Sub-100 picosecond charged particle timing with MicroMegas

Sebastian White, CERN/Princeton June 8, 2015

3rd Academy-Industry Matching Event on Photon Detection and RD51 Mini-Week

representing:

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K. McDonald, C. Lu &SNW(Princeton)

for RD51 common fund project: “Fast Timing for High Rate Environments: a MicroMegas Solution”- awarded 3/2015

overall goal of this R&D

is to go from 1-d to 2D vertex identification

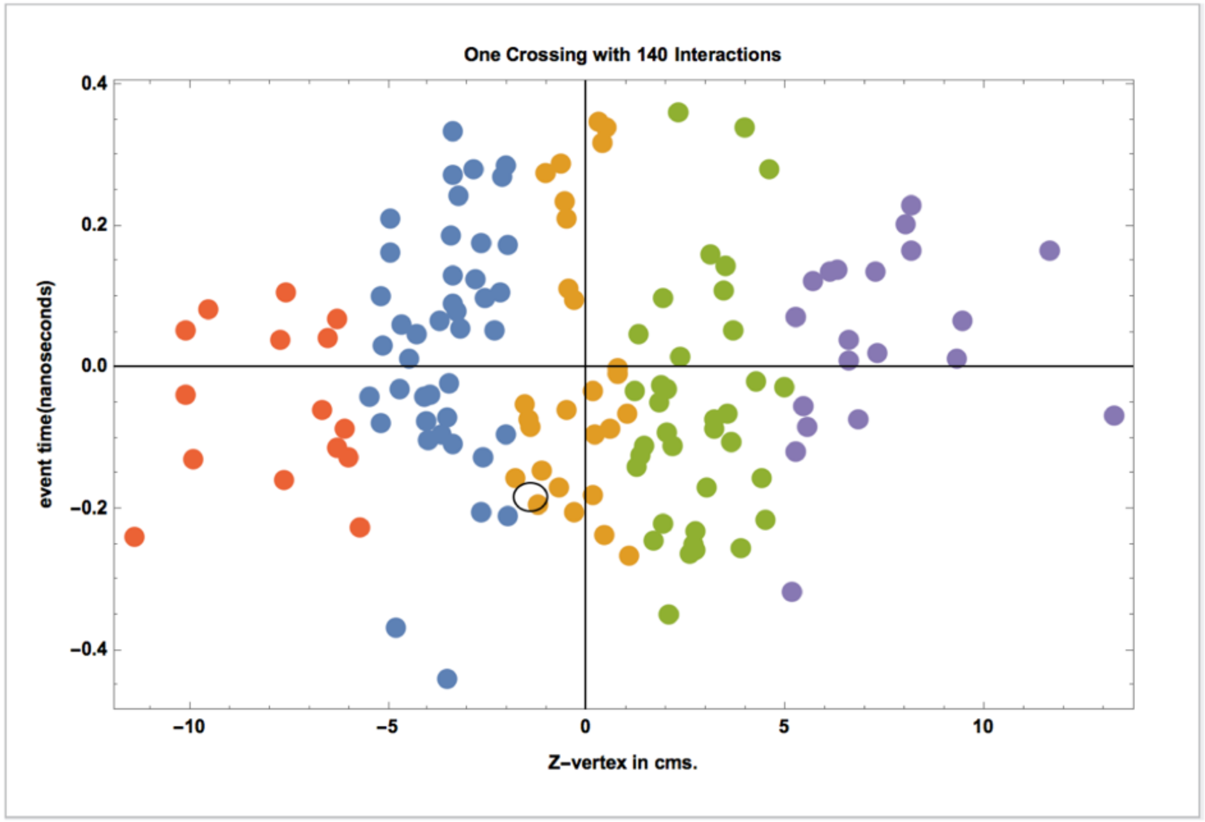
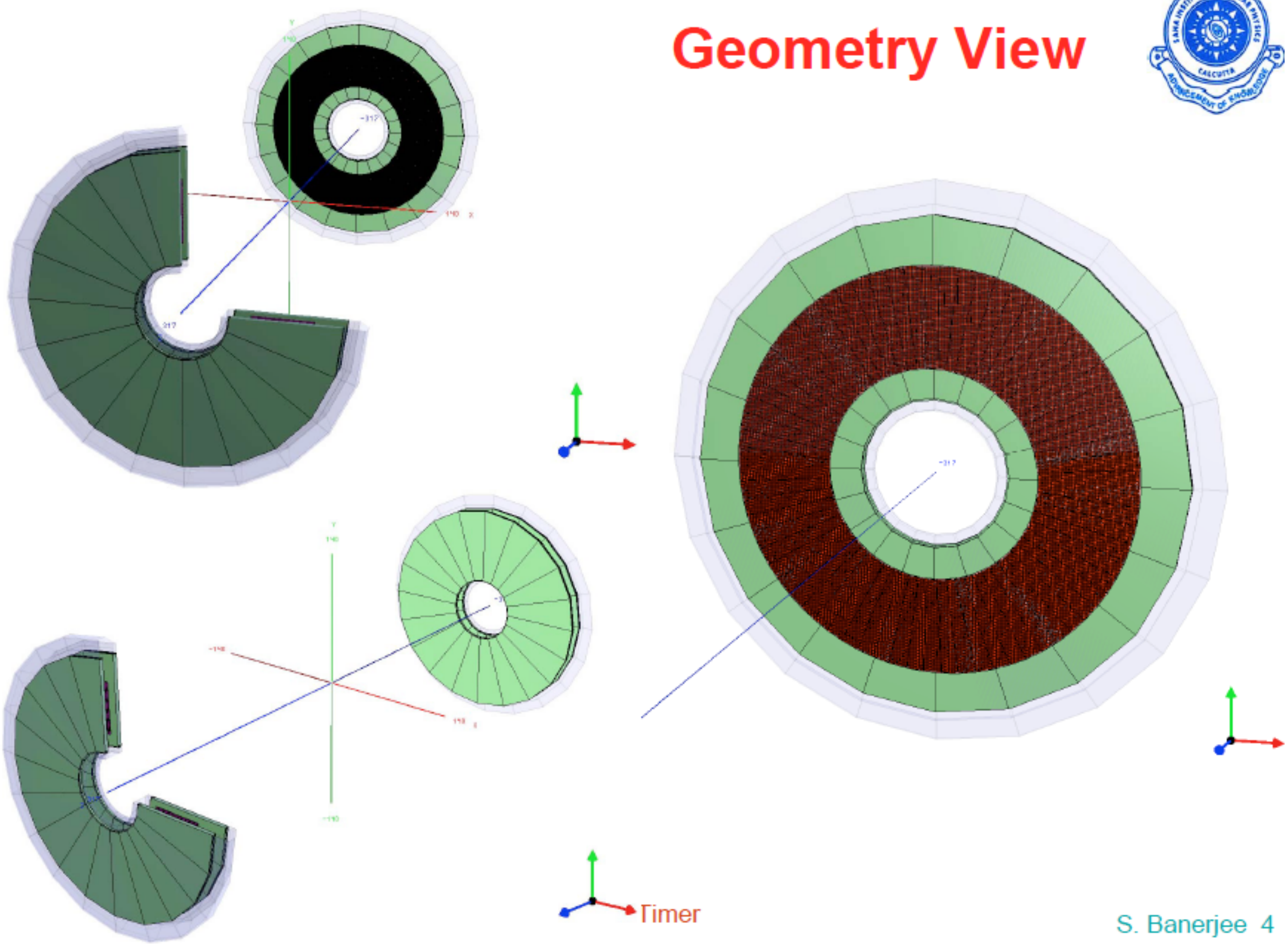


