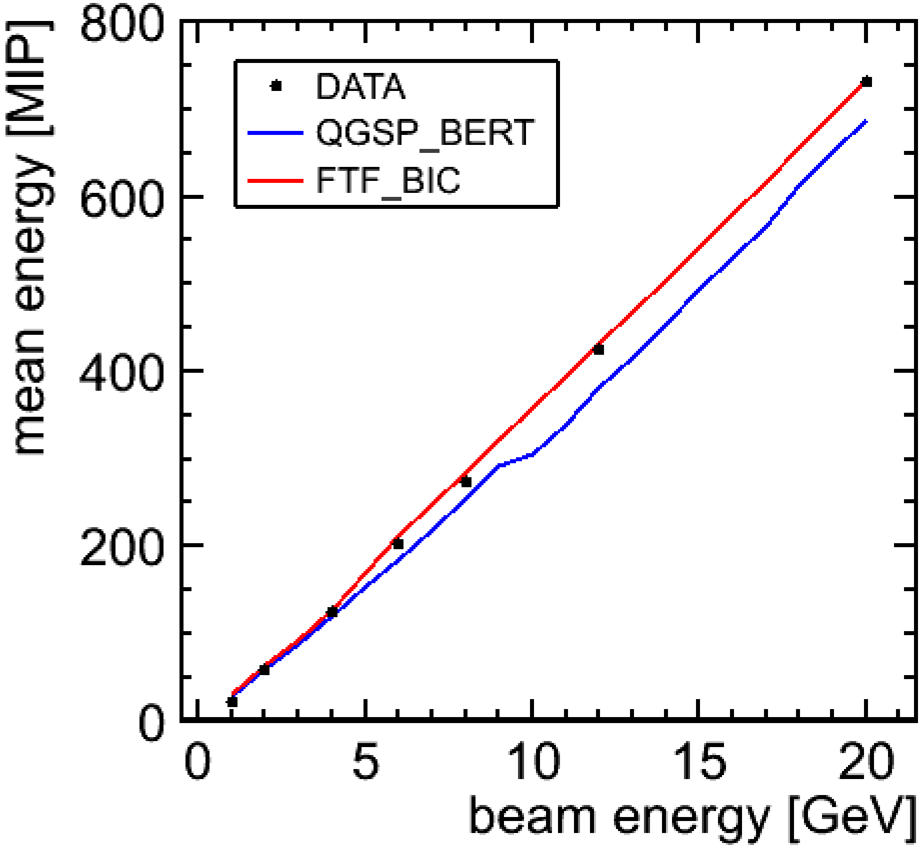


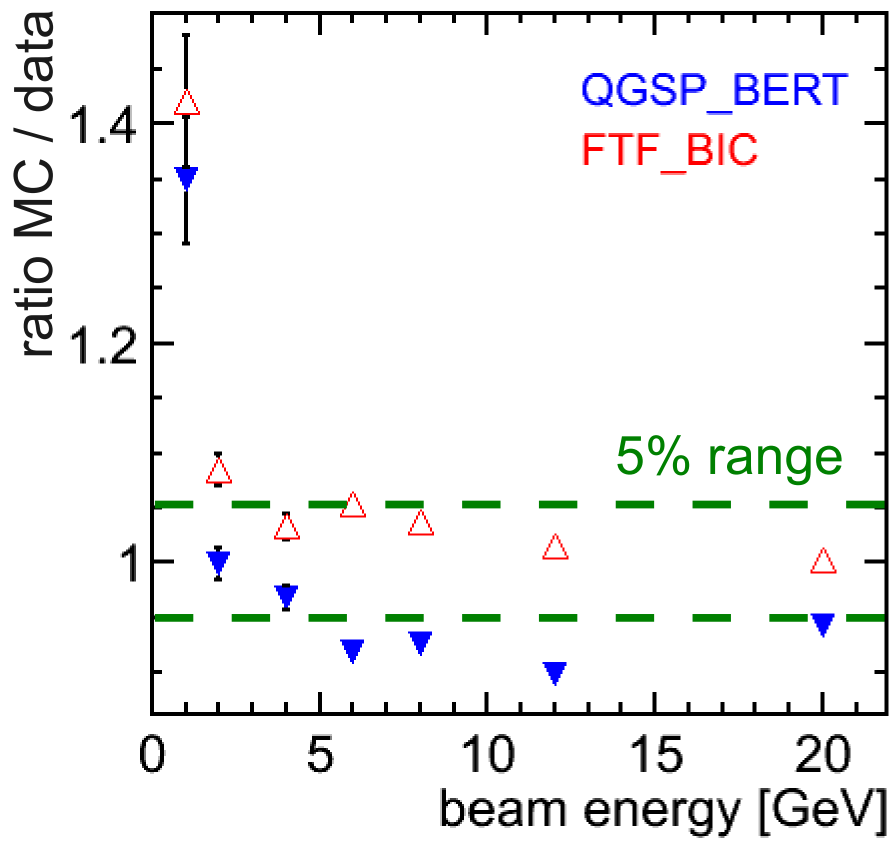


fit range for line: 8 GeV – 20 GeV

→ linearity better than 2% between 4 GeV and 20 GeV

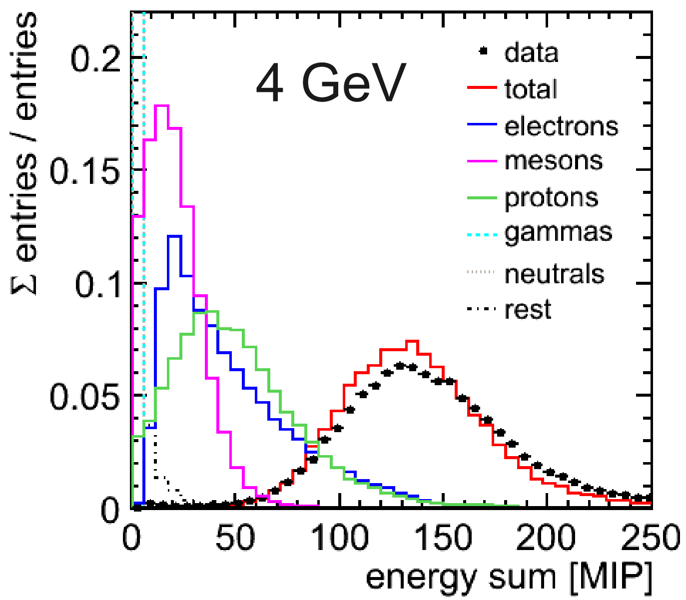
Energy Sum Data / MC





