Intercalibration of ECAL with Cosmics

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Motivation, Concept, Issues

Tests at PSI

Simulations

Conclusions

Motivation

ECAL has 36 (+ 1 spare) Supermodules, each with 1700 Xtals

Only 1 tested in beam in 2004

No test beam 2005,   maybe not 2006

Wish: few % inter-calibration of channels before LHC

Some success transporting lab measurements (MeV signals!)

Fast intercalibration with jet trigger at start of CMS should work

A pre-calibration with cosmics will:

- ensure each channel is properly tested
- provide intercalibration at few % level
- ensure systems (eg monitoring) are maintained

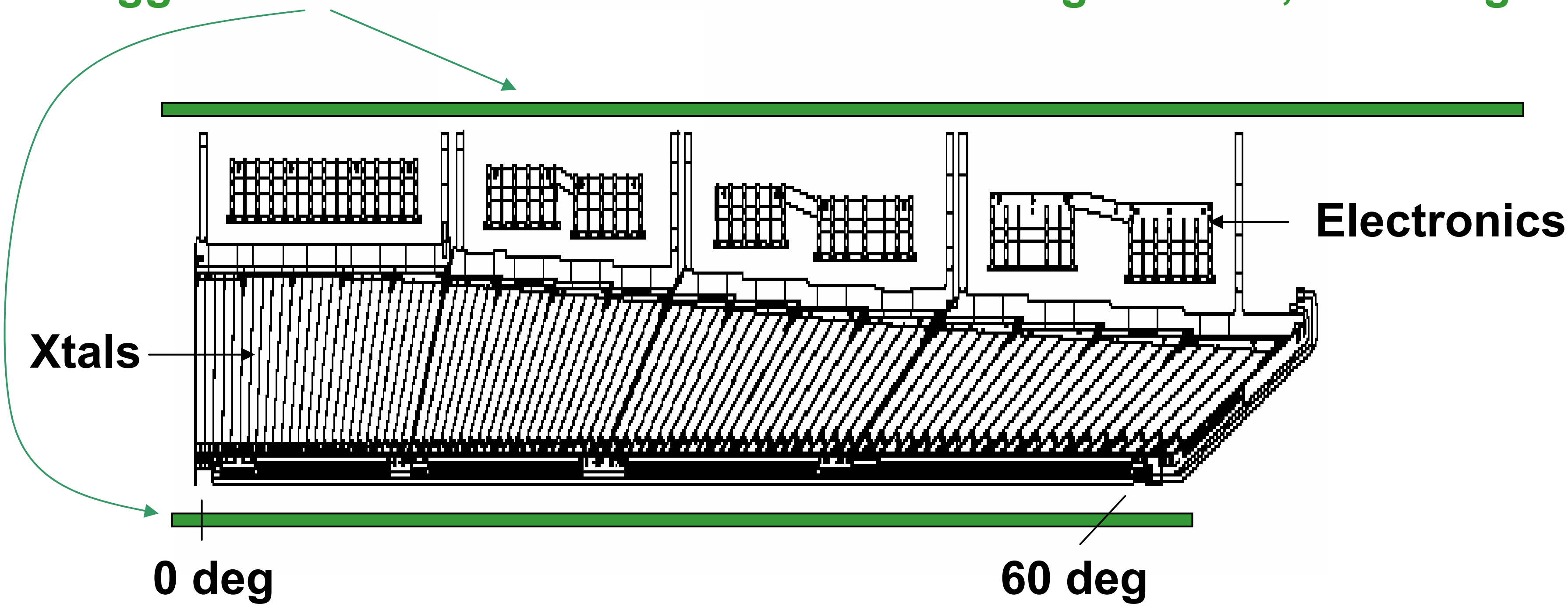
Supermodules in Storage

ca 3 x 0.5 metres, 2 tonnes

(Yellow frames for transport)

Concept

Trigger scintillators above and below covering full area, solid angle



Muon MUST enter/leave <u>same Xtal</u> through back/front face:

- wire chambers above and below (?)

Issues

SIGNAL: Cosmic muon traversing full length of Xtal:
- deposits ca 250 MeV,
- generates ca 1000 photo-electrons in APDs

NOISE: Electronics noise: 40–50 MeV rms, channel dependent:

➔ raise APD gain from 50 to 200. S/N then 20

(Track gain with monitoring system)

