Intercalibration of Supermodules with cosmic rays??

Q Ingram, CMS Week, June 2004

Open issues in April ECAL Week:

- Rate, vertical to 67 degrees
- Line width
- APD Gain
- Iron/concrete to stop slow particles
- Wire chambers

Set-up for a Super-Module

SM lying horizontally (*) with trigger scintillators and wire chambers above and below.

5-10 cm absorber above lower scintillator to suppress high de/dx tail(?). SEEMS UNNECESSARY

Trigger scintillators divided into broad hodoscopes to limit angular divergence of trigger particles.

Wire chambers used to require tracks to pass through crystal end faces. NEED ca 1 mm SPATIAL RESOLUTION AT XTAL

(*) tilting in eta would help the rate at large eta, where the crystal angle reaches 67 deg, but is mechanically risky:

Eg rate at 57 degrees is nearly factor 2 greater

Rate, signal

Rate: Vertical (0 degrees), hard component:
80 per (m^2 sec sr) = 300/week through a crystal

==> 200/week with 1mm cut at edges of Xtal

Trigger rate: Raw rate through SM without geometrical constraint ca 300/sec - I.e. this is upper limit

Signal: 210 MeV for minimum ionising muon

Nuclear Counter Effect: Doubles signal size ==> 10% loss in rate

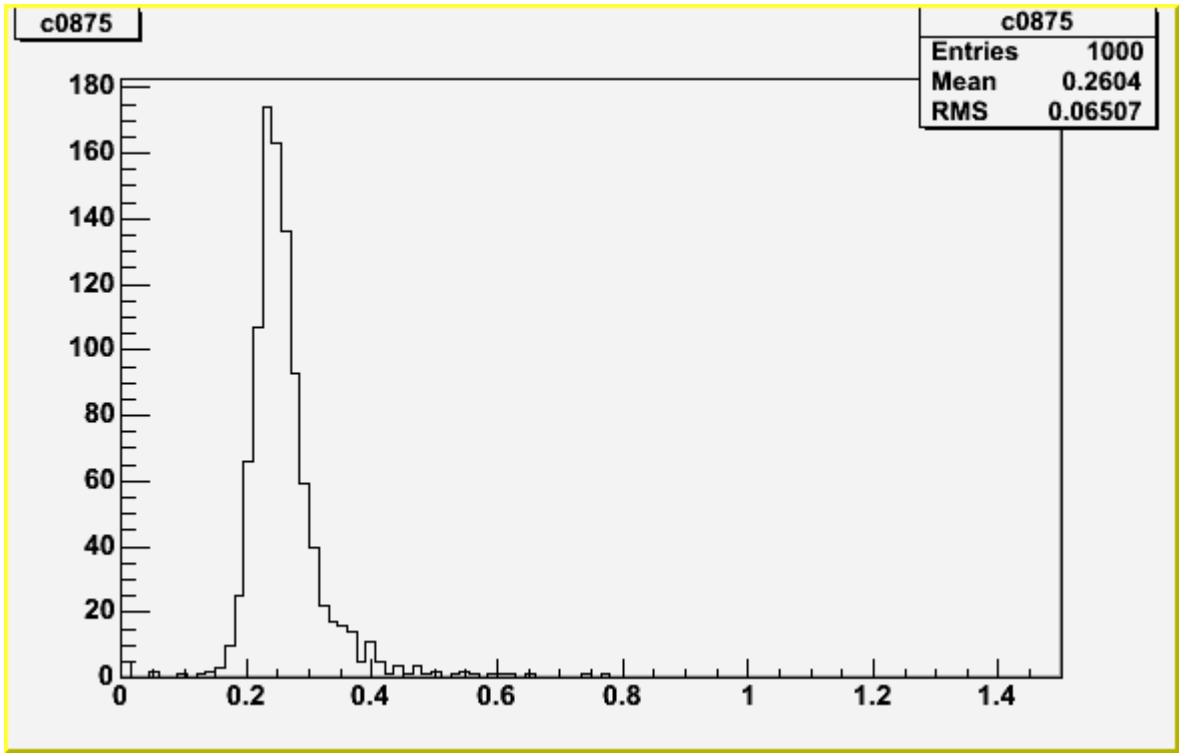
Noise: 50 MeV rms.