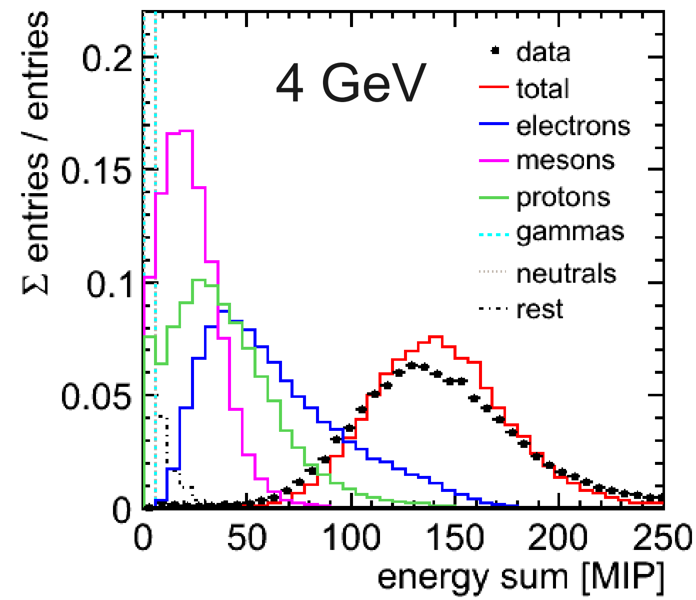
- Data and MC: mean noise subtracted
- MC data very preliminar:
  - Mip / GeV factor for 80 GeV μ calibration applied (FNAL μ: 32 GeV)
  - Particle gun placed directly in front of AHCAL center

