Calorimeter upgrades

Reduce the flash

Non-hydrogenous materials

For higher rates: need better pileup reduction and gain stability

Faster or segmented

Lead tungstate	best choice ($$), slow?
lead glass	less light/UV, large X_o
Cerium Fl	large X_o
New Calorimeter	$$$$
FSDs	$

maybe we can get away with new phototransducers to do this
and avoid the risk of narrow pulses…$$

Lead Tungstate

Radiation Length = 0.89 cm

Cost: $3/cc

Availablity: OK! despite CMS (and BTeV),
1000 crystals is a “small order”

Light Yield: 200 γ / MeV @ 420 nm for CMS-type crystals
(2 x 2 x 22 cm^3)

Speed: 85% within 30 ns, 95% within 100ns

N.B. terbium-doped (only “fast” dopant)

Increases light yield by factor of 2
adds emission peaks from 350-590
98% within 30%, 99% within 100 ns

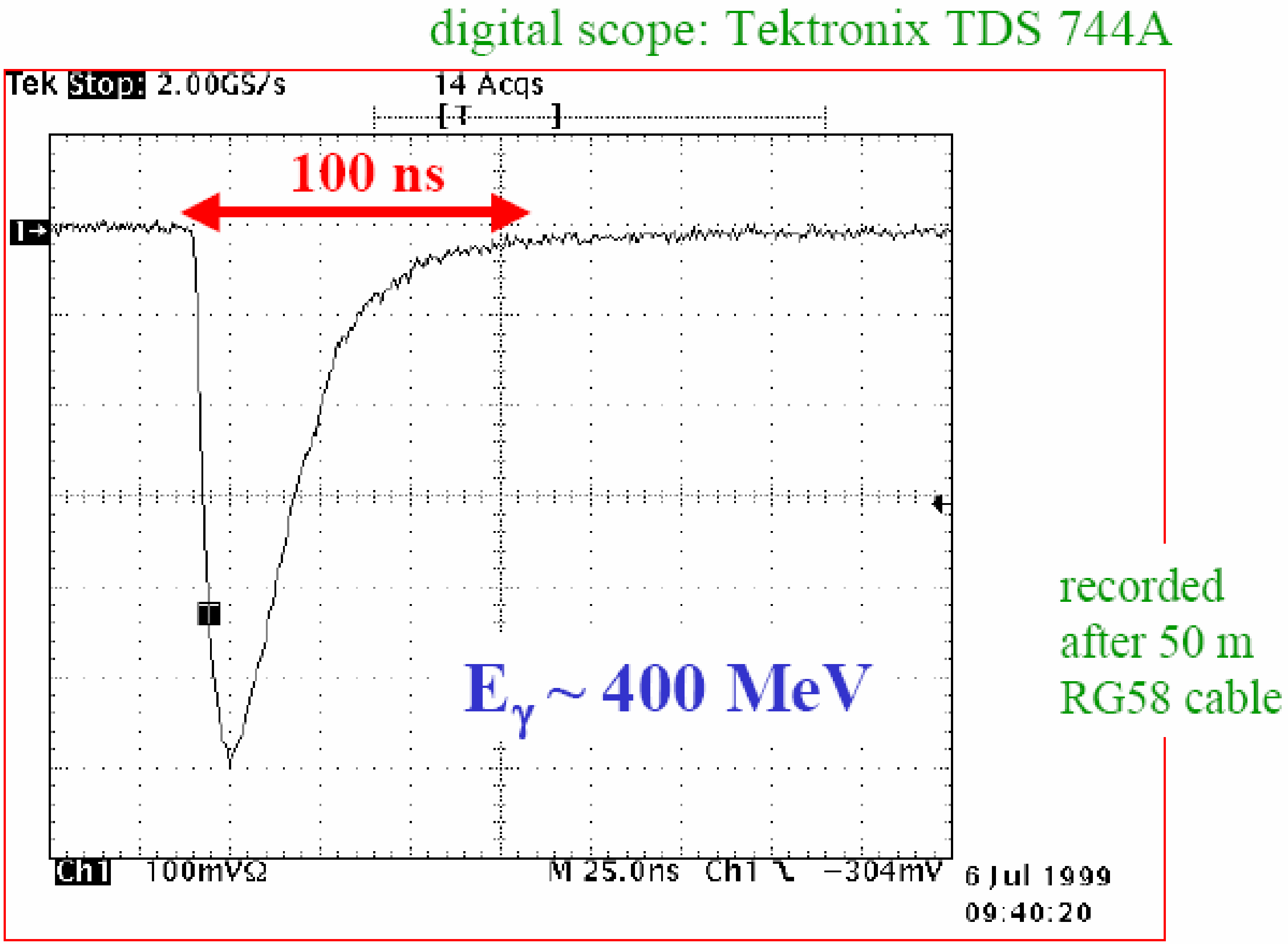
Cerium Flouride

Radiation length is twice as large, but light yield is 10x better
Fast and cheap (but not twice as cheap!)

BGO & NaI too slow, but bright

lead glass too dim, but cheap!