APD Gain: Set to 250 (?) (then noise negligible) -> 1 GeV signal

Track gain of each APD with monitoring system

GEANT simulation with 4 GeV Muons

(Alain Givernaud)



Peak 230 MeV

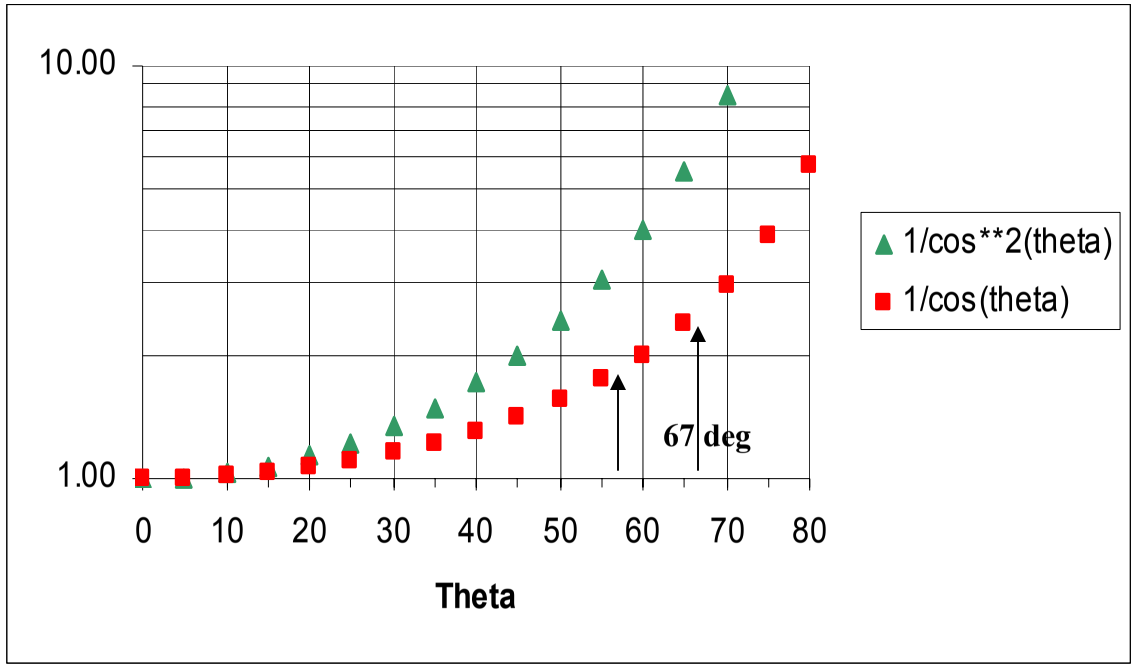
Width 67 MeV FWHM

ca 12.5 % rms

Angular dependence (1)

Range: With SM horizontal, the 4 modules have crystals at 0 - 28 deg; 28 - 40 deg; 40 - 57 deg; 57 - 67 deg

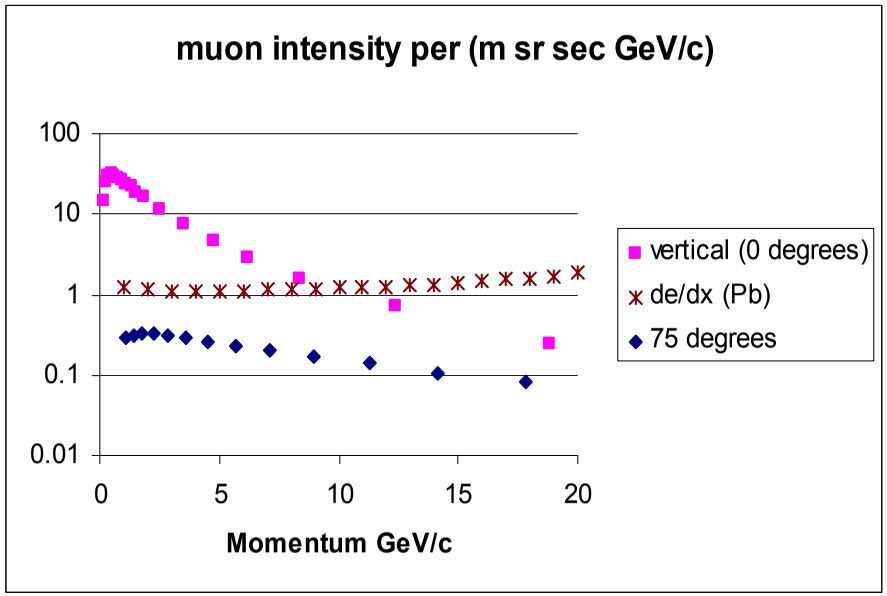
Cosmic flux: Overall rate ~ $\cos^2$ ==> accuracy ~ cos