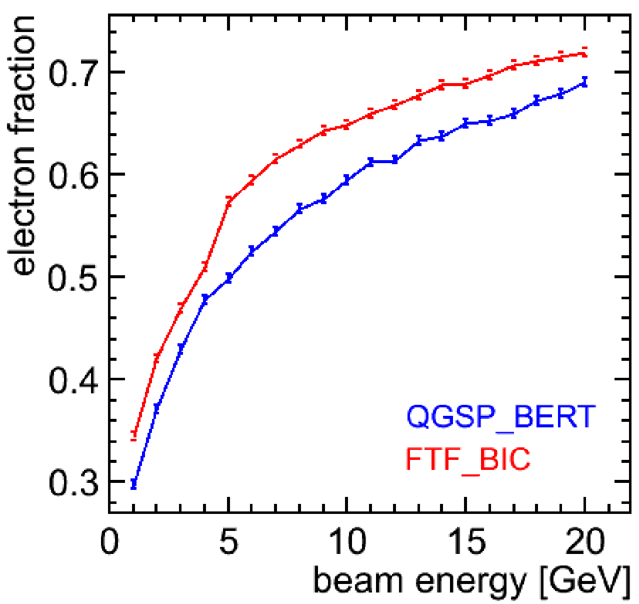
Energy Sum Data / MC



← QGSP_BERT

FTF_BIC →





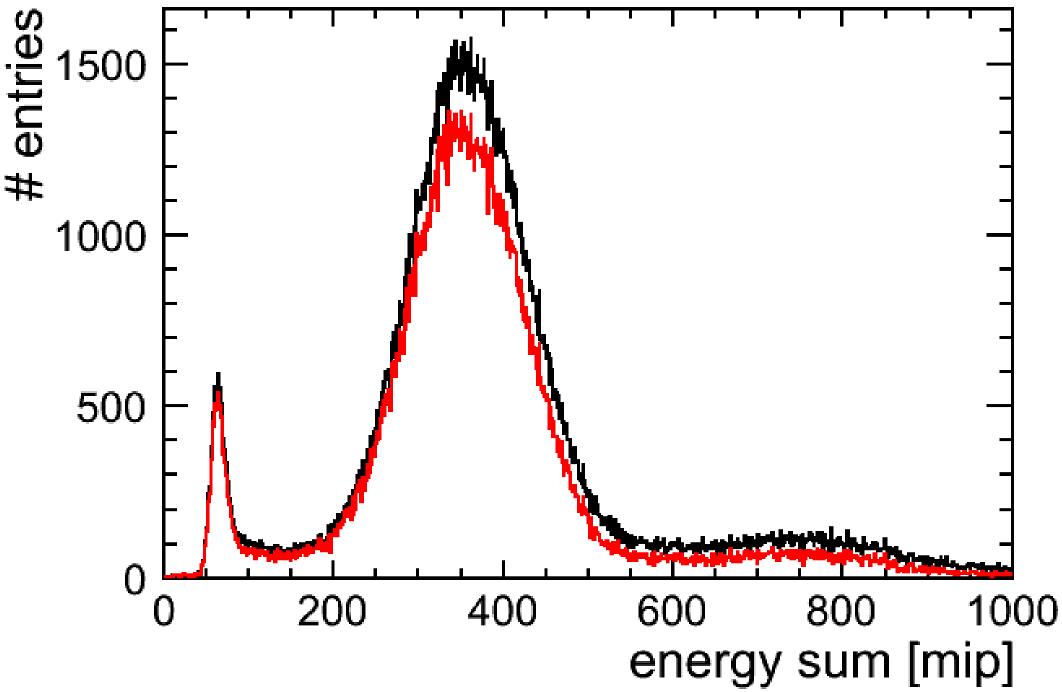
- electron fraction = $\frac{\text{mean energy sum (electrons)}}{\text{mean energy sum (total)}}$
- errors purely statistical
  → spread not reflected

Summary & Outlook

- **π content** above 2 GeV beam energy: > 98%
  → enhancement via Čerenkov trigger worked
- **AHCAL Linearity** (π data 4 GeV – 20 GeV): better than 2%
- **Data / MC comparison** using AHCAL π data from FNAL ongoing
- **Next steps:**
  - Improve simulation by applying the correct mip/GeV factor, adding missing components (Čerenkov, He tubes, FNAL instrumentation) and using the true beam position and spread
  - Check further shower properties, e.g. longitudinal profiles
  - Refine cuts for event selection
  - Investigate temperature (over-)correction