Lead tungstate scope trace.
Pileup reduction must be accomplished by segmentation



Read out from the back with APD's
Make it a bit larger than Moliere radius to contain shower:

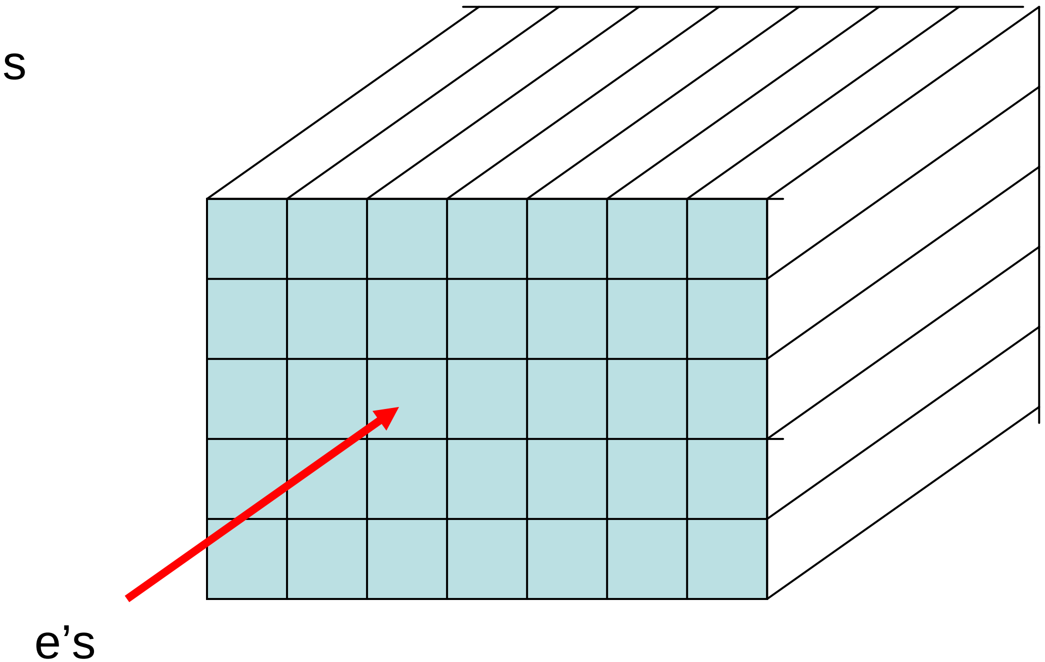
Block dimensions: $3 \times 3 \times 11$ cm^3

(so losing the tails of shower to noise floor are less important)

Need 7x5 = 35 per calo

840 crystals in all

$100 each ➔ $84k   hmmmm.



Read out by 1 APD. (or improve signal and cost with 2/crystal)

2×10^5 γ /GeV * 0.85 QE * .05 (one APD in center) = 8,500 pe / GeV

Issue is the Noise Floor (worse for fast shaping)

CMS preamps (45 ns peaking) ~ 40 MeV at highest gain X 2.5 for this configuration
We will lose any 100 MeV tails.

Readout Cost = $100/APD ➔ $85k + $15k preamp system

Pileup reduction from segmentation: ~ 10

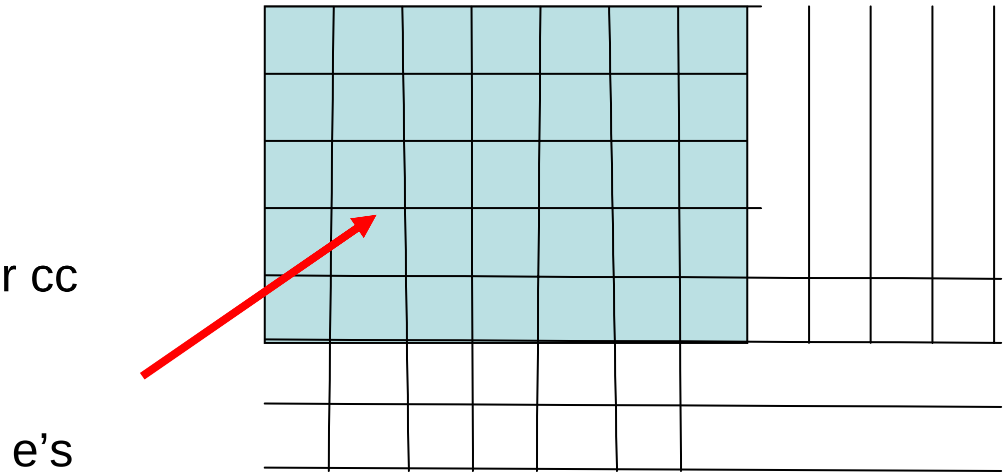
Another Optimization
Block dimensions: 2 x 2 x 11 cm^3

Need 11x7 = 77 per calo

1848 crystals in all

$44 each ➔ $81k

Same price for crystal since it is per cc
(some additional cost in prep)



Price of readout will go up to
$185k + $20k preamp system

Read out by 1 APD.

2 x 10^5 γ /GeV * 0.85 QE * .1 (one APD in center) = 17000 pe / GeV

CMS preamps (45 ns peaking) ~ 40 MeV at highest gain X 1.25 for this configuration
We will lose any 50 MeV tails.

Could simply use small PMT's: directly on the crystals

maybe it will be ok with backward-going muons and floor shielding.