Fig. 1. Simulation of the space(z-vertex) and time distribution of interactions within a single bunch crossing in CMS at a pileup of 140 events- using LHC design book for crossing angle, emittance, etc. Typically events are distributed with an rms-in time- of 170 picoseconds, independent of vertex position.

Efforts in CMS and ATLAS to evaluate usefulness for mitigation of vertex merging, Jet-misassociation, etc. in HL-LHC environment

Our group has been developing a dedicated fast timing solution with Si or MPGD options for end cap

Geometry View



We focus on timing layer for EndCap region of Phase-2 (CMS)

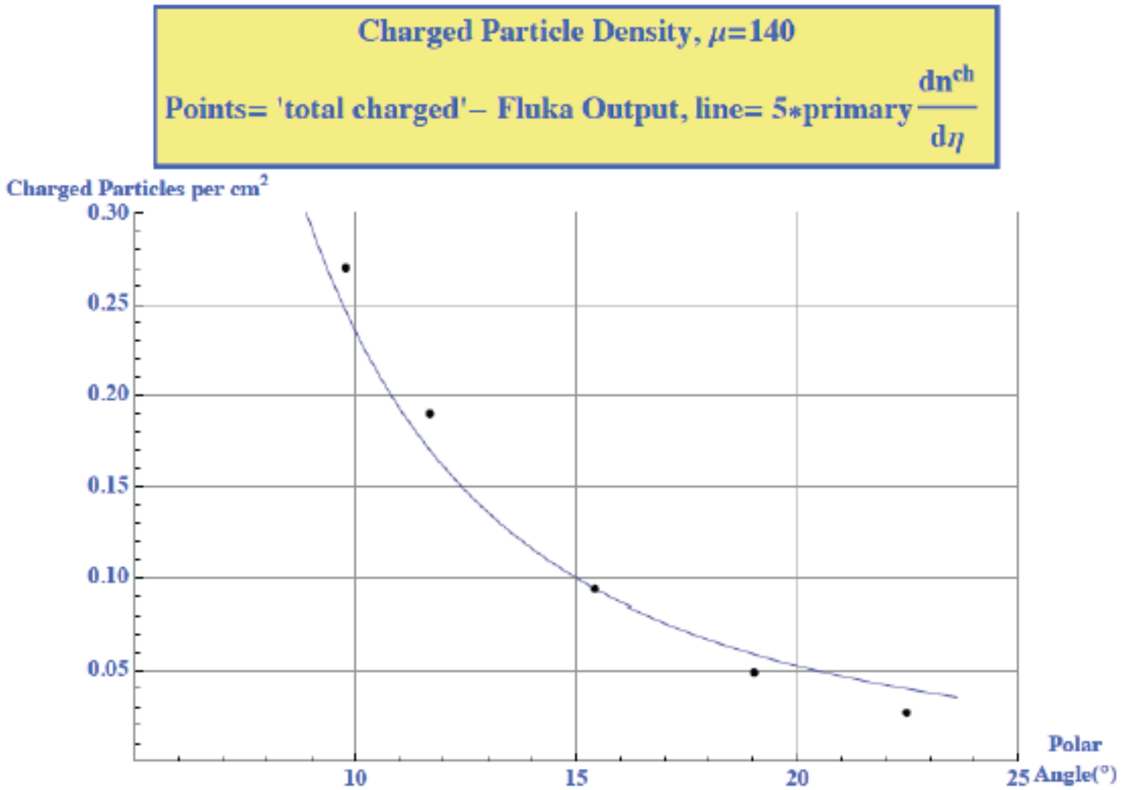
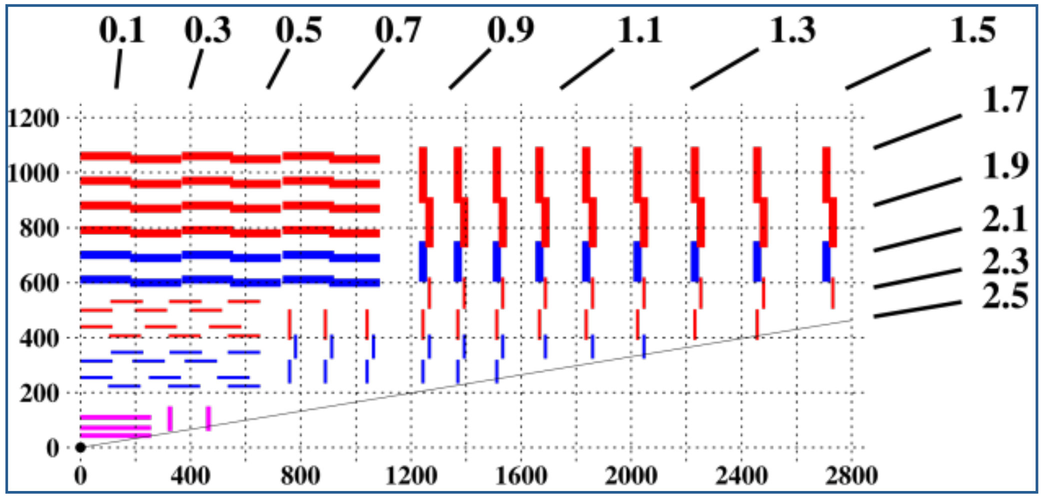
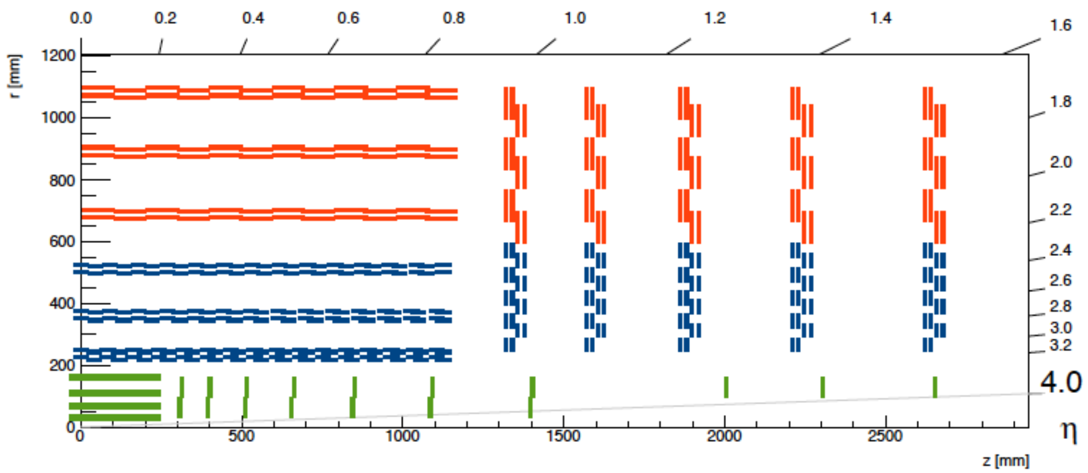