BACKUP SLIDES

Veto Wall

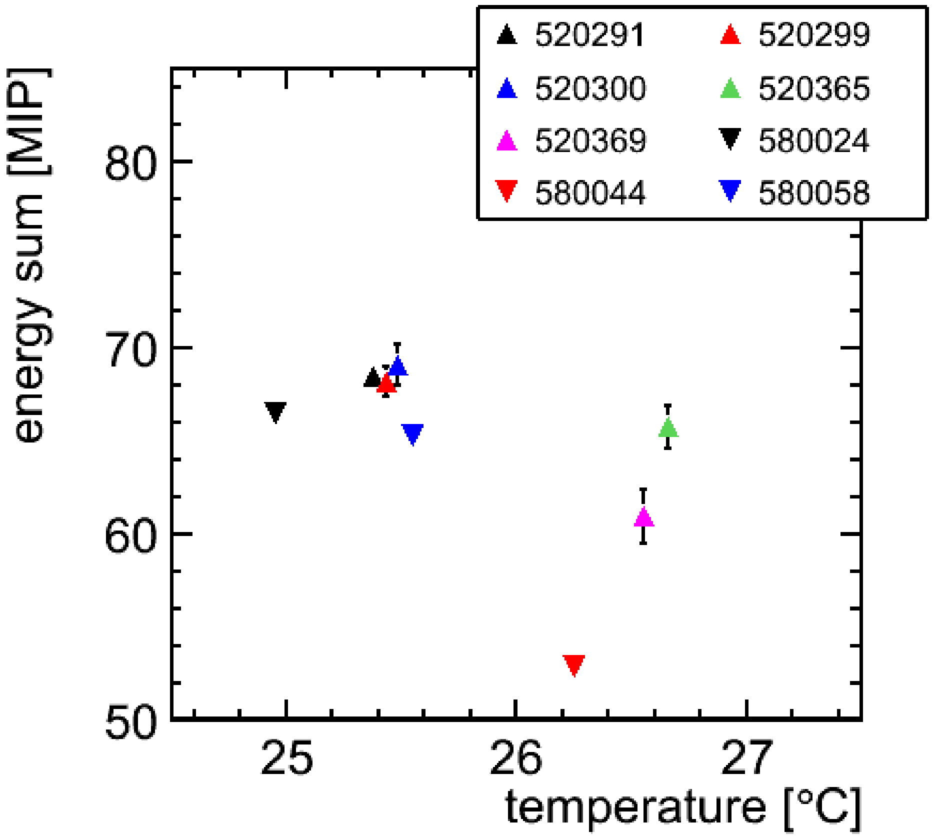


Run 520308
(-10 GeV)

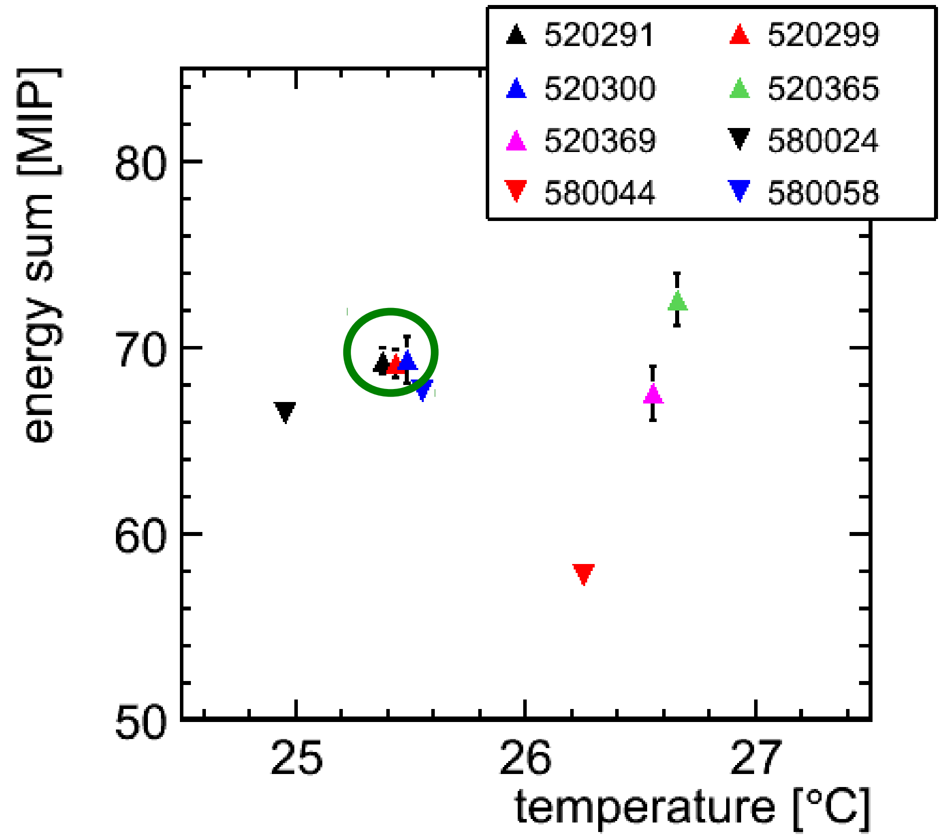
w/o cut on veto wall
with cut on veto wall

1x1 m^2 scintillator with 20x20 cm^2 hole
Reject ~10% - 40% of events (decreasing with beam energy)
no improvement of distribution visible -> do not use this cut