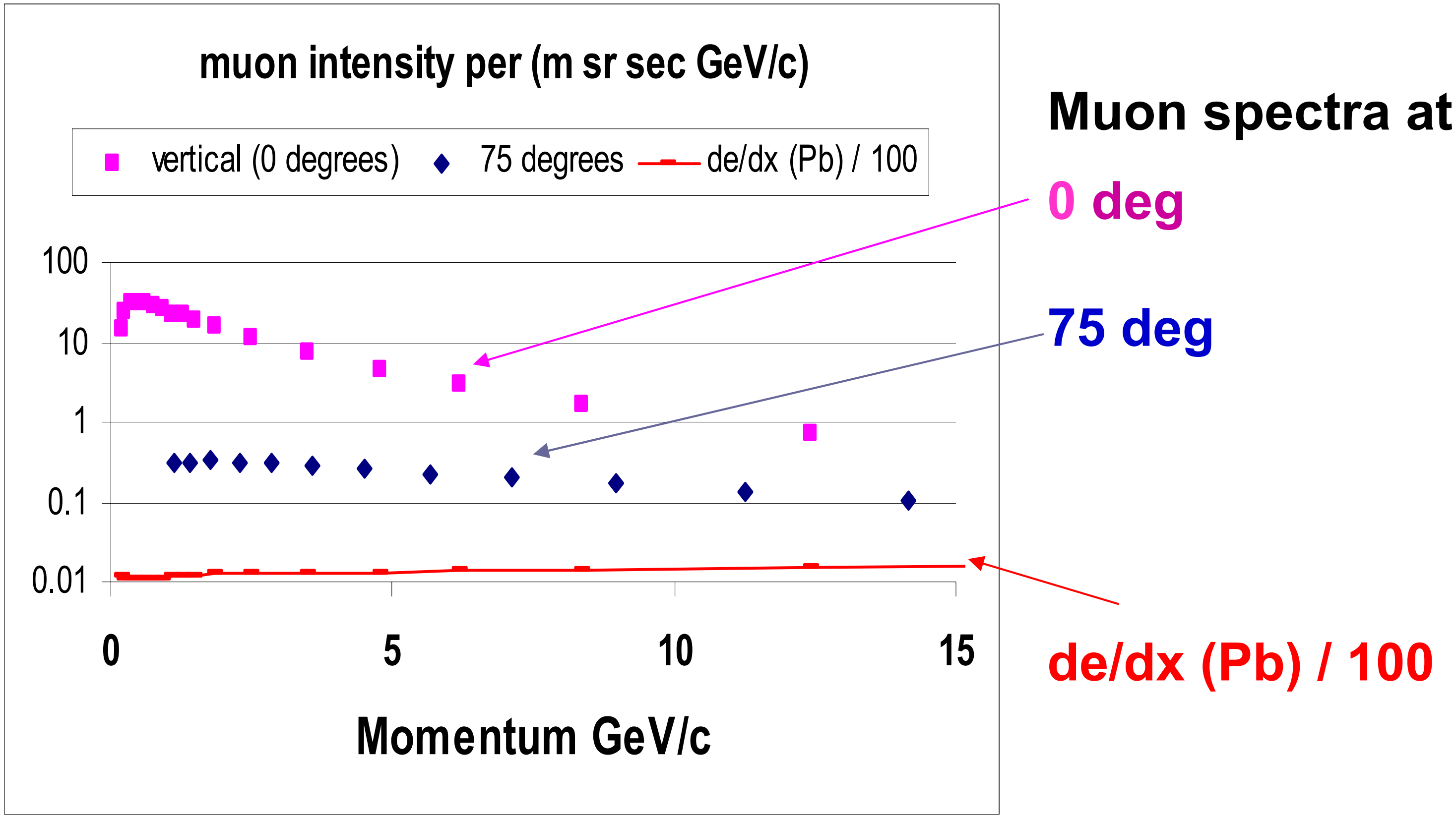
RATE: 300 /wk at 0 deg. ~ $\cos^2(\Theta)$ → 75/ wk at 60 deg

SYSTEMATICS: Smooth eta-dependence (P_μ , geometry). Other?

NUCLEAR COUNTER EFFECT: Adds ca 100 MeV to 10% of events

ABSORBER ABOVE LOWER SCINTILLATOR? N tonnes (no)

Cosmic Muon Spectrum



Muon spectrum gets harder with angle – signal will change with eta

Protons, electrons negligible

Tests at PSI

K. Deiters, Q. Ingram, D. Renker, T. Sakhelashvili

Feasibility study to check

a) Decent signal
b) Rate estimate
c) Effect of absorber in trigger

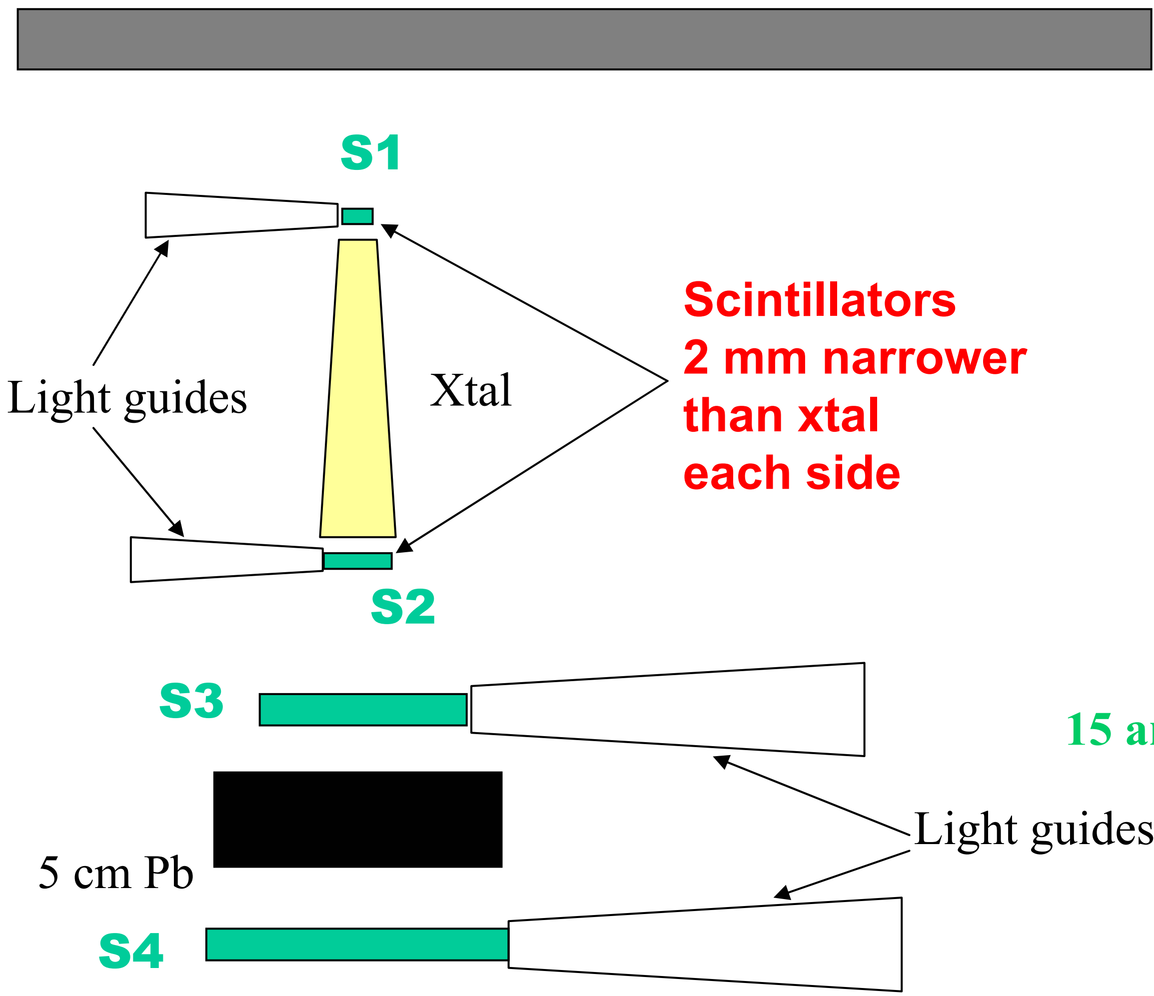
Set-up:

1 Xtal wrapped in Tyvek
APD gain 250
Amplifier noise 6 MeV rms (cf 250 MeV signal)
Trigger scintillators restrict entry, exit
Lead brick
Temp. correction (20–30 deg): - 8.5% /deg

Measured:

0 deg, 65 deg
13 deg with/without Xtal wrapped in 3 mm Pb

Tests at PSI (0 deg set-up)



30 cms concrete ceiling

Geometry not exact.

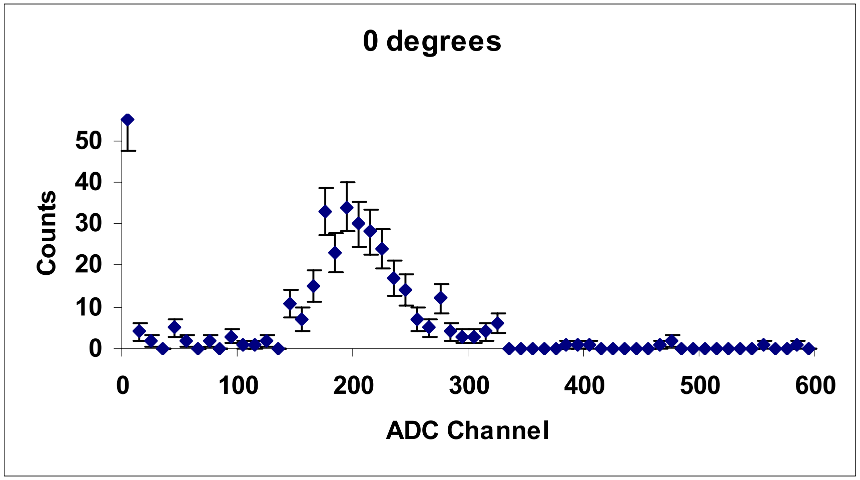
Trigger: S1.S2

Hits in S3, S4 recorded

S3 and S4
15 and 22 cm square paddles

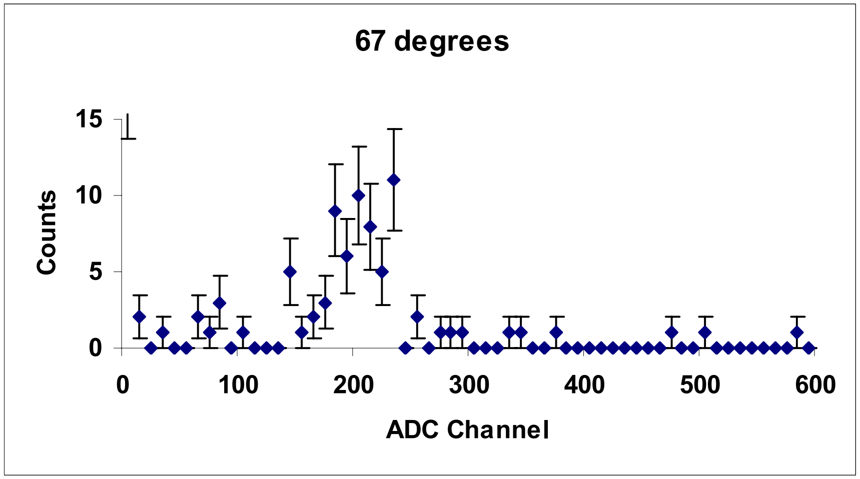
Paddle light guides at
90 deg to small counters