Angle	1/cos2	1/cos
67	6.6	2.6
57	3.4	1.8

Angular dependence (2)

But the spectrum changes too:



spectrum at 0 deg, 75 deg

and de/dx vs momentum

➔ **average de/dx will increase with eta, by of order 20%**

➔ **other angle-dependent effects (low energy muons, hadrons) ?**

➔ ***Calibrate with rotated single crystal***

Any residual eta dependence would be a smooth function

Set-up at PSI

(Q Ingram, D Renker, T Sakhelashvili)

APD Gain set to 250 - (at gain 50, signal barely above pre-amp noise).

Could be some shielding by adjacent buildings at 0 deg.

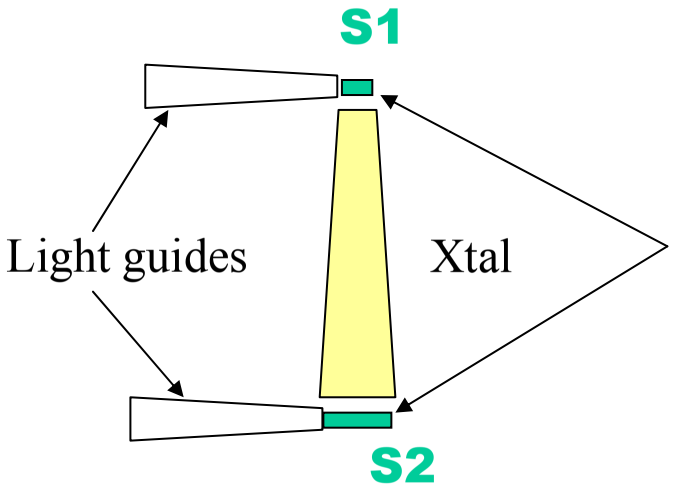
Temperature varied from 22 to 28 deg. Corrected data, 8% per deg.

Time between events consistent with exponential, as expected.

Set-up at PSI (0 deg)

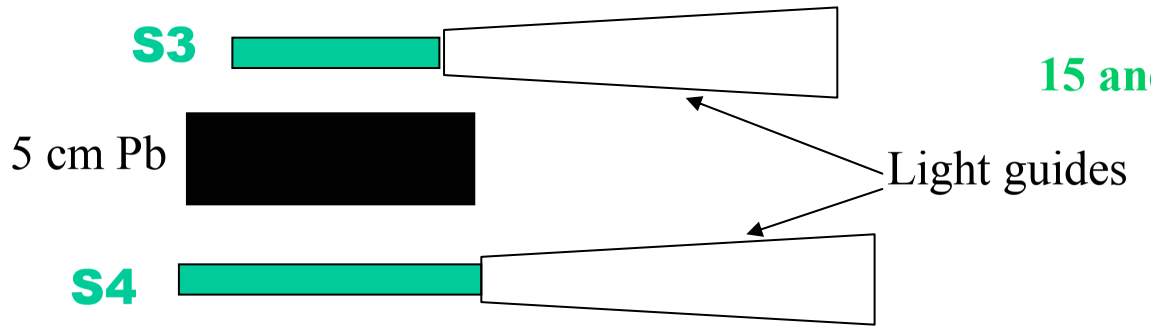
30 cms concrete ceiling

Geometry not exact.