Temperature Correction: 2 GeV π Data



w/o temperature correction



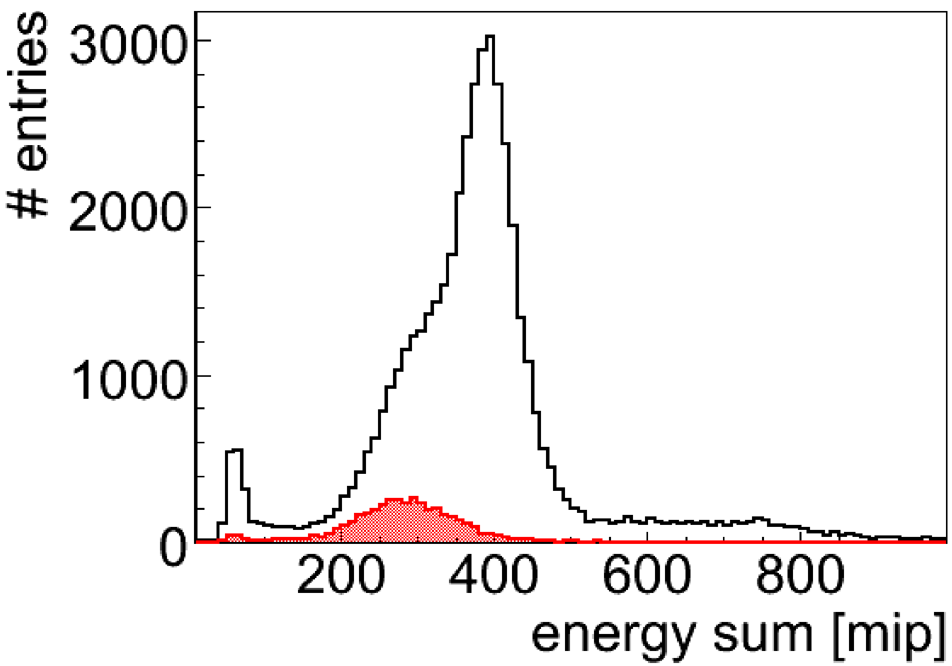
after temperature correction

→ merge runs for analysis:
520291
520299
520300

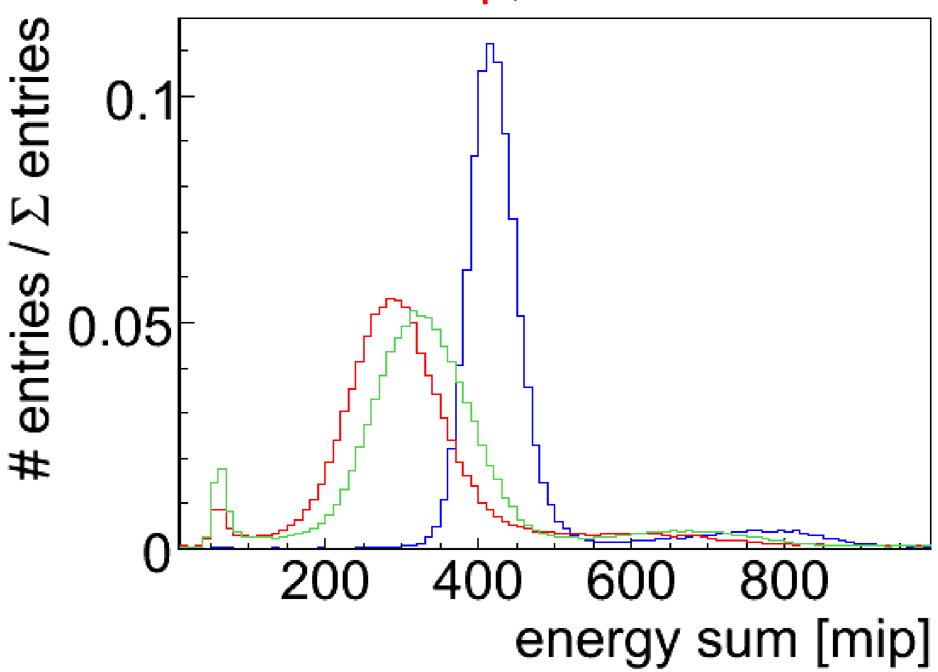
Example: Enhancing p / π / e Content

Beam energy: 10 GeV

1 run: 'mixed' data



3 different runs: p, π and e enhanced



mixed → 10x10
offline selection of p:
10x10 && $!C_{inner}$ && $!C_{outer}$
< 10 % of collected events