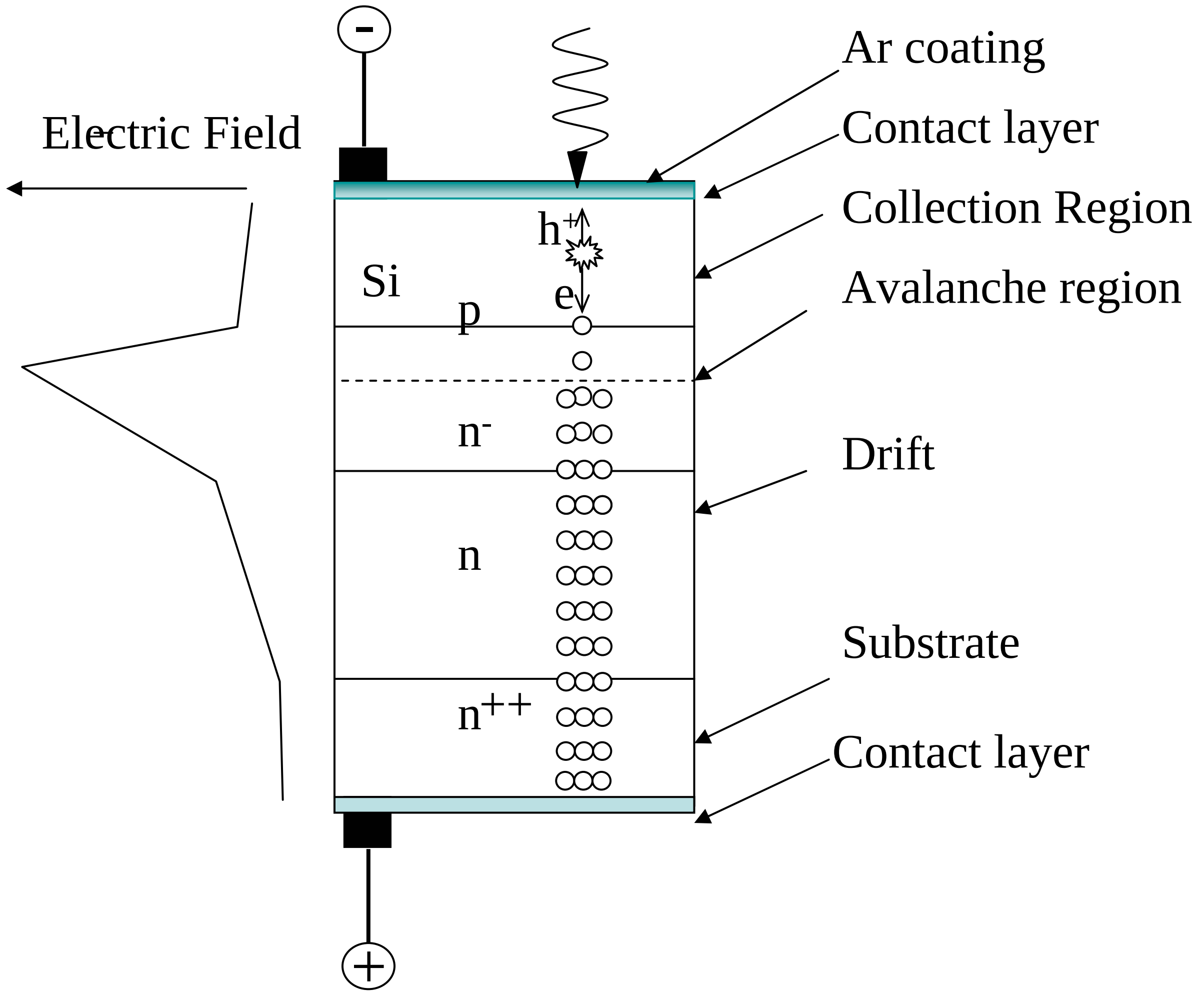
Pileup rejection factor ~ 20

Photo Transducer Options

	Advantages	Disadvantages
PMT	cheap, exist, no special electronics	need light guide, QE~20% (blue) narrow pulses
APD	QE ~ 80%, no light guide, high rate only 50V bias, Hamamatsu: \$30 for 5x5 mm^2	low-noise amplification needed (could use ECAL electronics) Gain=50 -200
APD array	as above + large area arrays, Gain=2000	in development by RMD
SiPM	Gain=10^6, Fast, simple, QE ~ 20% no light guide. \$80 for 3x3 mm^2	in development

HPD poor option: QE~20%, gain=2000, Fringe field ➔ light guide

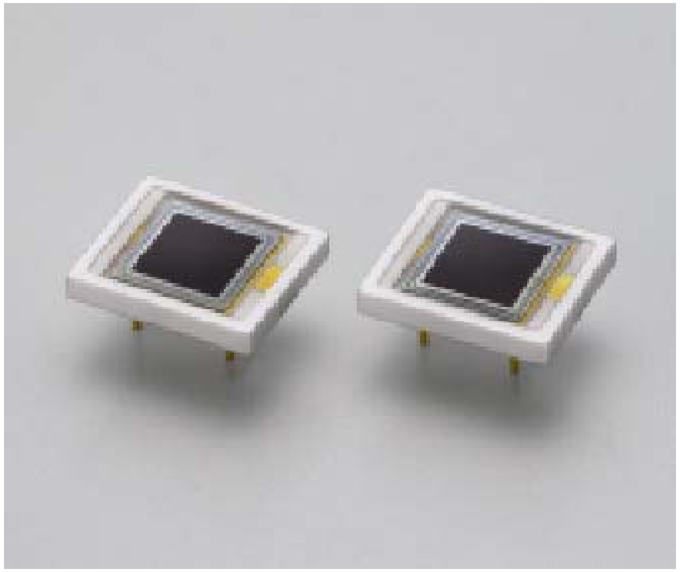
UNLESS you can shield B-field, put electrostatic-focussed type directly on crystal for large area collection and focussing.