Trigger: S1.S2

Hits in S3, S4 recorded

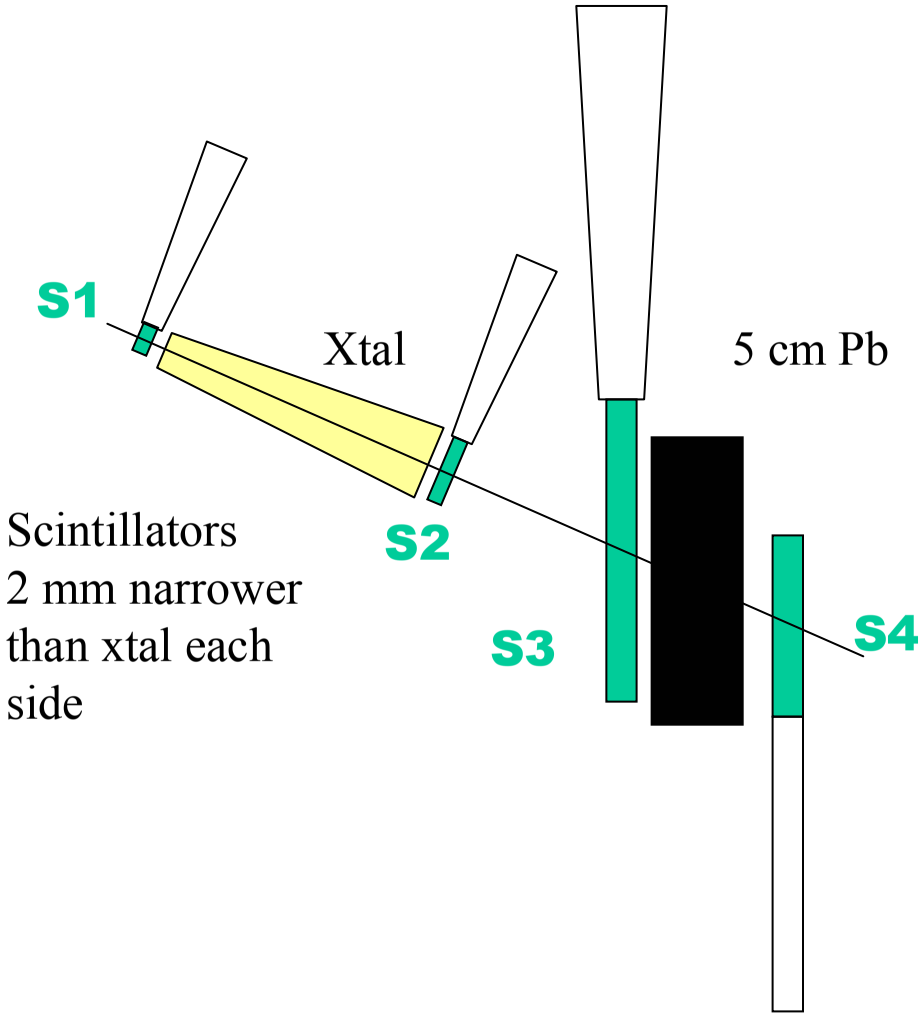


S3 and S4
15 and 22 cm square paddles

Paddle light guides at
90 deg to small counters

Set-up at PSI (67 deg or so)