Figure 2: The charged particle density in the region of the dedicated timing detector. The points are FLUKA output for "total charged". The line is calculated from estimates of primary charged particle density-dn/deta- scaled up by a factor of 5. FLUKA output is roughly consistent with a constant factor over this angular range.

current model in CMSSW matched to:



if tracker extended in Phase2, complementary role?

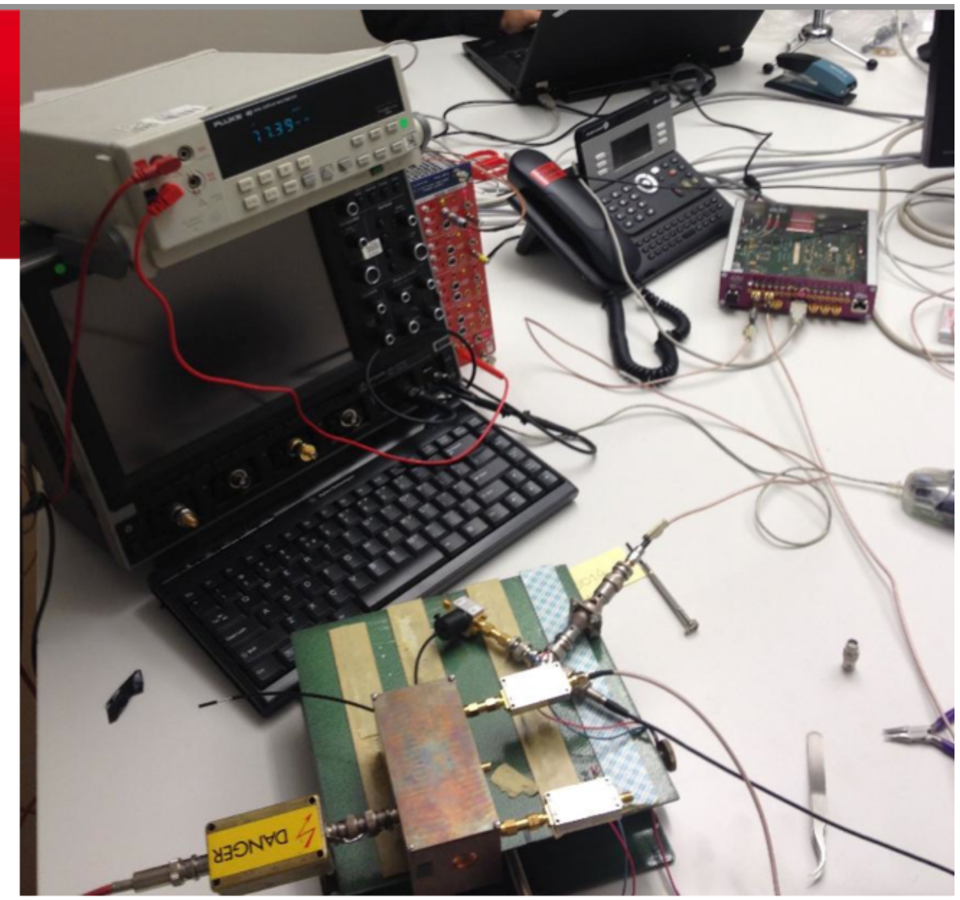


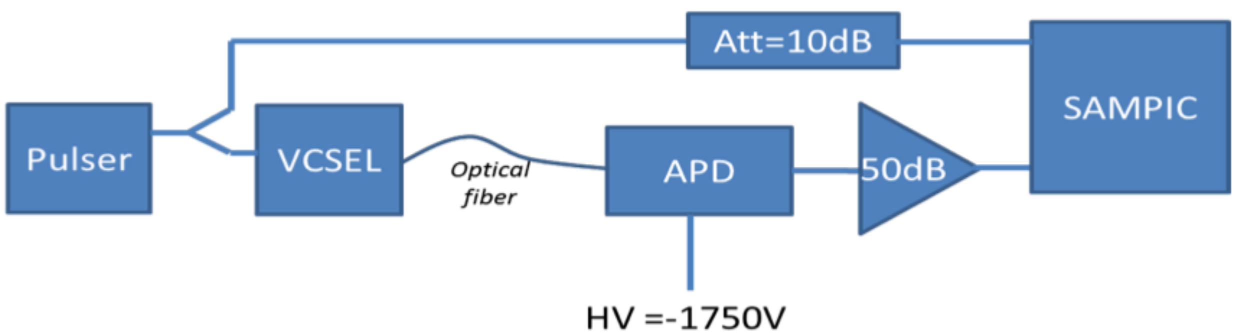
physics justification for timing layer likely stronger if we can extend timing well beyond eta=2.6
{in fact, ATLAS opportunity only starts at eta~2.6}

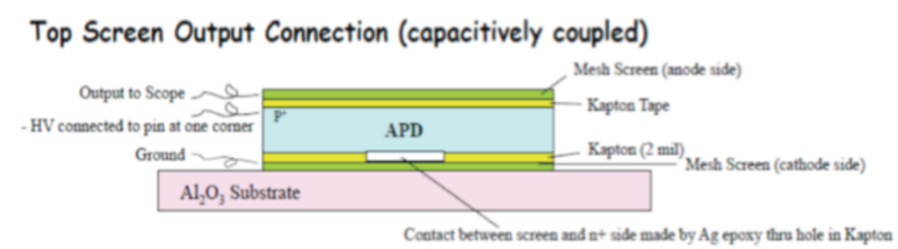
pre-existing collaboration with Orsay/Saclay on timing- see D. Breton's Elba talk:

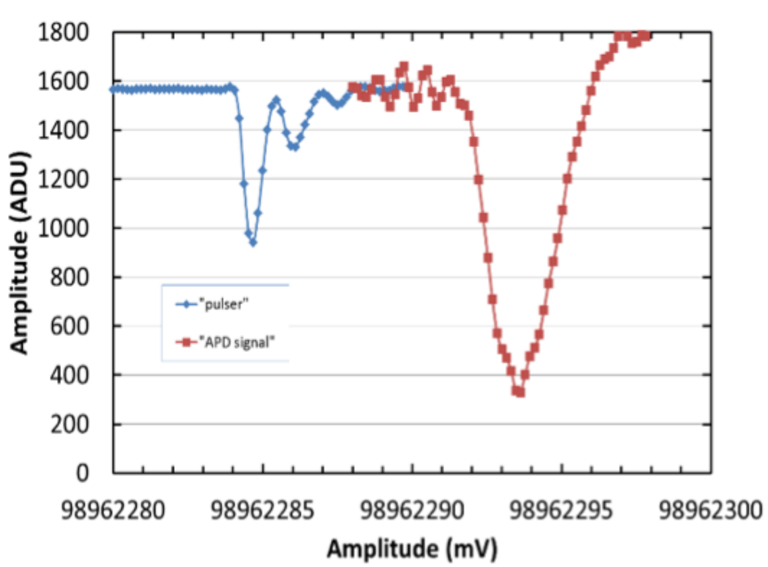
MEASURING PICOSECONDS …

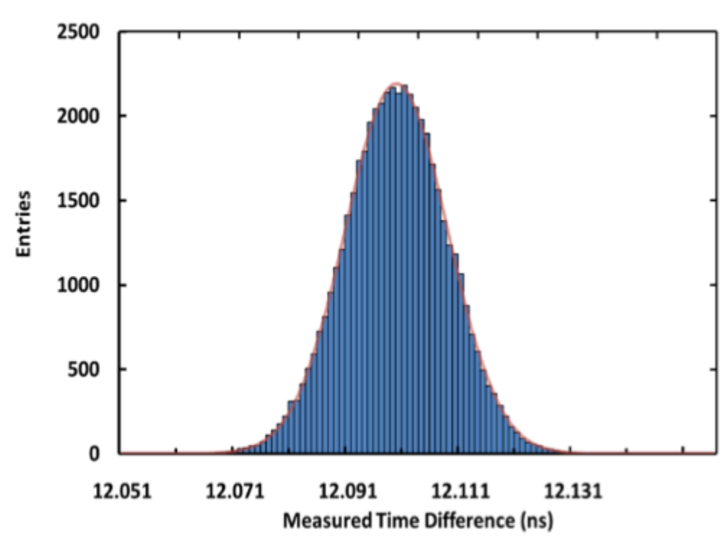
- SAMPIC module has been connected to **S.White's fast mesh-APD** at CERN (see S.White's poster).
- Goal : measure the **time difference between the pulser and the APD signal** => detector time resolution
- All measurements below performed in ~**1 hour.**
- Best measurement **< 10 ps rms**

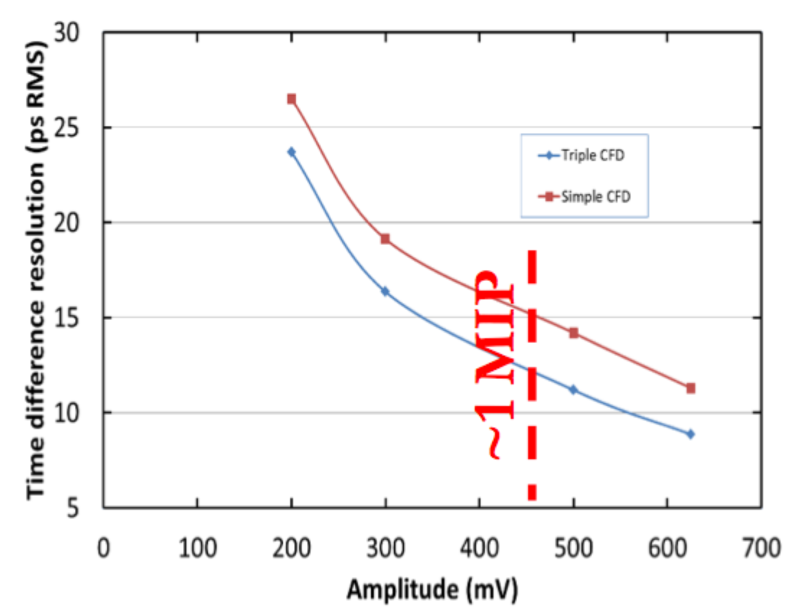












Our RD51 Project undertaken as a hedge against cost/ raddam issues w. solid sensors.