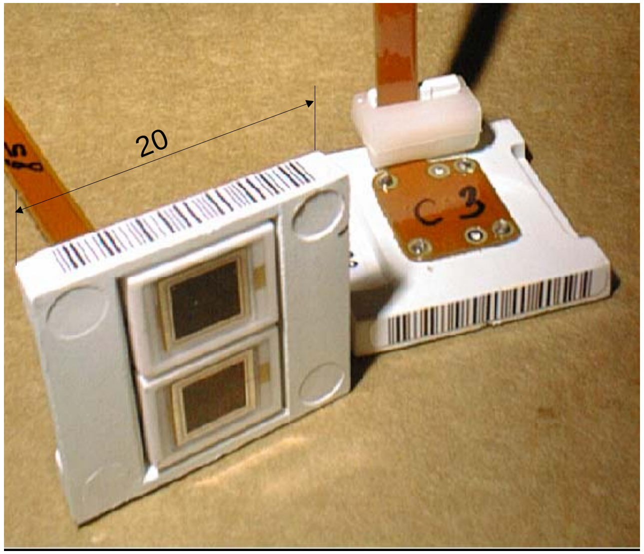


Electrons generated by the incident light are multiplied in the high field region at the junction.

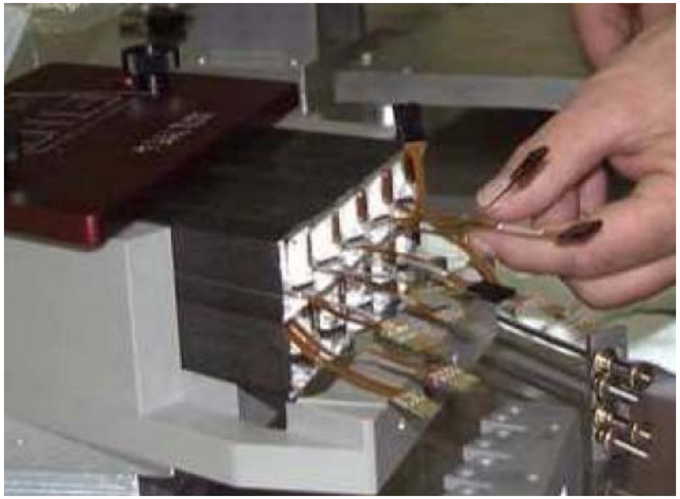
ECAL uses Hamamatsu APD's

5 mm x 5 mm active area: 2 APD's to a Lead Tungstate Crystal



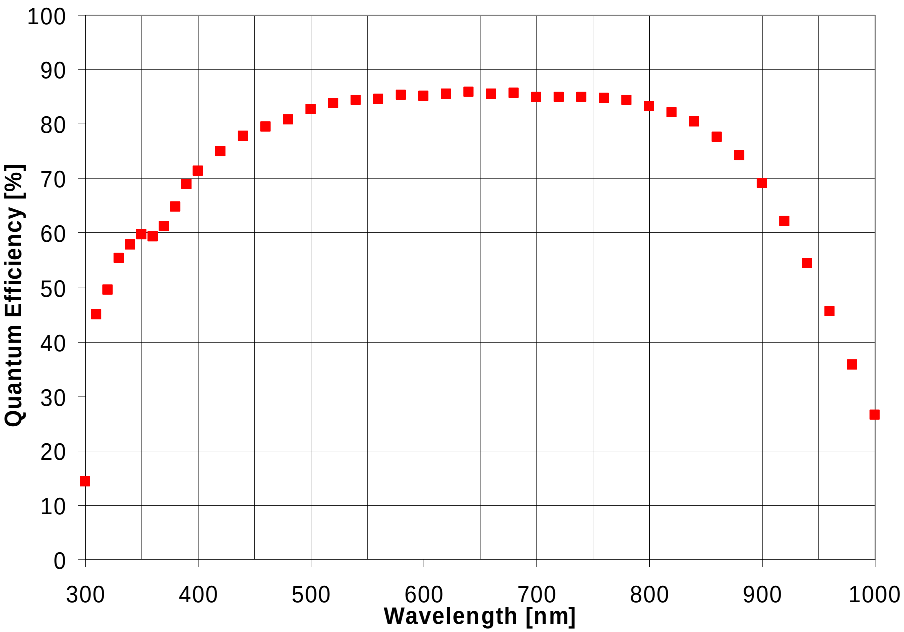


- APD's are now mass production items:
  140,000 used for CMS.
- Electronics well established, easy to copy
- Lifetime tests & yield established
- Supply assured and cheap