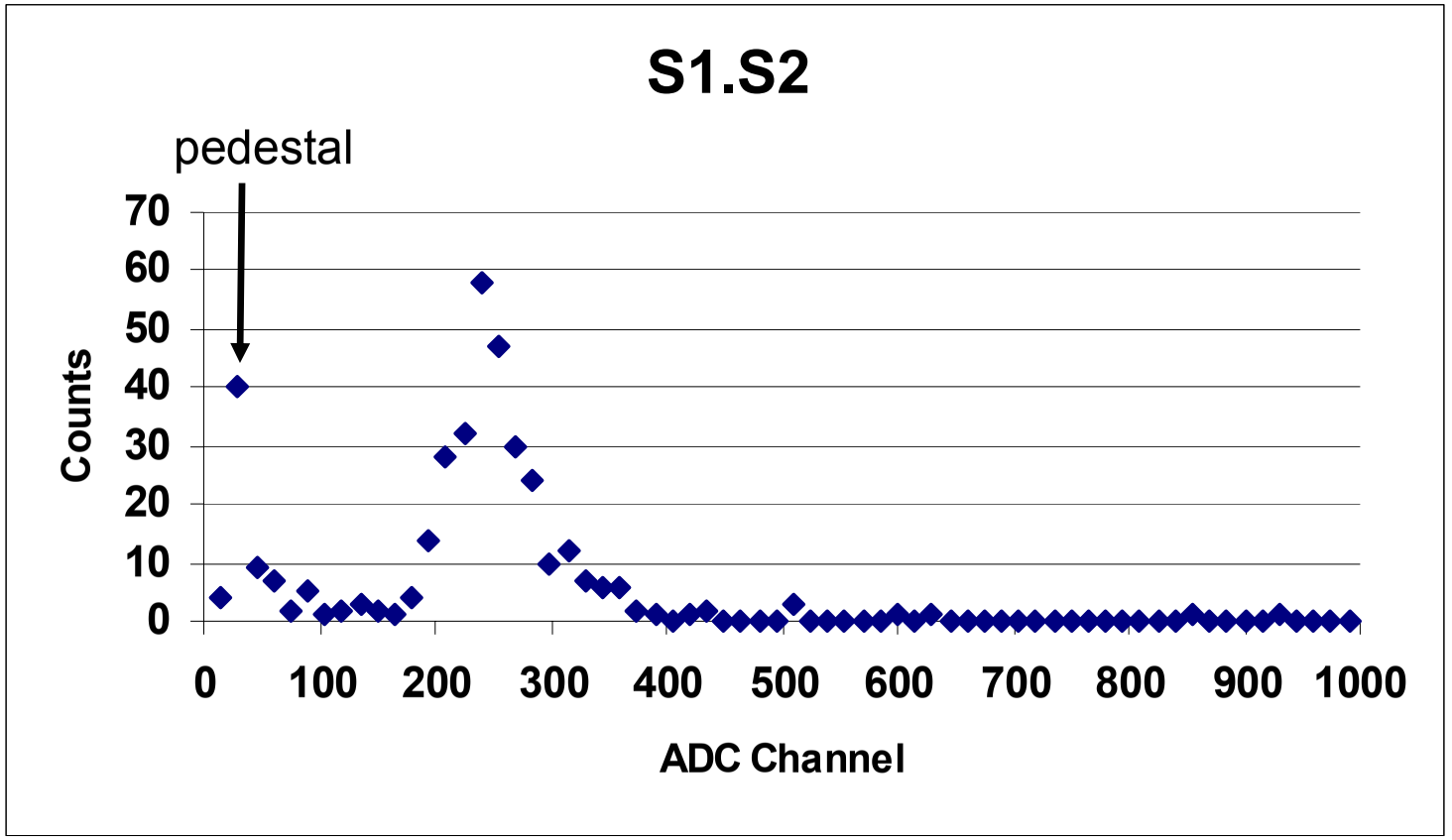
Geometry not exact.