Results of Tests at PSI



0 deg; 11 ¾ days

Gaussian fits give σ = 14.5 %



67 deg; 15 days

Conclusions from Tests at PSI

Clear signal 0, 13 and 65 deg, σ ~ 15%

Rate in line with expectations

No need for absorber

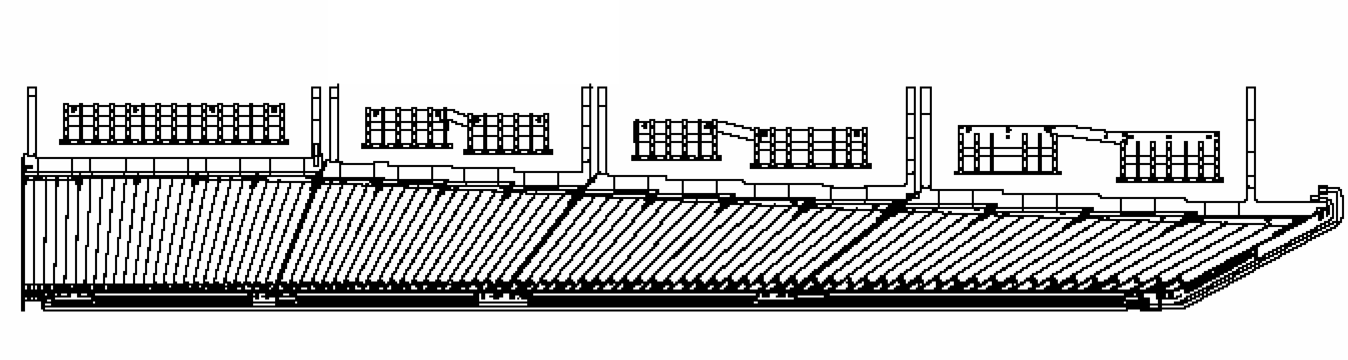
No big difference if Xtal wrapped in Pb
(to simulate Xtal in matrix)

{ Multiple coincidences needed for clean trigger
(eg suppress coincidence from light guide Cerenkov) }

Statistical accuracy:

15/Sqrt(300) = 0.9% per week (0 deg)
and 1.8% (60 deg)

Practicalities with a Supermodule



3 m long; 0.5 m wide at back ***(i.e. above in this picture*****)**

Xtals point divergently at back

± 6 deg acceptance per Xtal for full solid angle

Cannot get detectors close at back (electronics etc)

➔ Detector scale: 5 x 1 m at back; 3 x 0.6 m at front

Defining Muon Trajectories

ESSENTIAL: trajectory must enter front and leave back of SAME Xtal

Original idea: Use surrounding Xtals as veto. No chambers (simple).

But: Noise means veto level must be ~10-15% of signal.
Not sure it would work (no simulations).

Next idea: Define trajectories with wire chambers. Only practical chambers found are CMS Muon Drift Tubes (DTs).

But: DTs designed for multi-GeV, normal incident muons: good resolution but massive → multiple scattering

- cannot give mm resolution at Xtal entrance/exit
- performance "deteriorates" at large angles (eg ≥ 45 deg)

Defining Muon Trajectories

Simulations: With realistic estimates of multiple scattering
- signal has long wings
- rate falls fast with (ineffective) tight geometrical cuts

➔ abandon idea of using chambers for tight cuts

But now simulate applying vetos by adjacent Xtals –

Final idea: Use surrounding Xtals as veto, with
One chamber ONLY at front face (closer, smaller)
and apply loose cuts on trajectory

Simulations

Thanks to W Bertl (PSI) & E Frlez (U Virgina) for supplying the working GEANT package

Based on GEANT simulations developed and tested at PSI.

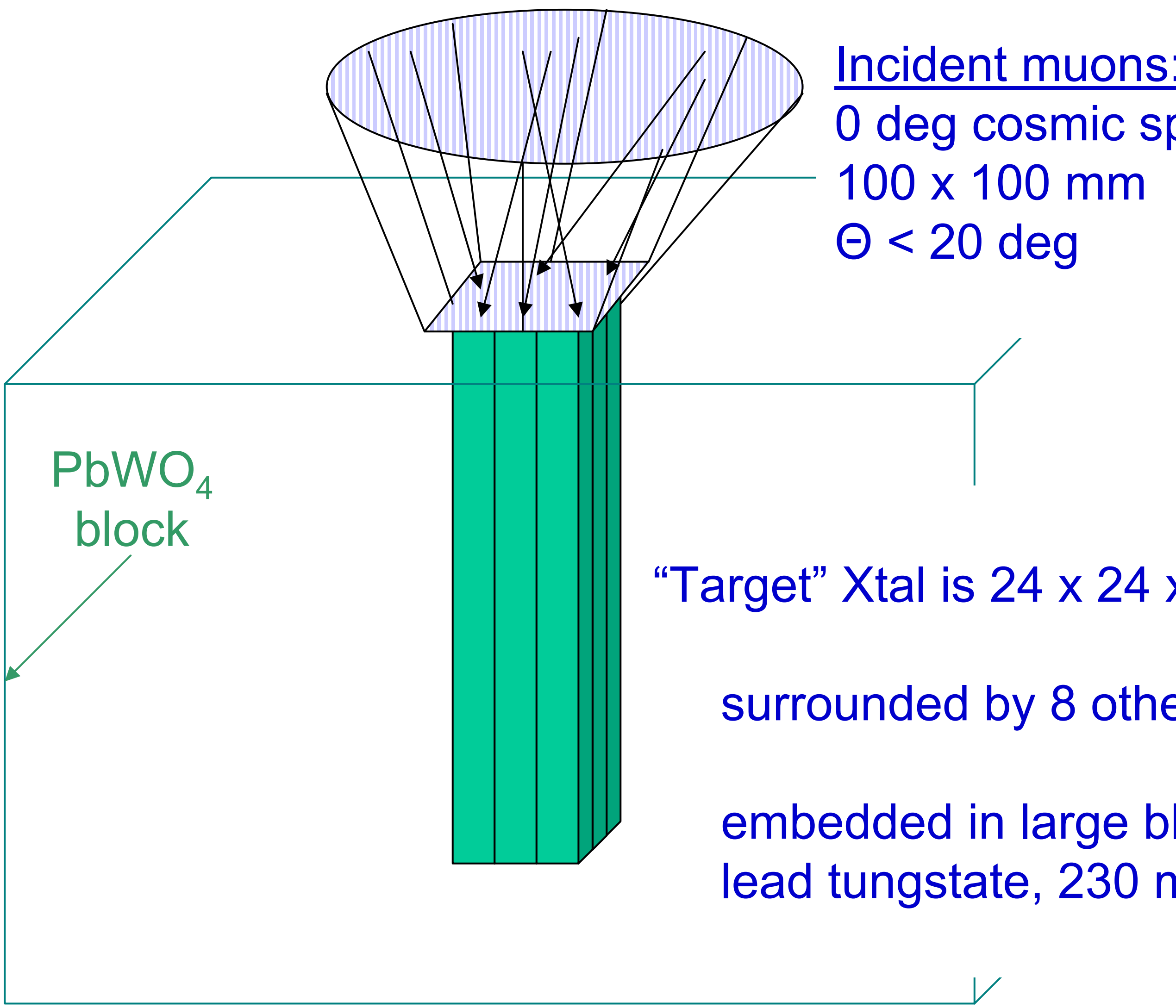
Input: vertical cosmic ray muon flux truncated at 10 GeV/c