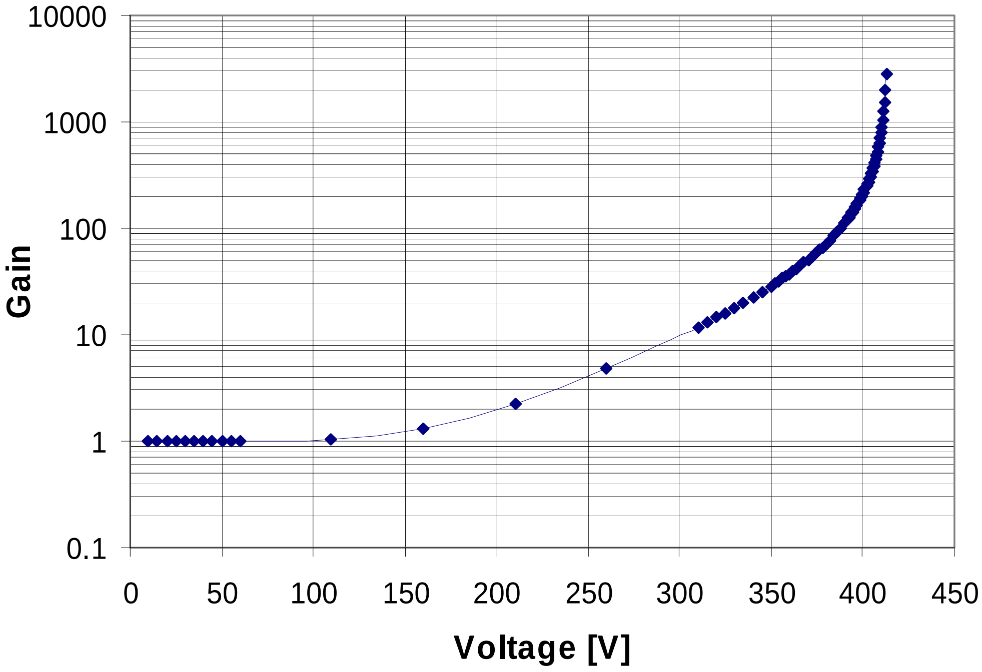


ECAL uses Hamamatsu APD's

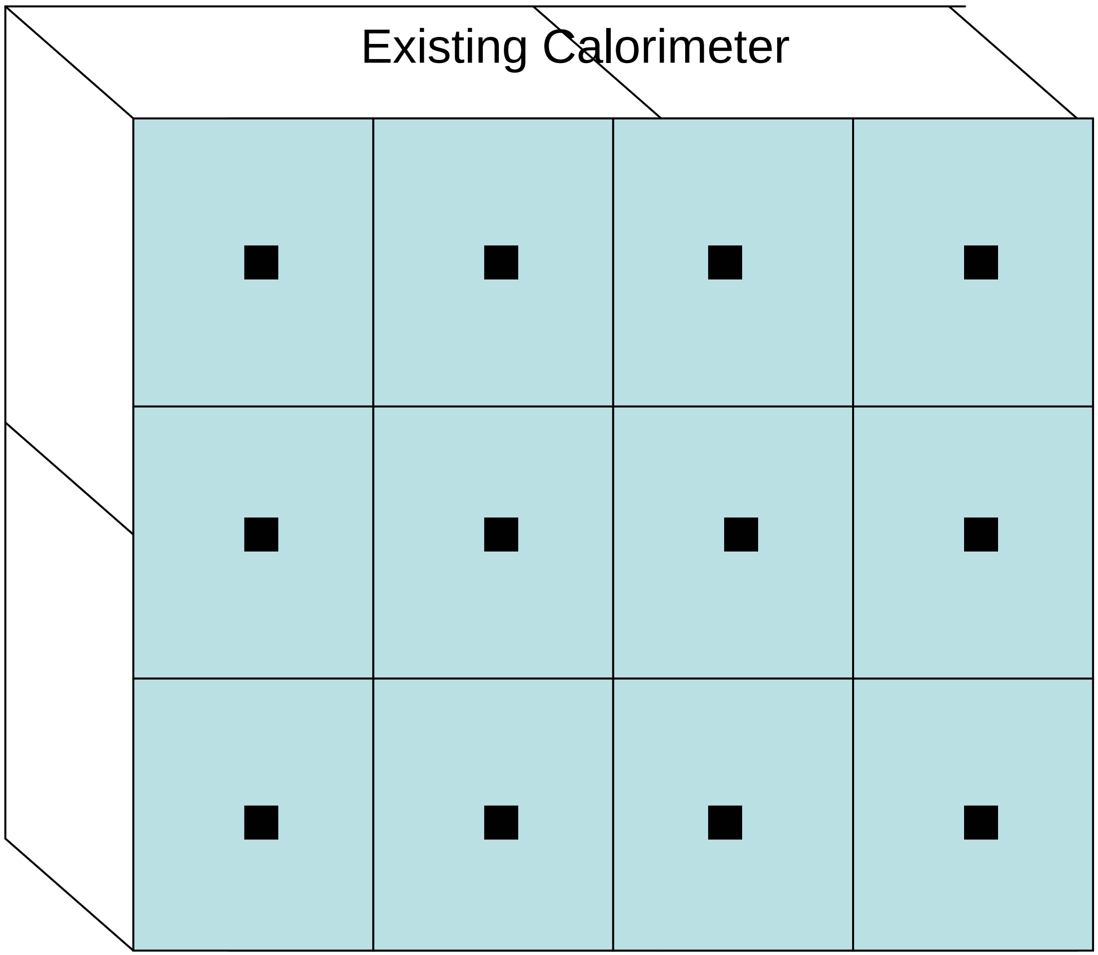
QE vs wavelength



Gain vs Bias: CMS runs at G=50,
but G=200 has comfortable headroom.



Even reading out existing calorimeter with different photodetector may gain you something!Turn on side and cut off & replace



No narrow pulses

More light, finer segmentation

Best pattern to be optimized
(cost may drive it)

550 pe/GeV for PbSci

APD
* 2.6 light guide
* 4 QE differential
* 0.1 air light guide ??

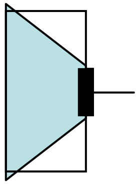
572 pe/GeV
Noise ~ 600 pe (forget it!)

Electrostatic-focussed HPD
* 2.6 light guide

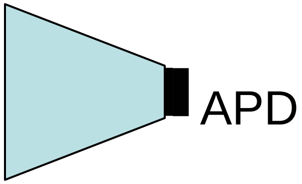
1430 pe/GeV
Noise ~20 pe

Can we shield and leave shielding in place for run?