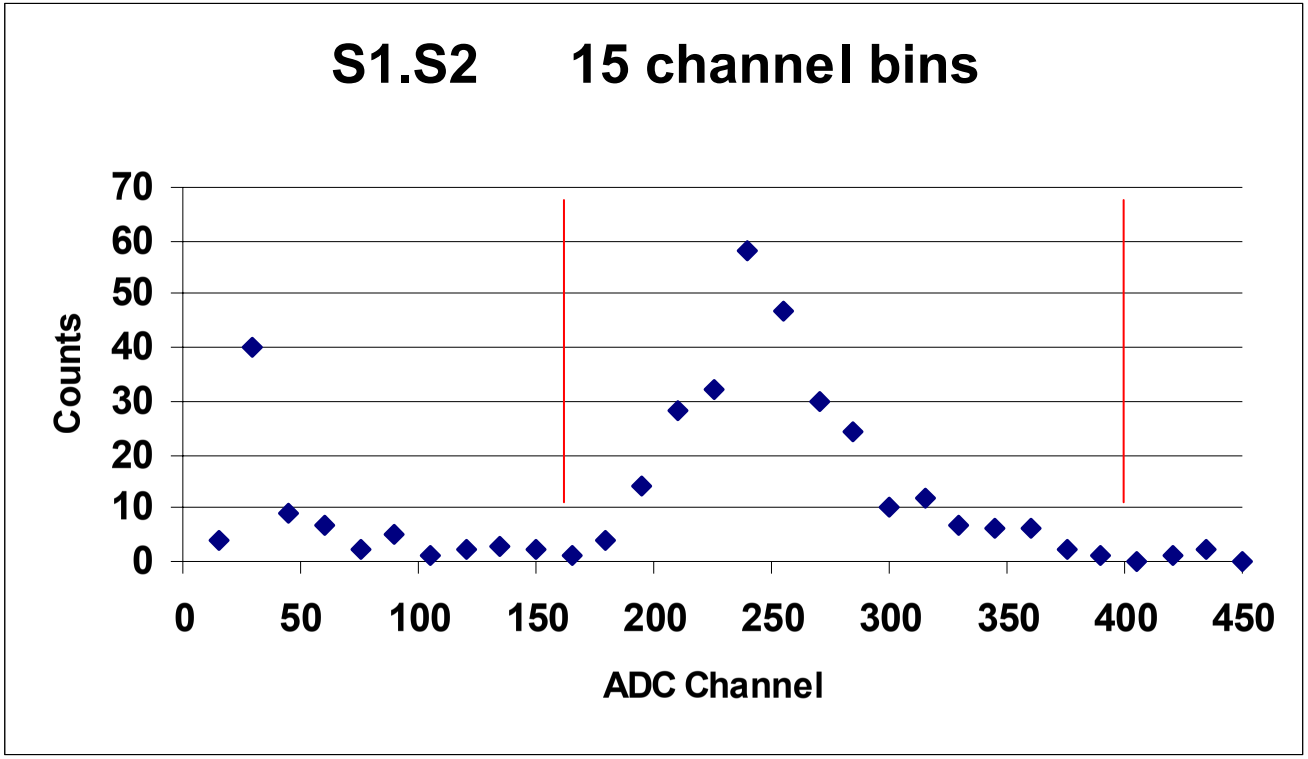
S3 and S4
22 and 13 cm square paddles

S3 light guide under small counters, S4 light guide at 180 deg to small counters

Spectrum after 11 days & 18 hrs (0 deg)