Xtal defined as 24 x 24 mm square rod in centre of 23 cm thick block.

8 similar Xtals defined around central one

Uniform illumination of 10 x 10 cm area with Xtal at centre and incident angle < 20 deg.

GEANT Input



Incident muons:

0 deg cosmic spectrum

100 x 100 mm

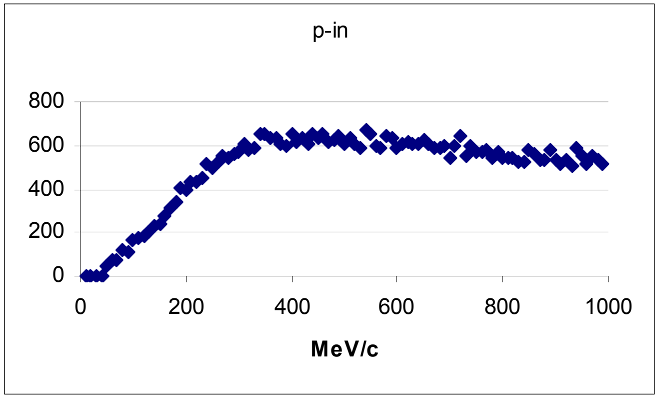
Θ < 20 deg

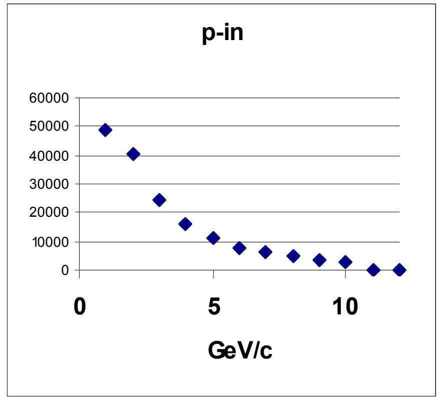
“Target” Xtal is 24 x 24 x 230 mm rod

surrounded by 8 other Xtals,

embedded in large block of
lead tungstate, 230 mm thick

GEANT Muon Spectrum

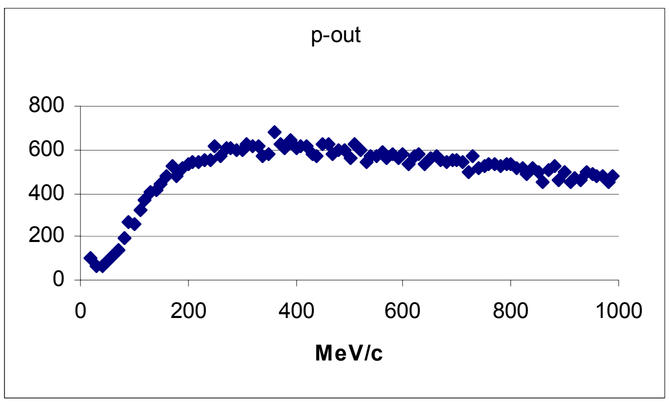




0 – 1 GeV/c

0 – 20 GeV/c

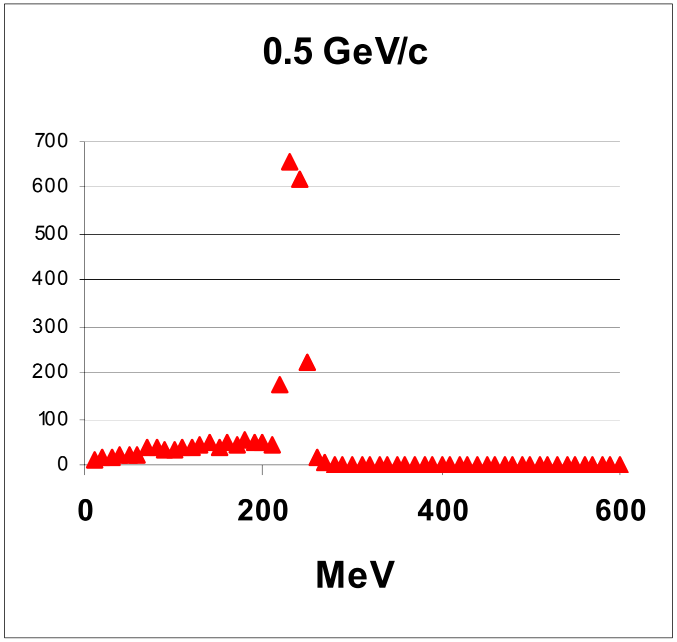
Incident momentum spectrum reasonable.