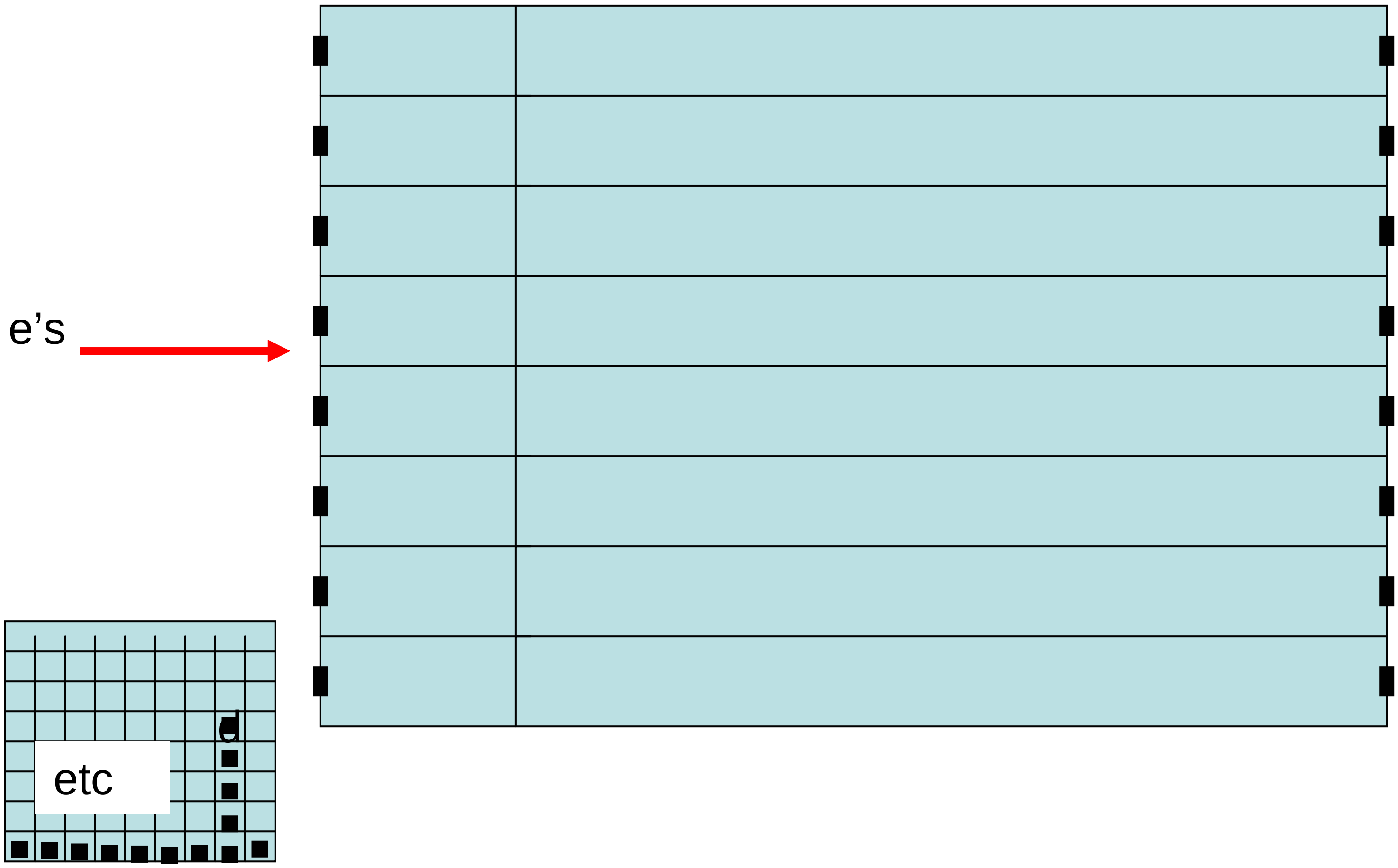
Shielded (?) Electrostatic HPD



Stubby air light guide to mix light



Hybrid – Use lead tungstate to create preshower detector with real x-y blocks (no-ambiguity) with readout from the front



Even lead glass might work

Can we borrow/purchase used blocks?

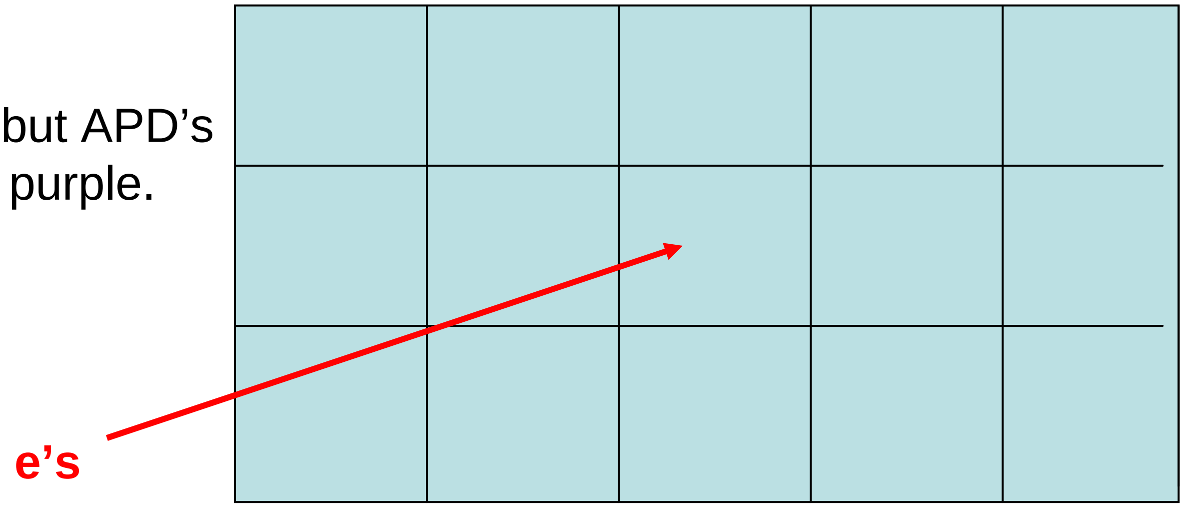
Radiation length = 2.7, Moliere radius at 4.7 makes it deeper (30 cm)

7 x 9 cm blocks ?