p → 20 psia, 10x10 && $!C_{inner}$ && $!C_{outer}$

π → 5.7 psia, 10x10 && C_{inner}

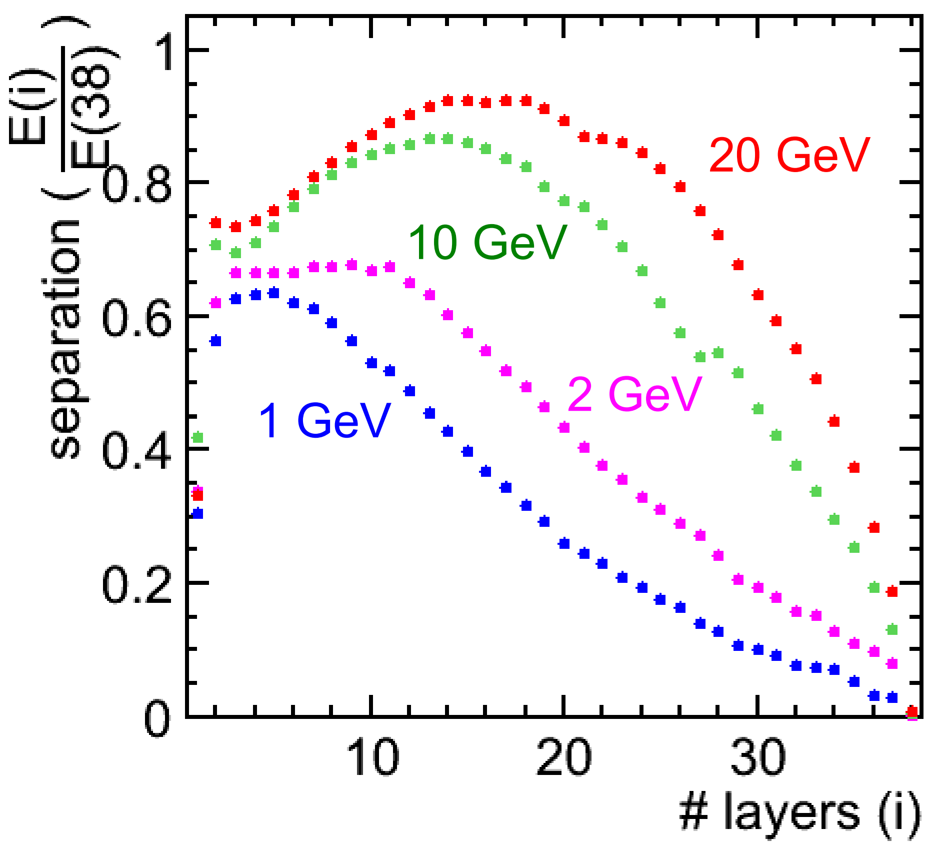
e → 3 psia, 10x10 && C_{outer}

e / π Separation Power

quantifying the convenience of various variables for e / π separation:
determine overlap between distribution for e and π (MC, normalized to 1)
separation = 1 – overlap

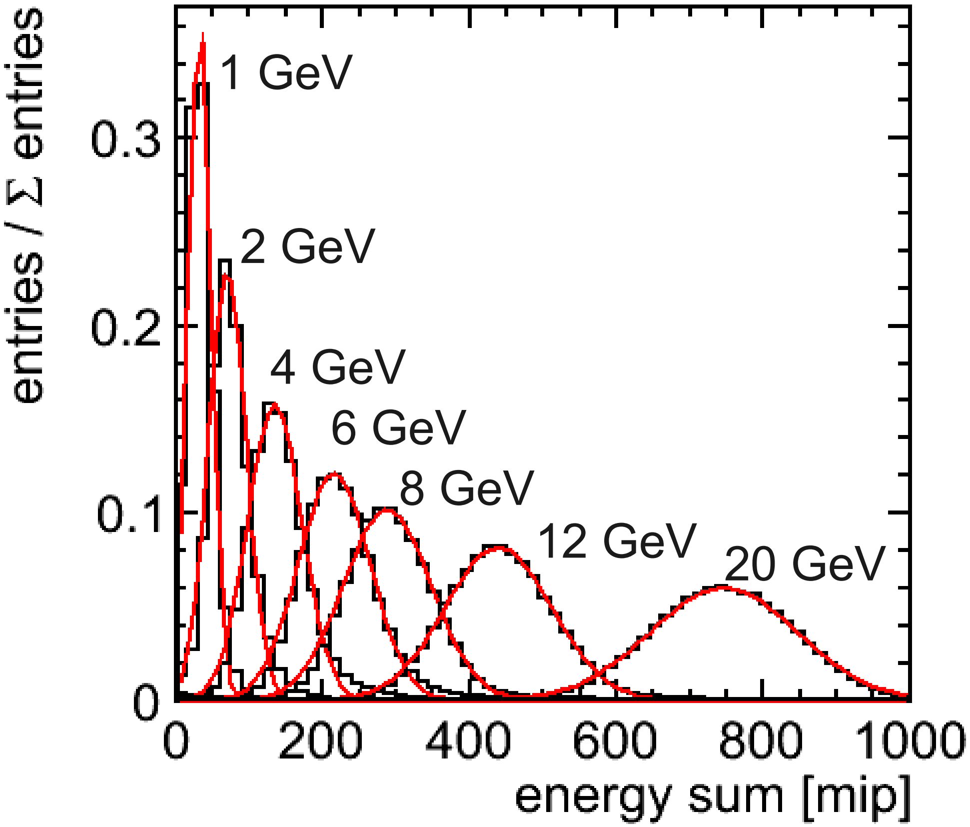
	separation	
	1 GeV	20 GeV
E (all)	27%	70%
#Hits (all)	22%	94%
E / #Hits (all)	18%	95%
E (5)	67%	77%
E (5) / E(all)	61%	71%
E (5) / E(10)	50%	48%
E (16) / E(all)	36%	89%