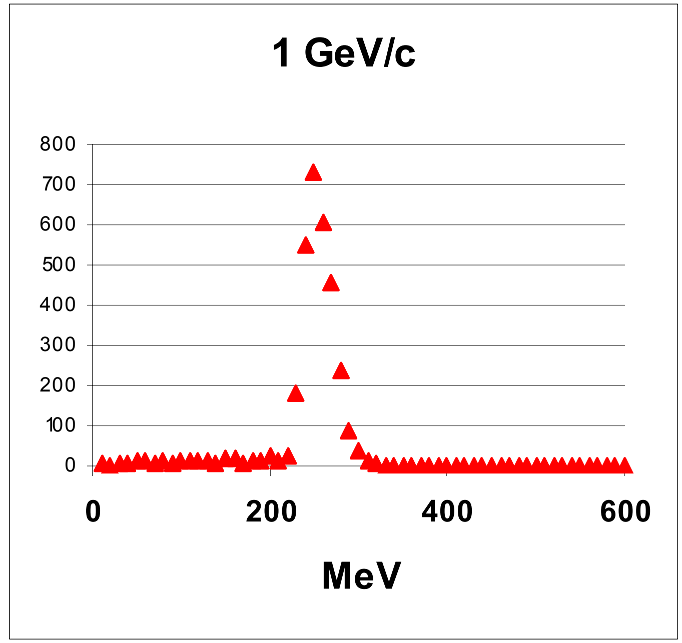


P-out

0 – 1 GeV/c

Energy deposited in Target Xtal (GEANT)





Monoenergetic muons, with clean cuts on entrance and exit positions

Tail at 0.5 GeV/c due to muons leaving Xtal and then scattering back in.

Simulations

<u>Smear coordinates</u> based on estimates of spatial resolution:

Showed using tight geometrical cuts with likely resolution still leaves long tails and with quickly reduced rates

<u>Apply Veto:</u> on largest energy deposit in single neighbouring Xtal

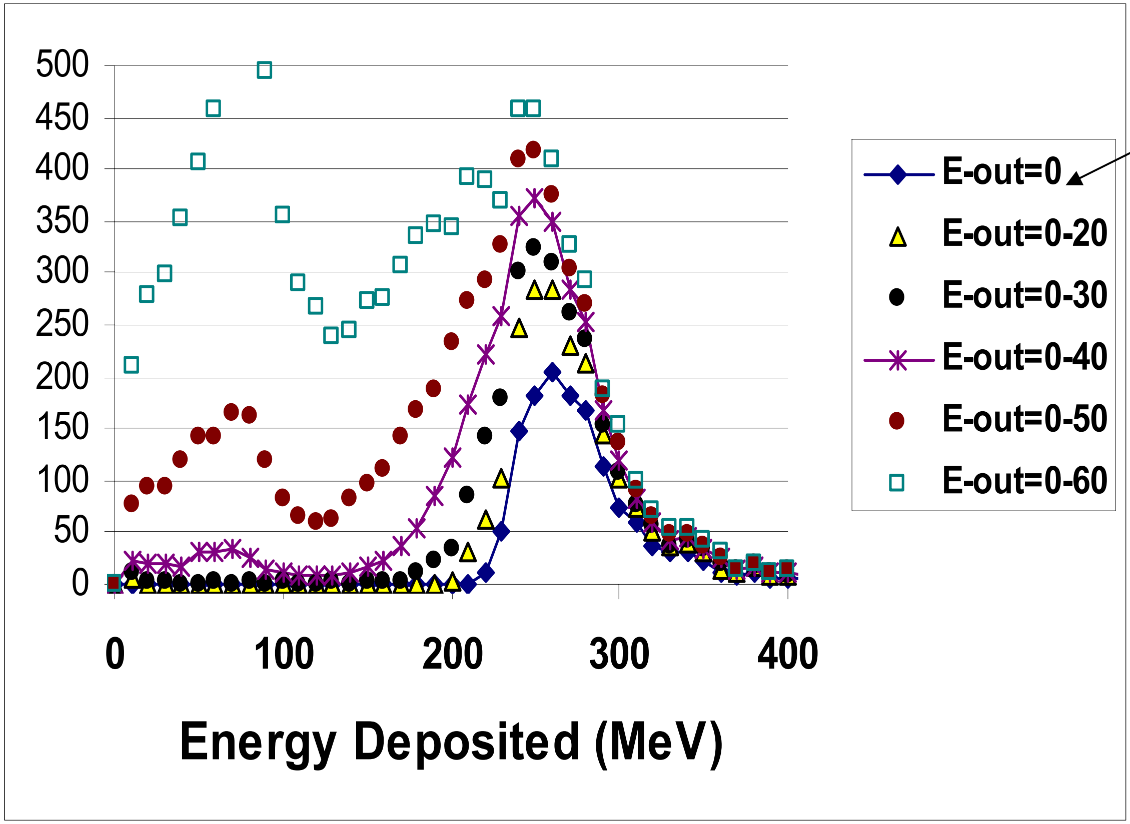
Loose geometrical cuts – i.e. smearing is effectively almost ignored, but track roughly correct.

Simulated Spectra vs Veto Level

PAUL SCHERRER INSTITUT

Energy deposited as function of veto level set on neighbouring Xtals.