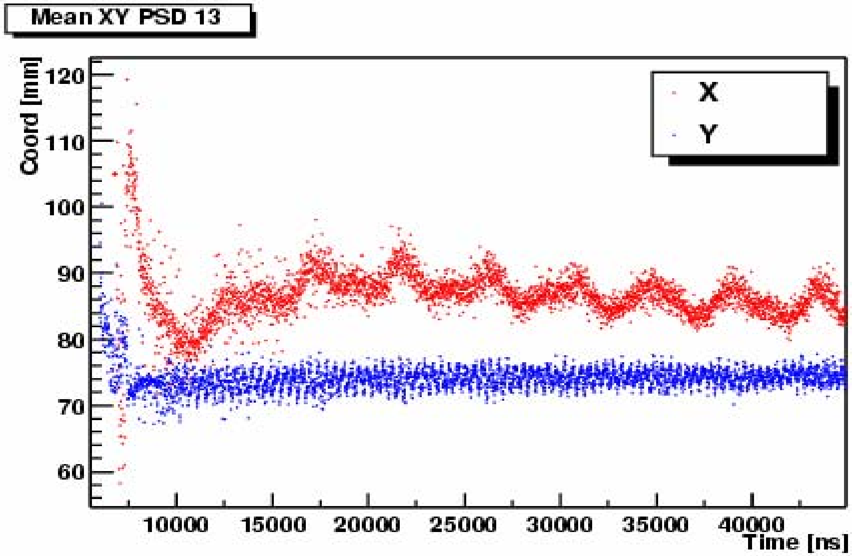
Factor of 10 less light, but APD's good QE even in deep purple.

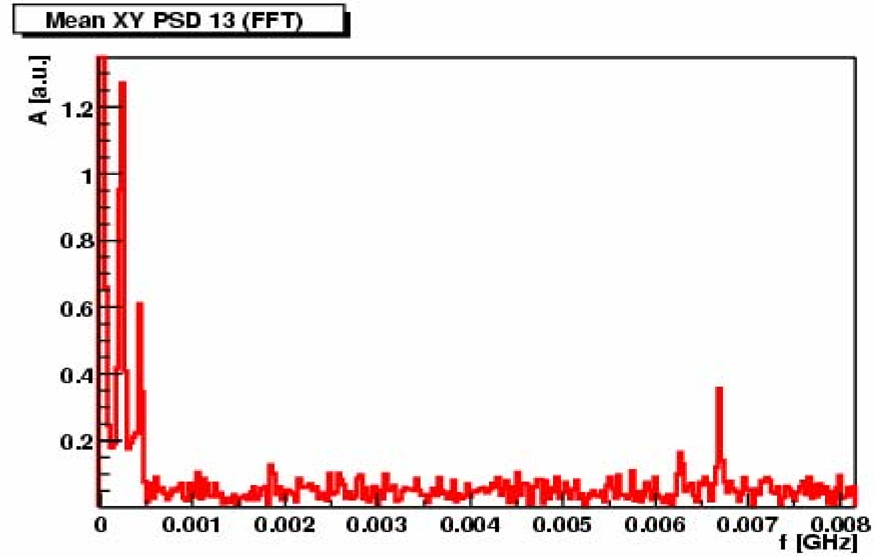
Needs air light guides

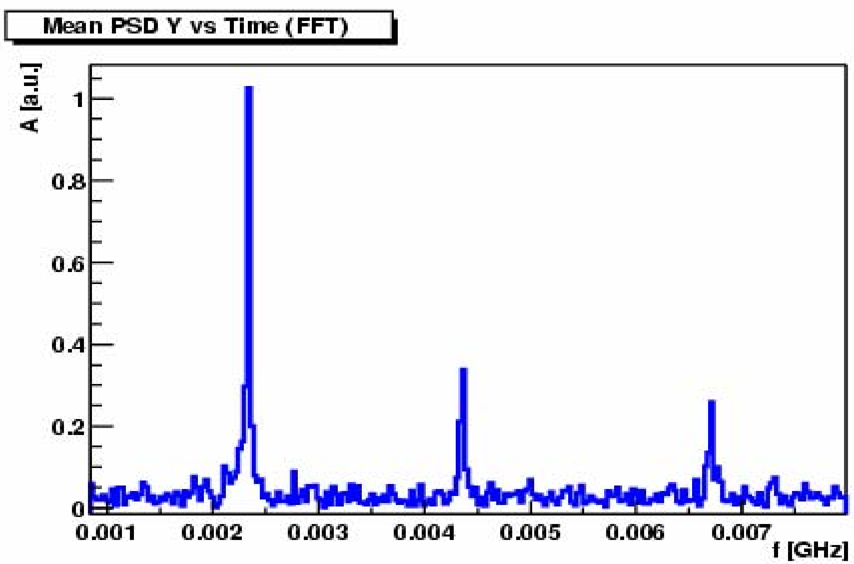
It's a stretch



Further pileup reduction using a front segmented detector as well as muon loss detection and beam dynamics. Example below is PSD in 2001 (X mean and Y mean vs time)