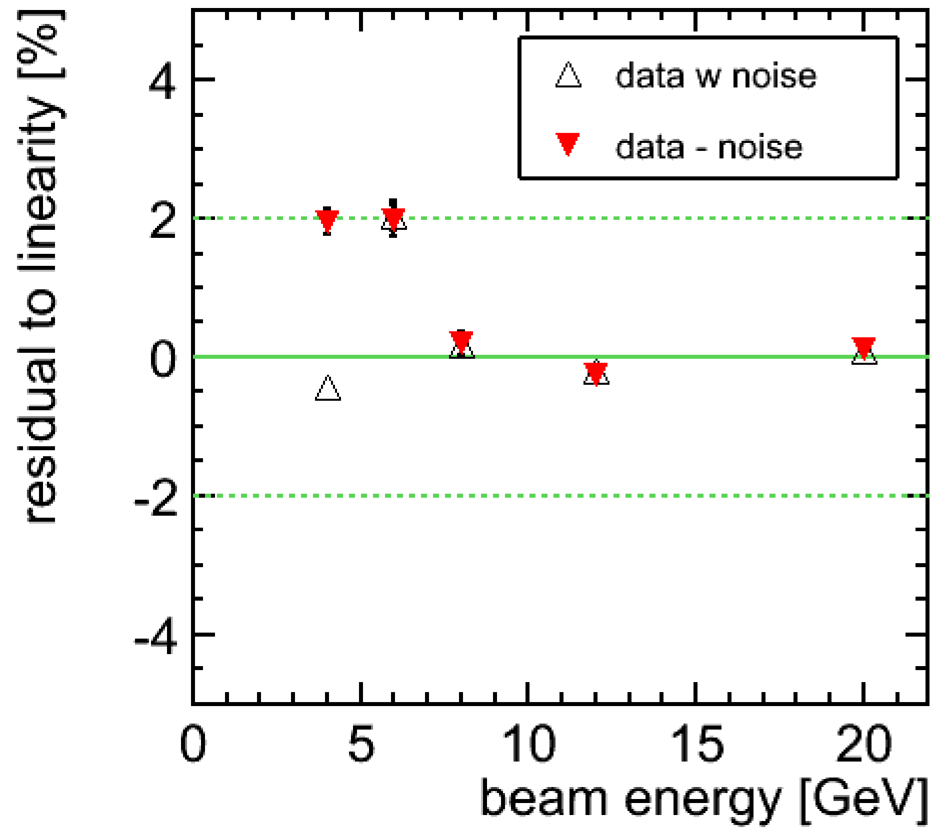
E (i) = Σ E (layers 1 – i)