Spectrum after 11 days & 18 hrs

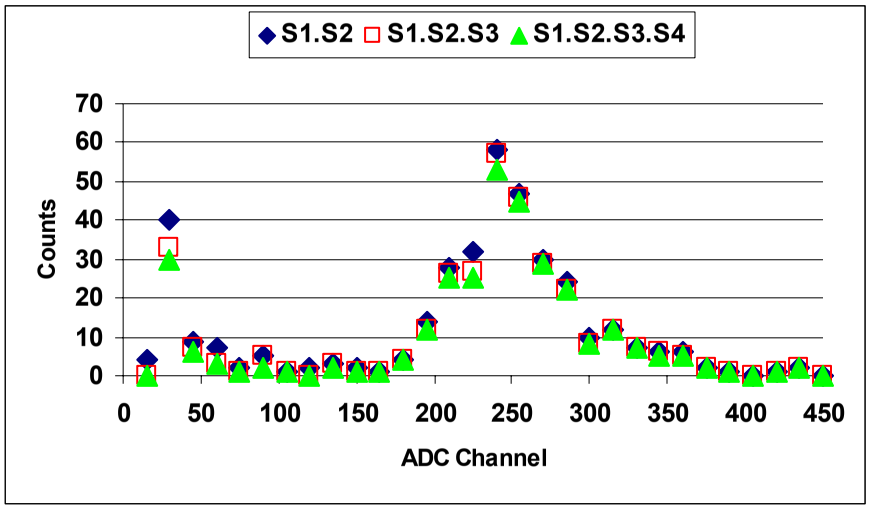


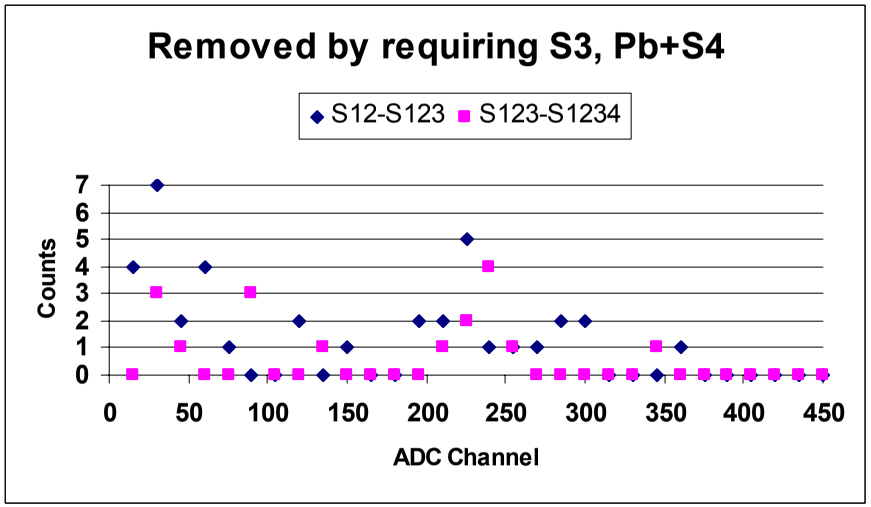
Channels 160 to 400: 282 Counts; Mean chan 248 = 221 over pedestal

FWHM = ca 60 channels corresponding to 11.6% rms for Gaussian

Accuracy of peak position = 11.6/Sqrt(282 * 7 / 11.75) = 0.89% per week

Spectra after 11 days & 18 hrs





Effect of requiring S3 or (S3.(Pb).S4)

Triggering

“Safe” discriminator thresholds gave “high” rate from presumably Cerenkov signals in light guides.

Raised thresholds still gave some such triggers, and reduced S3 & S4 efficiencies by ca 5%.

Spectra of good events with S3 or (S3.S4) missing from the trigger not significantly different

– except for more events with low ADC values.

➔ NO NEED FOR SHIELDING ABOVE TRIGGER

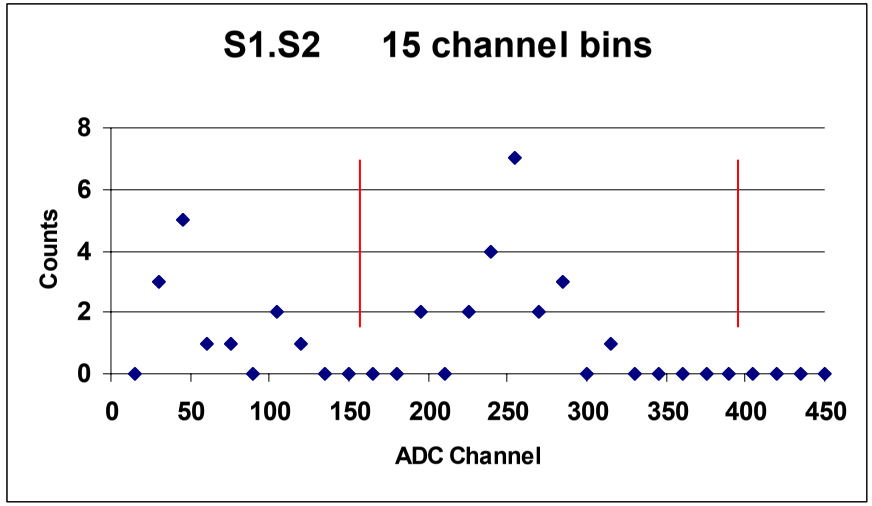
Counts and Mean Channel (0 deg)