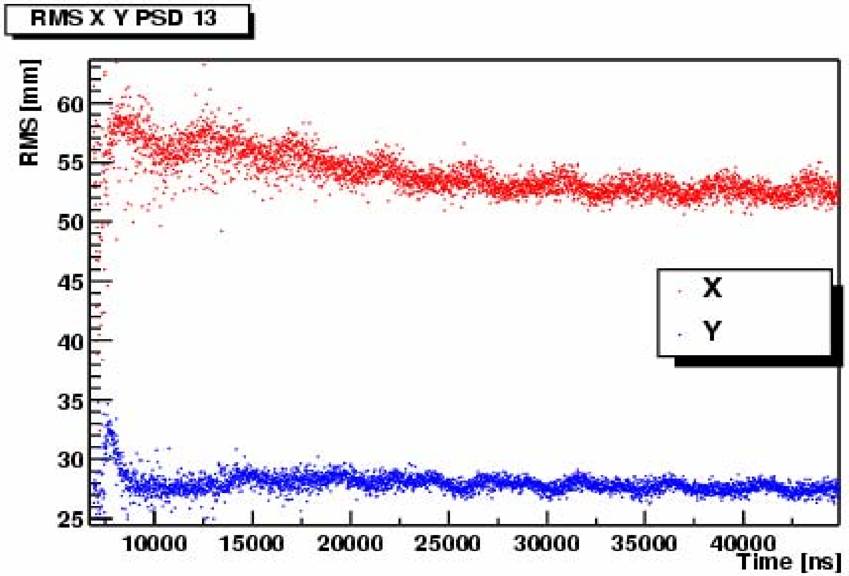


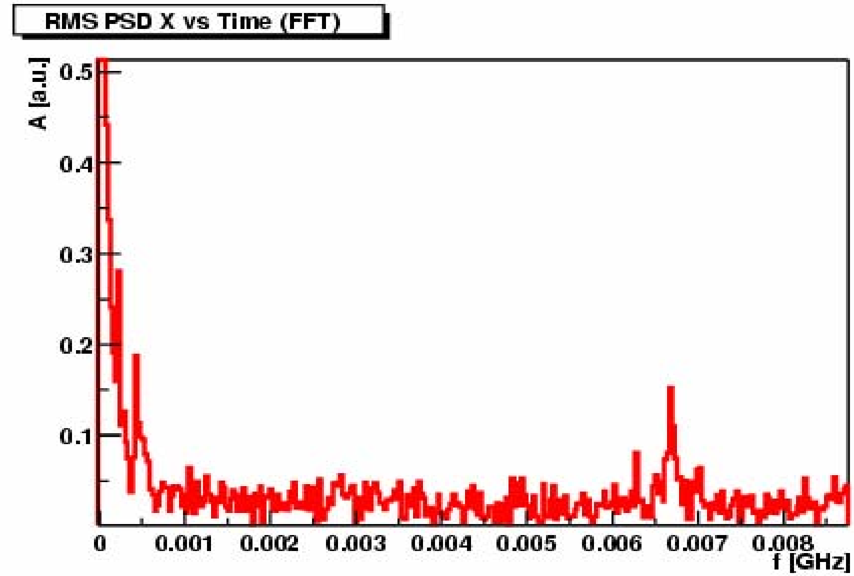


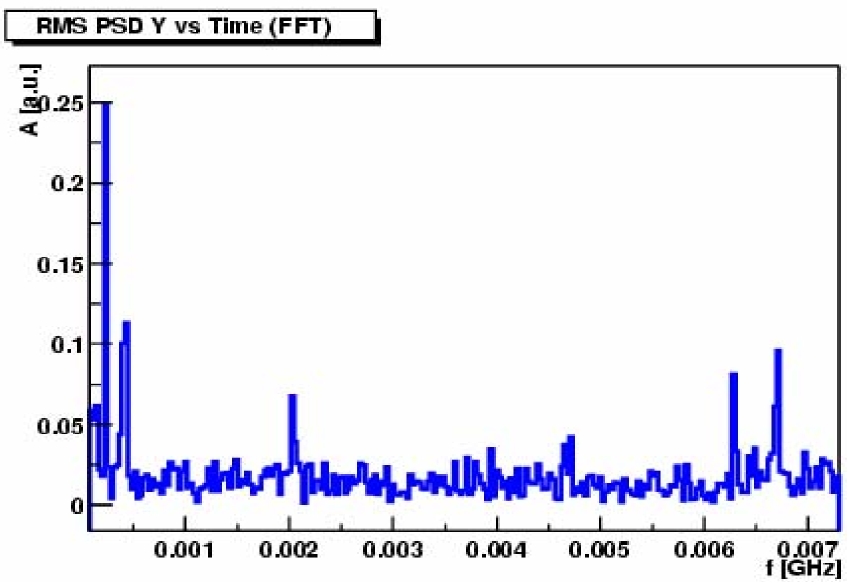


229 kHz - g-2;
420 kHz - CBO;
460 kHz - twice g-2;
2.336 MHz - Vertical BO for low n;
4.36 MHz - Beating: Fast Rot - VBO;
6.72 MHz - Cyclotron (Fast Rotation);
9.04 MHZ - Beating: Fast Rotation + VBO;
11.08 MHz - Beating: twice Fast Rotation - VBO;

X and Y rms distributions from PSD (2001)







1) runs > 9862 (so the quads time is ~ 7 us)
2) Energy corrected according to X&Y coordinates (separately, so for Y distribution X is integrated and vise versa)
3) 1.8 < E < 3.2 GeV
4) Time window for Calo-PSD matching is 25 ns (PSD 13, 15, 18, 24) and 35 ns for PSD 14. Histogram bin width is 10 ns.
5)Runs > 9862; before Br; lown
6) No randomization
7) 1 hit in Y; 1 hit in X