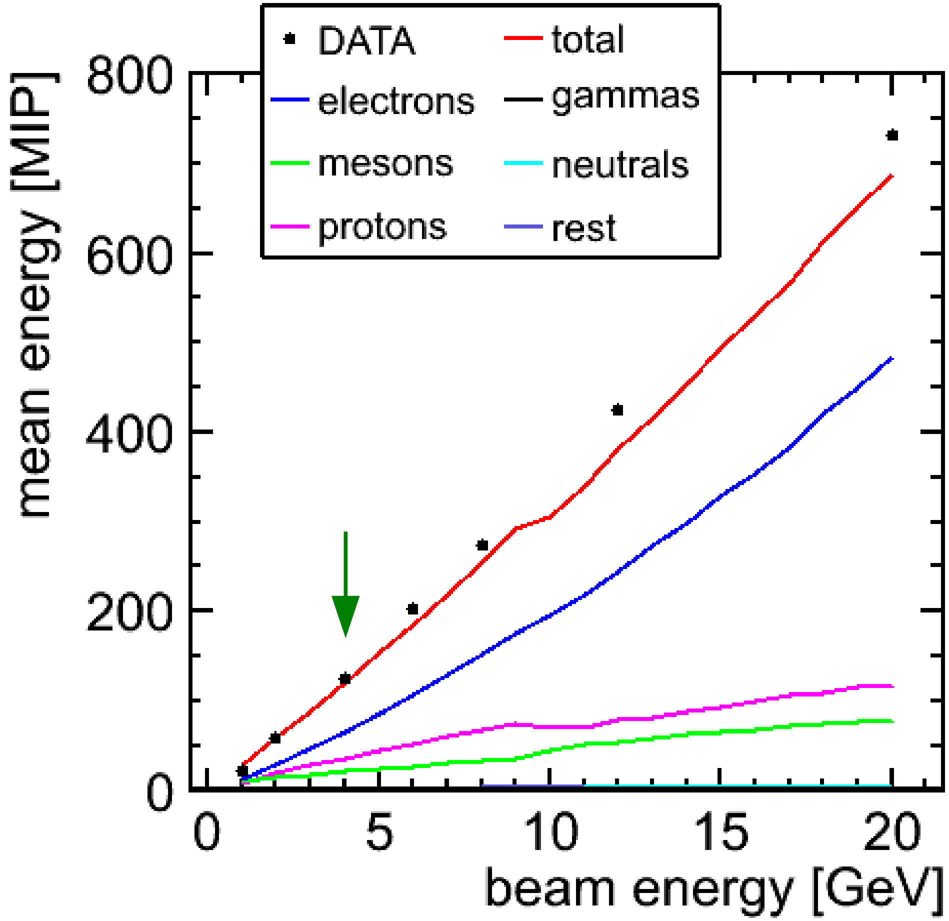
Reconstructed Energy

residual = (data – line) / line

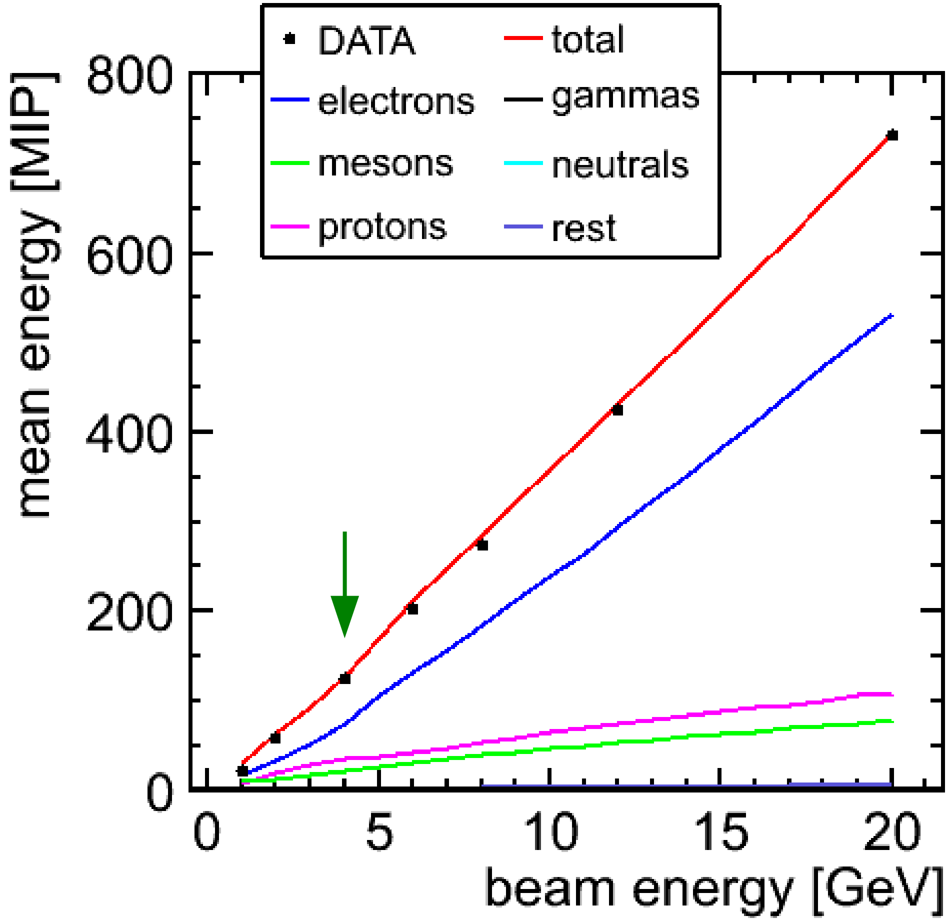




Energy Sum Data / MC



QGSP_BERT



FTF_BIC