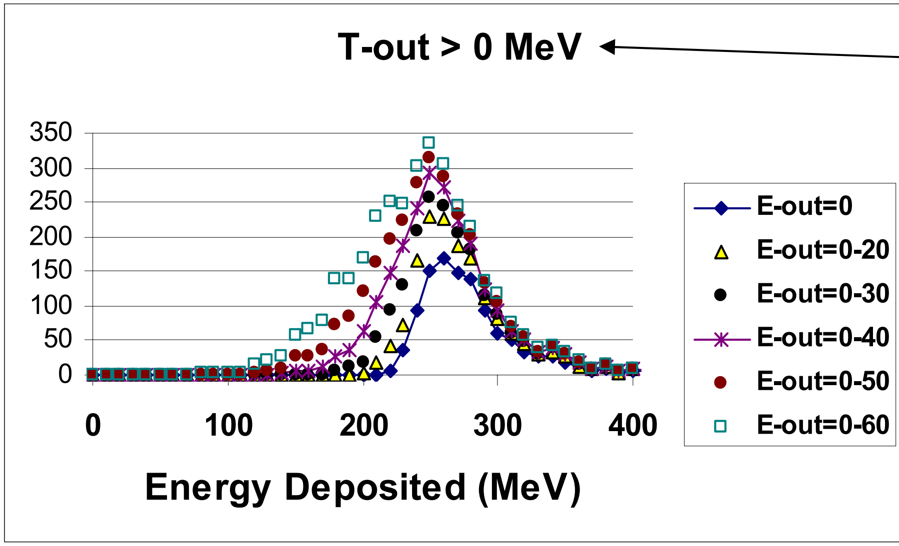
No additional cuts {i.e. “no chambers” but |x|, |y| < 5 cm, Θ < 20}



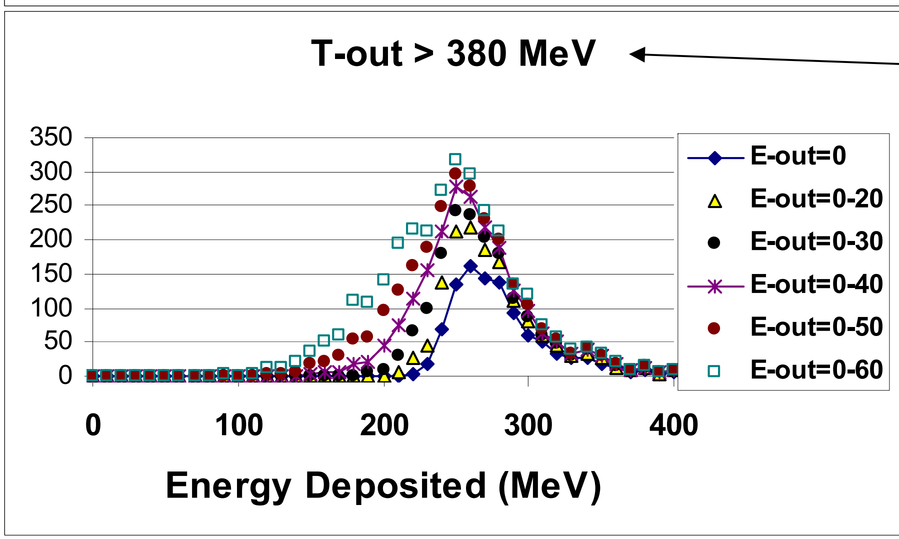
Veto Level (effective MeV)