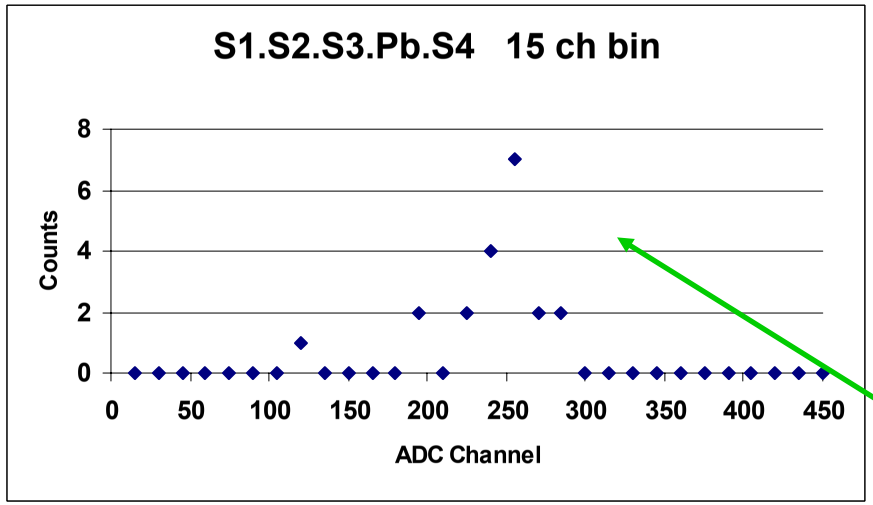
	S1.S2	S1.S2.S3	S1.S2.S3 .Pb.S4		Removed by S3	Removed by Pb.S4	Removed by S3.Pb.S4
Counts ch 160-400	282	265	256		17	9	26
Counts ch 0-160	75	54	46		21	8	29
Counts over ch 400	10	10	10		0	0	0
Mean chan. 160-400	248.4	248.8	249.1		240	242	241
Counts ch 300-400	34	33	32		1	1	2

Rate S1.S2 in channels 160-400: 168 / week (24/day)

(compared to expected 180 / week)

Spectrum after 5 days (67deg)





Channels 160-400 (S1.S2)

Mean chan: 245

(cf 248 at 0 deg)

Rate: 4.1 /day

(cf 24 at 0 deg;
1/cos**(67) = 6.6)

~ complete suppression of bad triggers

Pb brings nothing useful

Counts and Mean Channel (67 deg)

	S1.S2	S1.S2.S3	S1.S2.S3 .Pb.S4		Removed by S3	Removed by Pb.S4	Removed by S3.Pb.S4
Counts ch 160-400	21	20	19		1	1	2
Counts ch 0-160	13	5	1		4	8	12
Counts over ch 400	4	4	4		0	0	0
Mean chan. 160-400	244.5	242.6	239.4		283	303	293
Counts ch 300-400	1	1	0		1	0	1

Rate S1.S2 in channels 160-400: 29 / week (4/day)

(compared to expected 28 / week)

Conclusions

1. Looks plausible at 1-2% level in 1 week from rate point of view

2. Line width at least as good as estimated

3. APD gain probably must be raised, and must be tracked by monitoring system

4. Needs wire chambers with ca 1 mm resolution at Xtal ends

5. Angular (eta) dependence of signal would need correcting for

6. Quite a lot of work to set-up and run

7. Final check of method by checking result with test beam calibration of that SM

8. Would ensure that every channel was tested individually for ca 1 week before final installation

Post-script

1. Set-up

Original idea: use adjacent crystals as veto to ensure track goes exits through front and back faces – no wire chambers.

Noise means veto level of ca 100 MeV = 10% of signal – too high for clean measurement?

2. Matrix effects

PSI set-up single Xtal. No effect from tracks scattering out of Xtal and then back in. (Multiple scattering 2.4 mm rms for 4 GeV/c.)

➔ Both best tested with a matrix set-up (rather than simulations)

Signal, accuracy

Accuracy: Precision is sigma(peak)/Sqrt(counts)

Width of peak:

From Landau broadening	10% (???)	
From variation of dE/dx	10% (???)	
From statistics	3.3 * Sqrt (F) %	
F (Excess Noise factor)	*= 3.5*	*at M=250*
Noise	5%	
Total	15% rms	

but biggest uncertainties are main components

15%/Sqrt(300) = 0.9% accuracy in 1 week for

intercalibration, at 100% efficeincy

Nuclear Counter effect: doubles pulse height => 10% loss in rate

Angular dependence (3)

Depending on the detailed set-up, there may be an additional tail in the spectrum at higher de/dx due to low energy muons.

The absorber thickness will change with angle and so this tail would vary.

There may be some small contribution from hadrons, although I think these will be negligible: if significant this would also be angle dependent.

All these effects should be included in a calibration with a single crystal rotated through the 67 degrees.

Any residual eta dependence would be a smooth function