Practical possible level around 35 MeV

1 Chamber at Front, Loose Cuts



No Absorber above trigger scintillator

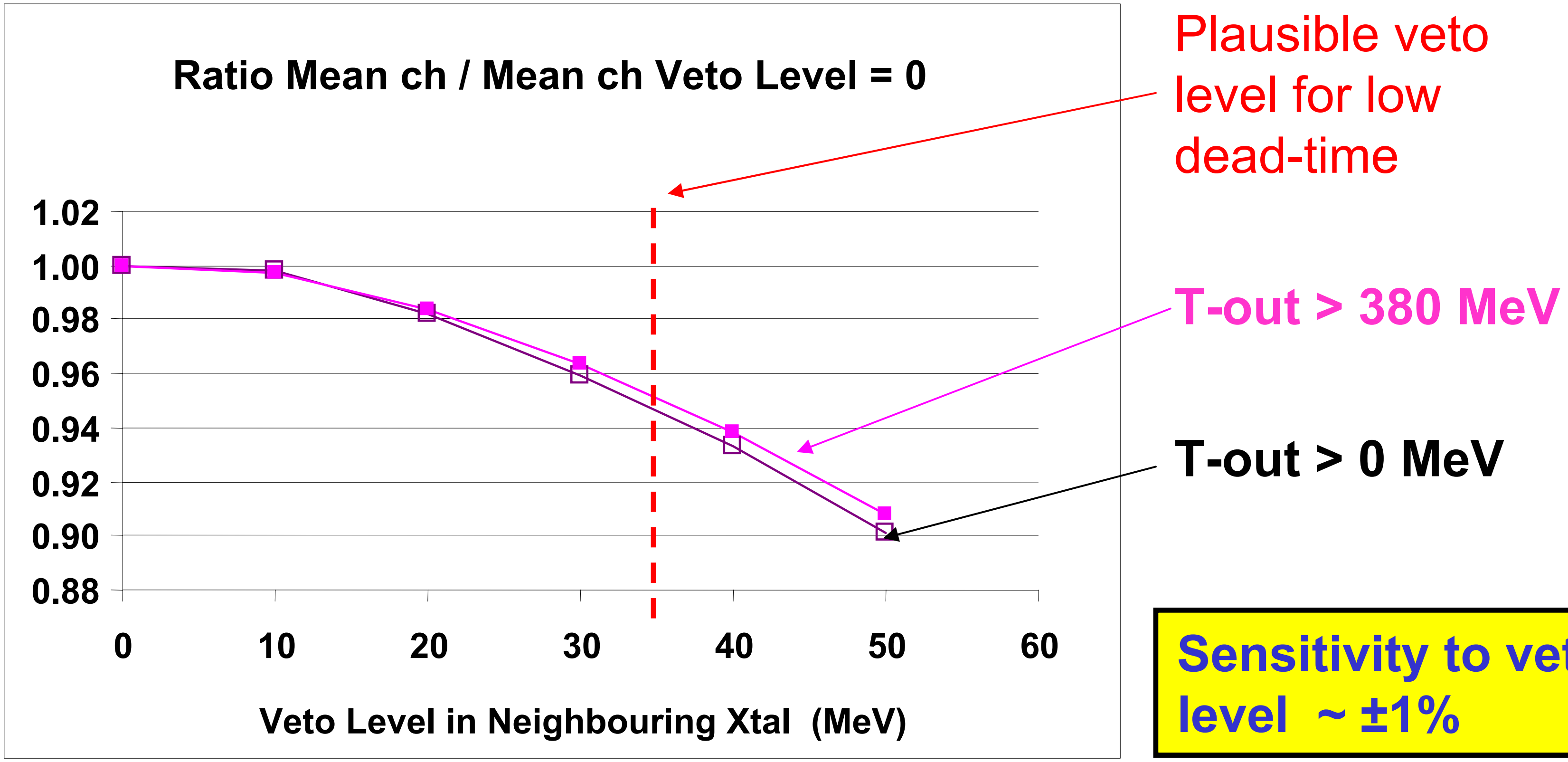


With 30 cm Fe Absorber

No significant change

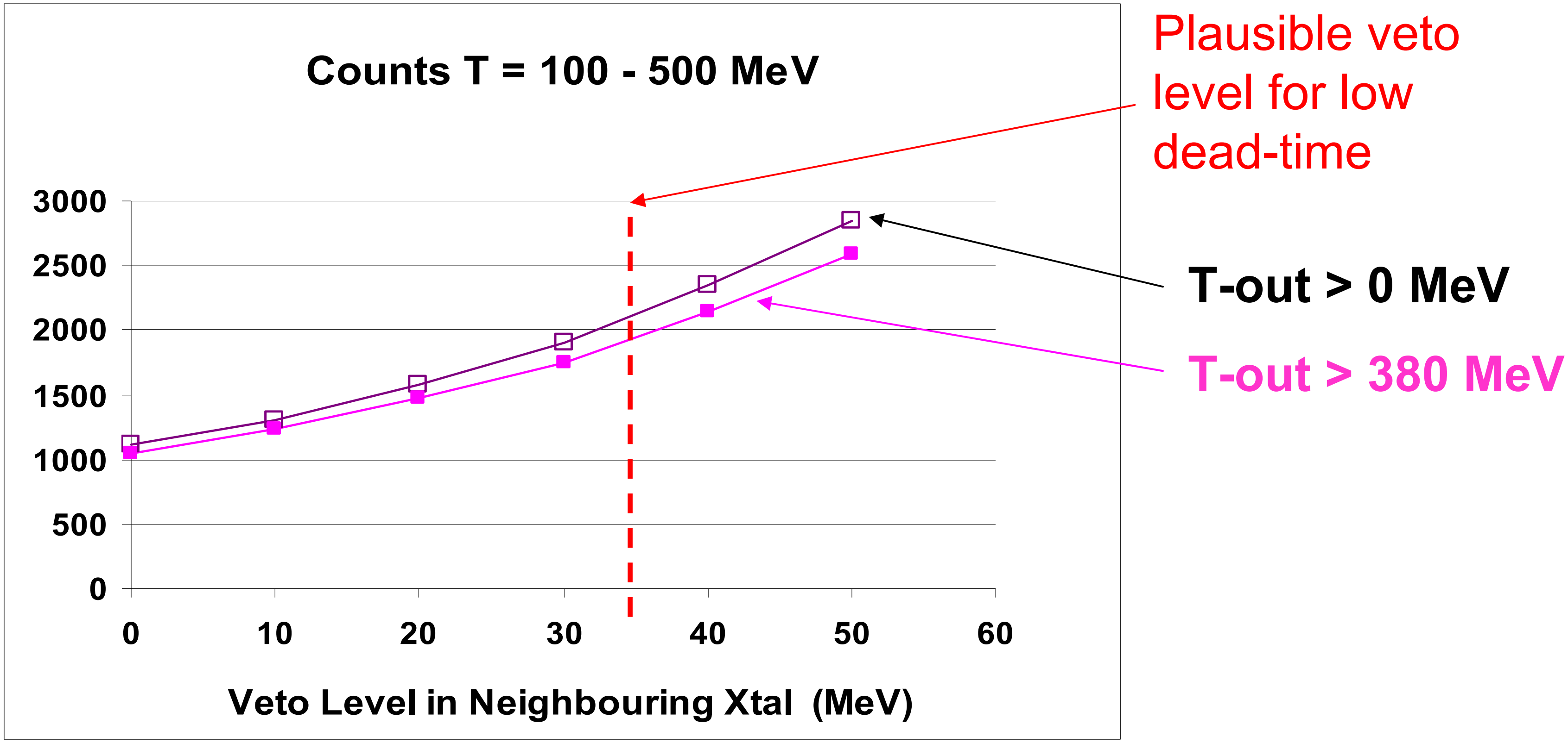
Sensitivity to Veto Level

Simple mean from 100 to 500 MeV as function of Veto Level (normalised to Veto at 0 MeV)



Sensitivity to veto level ~ ±1%

Rate vs Veto Level



Rate with 35 MeV Veto is double that with perfect geometrical cut

Conclusions

Will ensure each channel properly tested

Few % intercalibration looks feasible – signal, noise, rate

Sensitivity to Veto Level ~1%

Systematic variation over length

Edge Xtals different (not full veto)

First check with part of Supermodule calibrated in beam 11/04