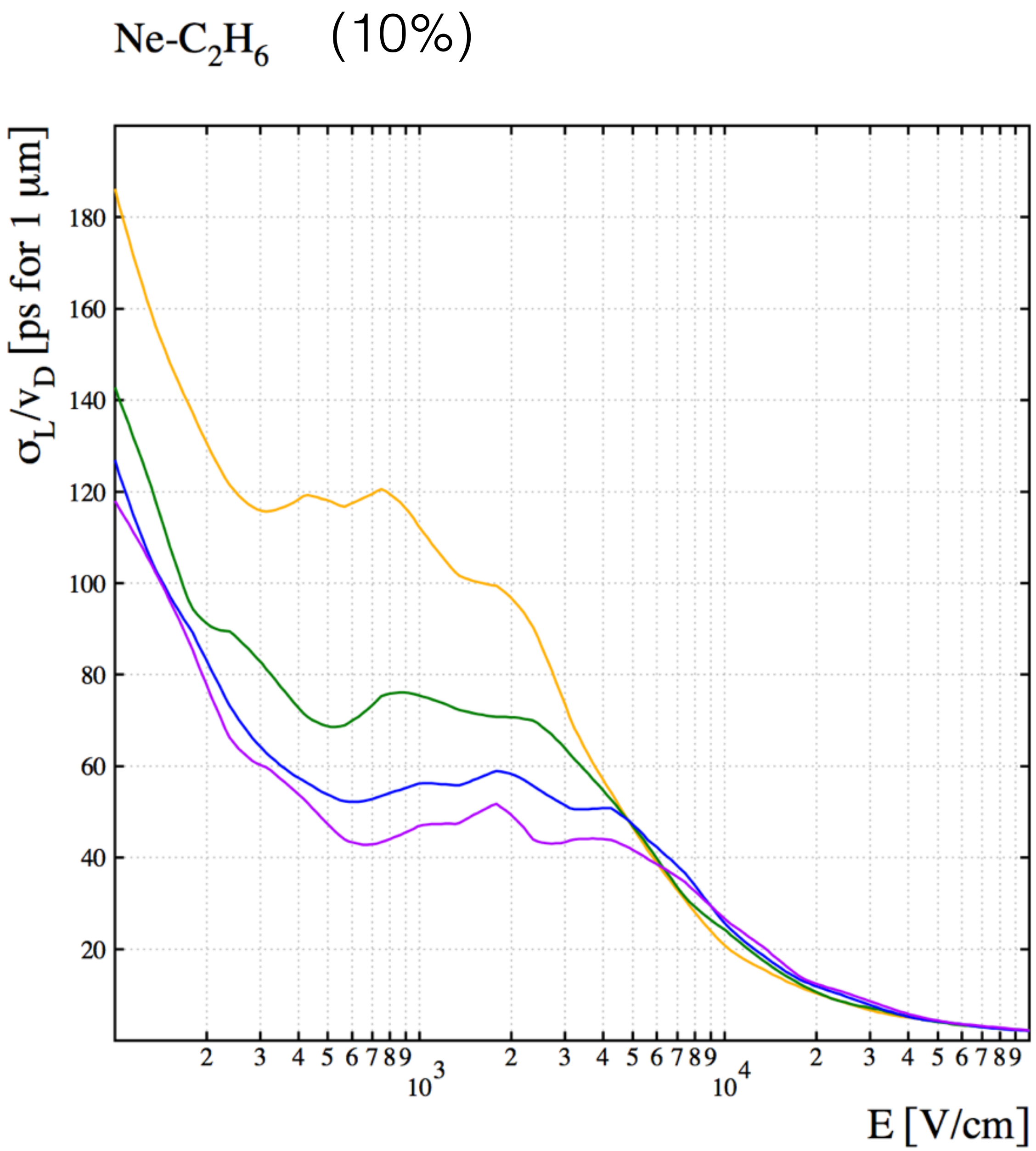
very little out there as options:

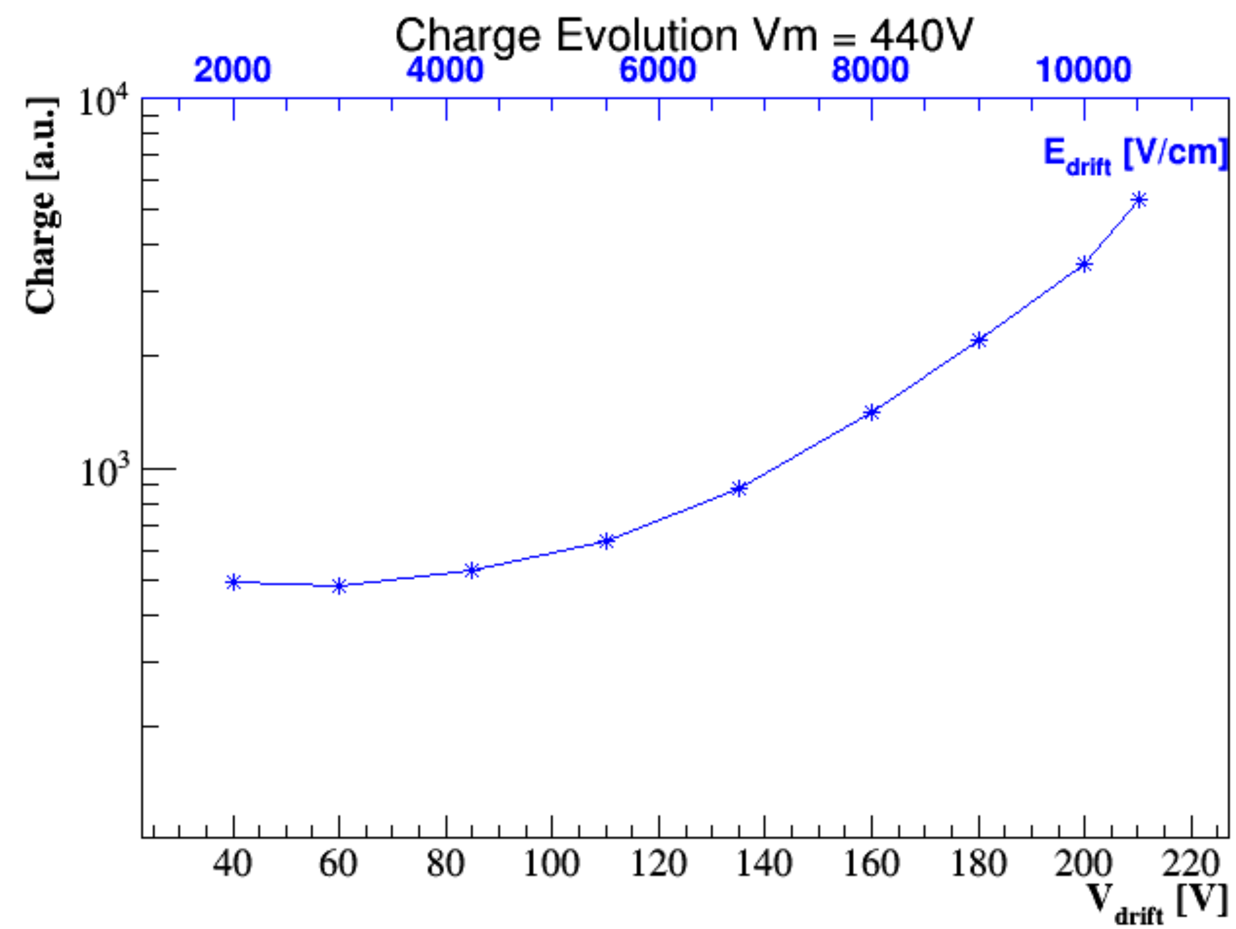
- CVD diamond-> ~95 picosecond
- GTK silicon->150-200 picosecond
- "LGAD" (similar t-resolution but rad issues at ~10^{14} neq/cm^2)
- Our Hyperfast, mesh readout, Si APDs still to be evaluated @>10^{14} neq/cm^2

what precedent for fast timing with Micromegas?

- at the 2001 Vienna Wire Chamber Conference Charpak, Ioannis, et al. demonstrated 680 pico sec rms (single pe) {NIM A 478 p.26 (2002)}
- Could this be developed into a charged particle detector w. MgF_2 radiator and proper choice of gas/field configuration?

Diffusion limited time jitter



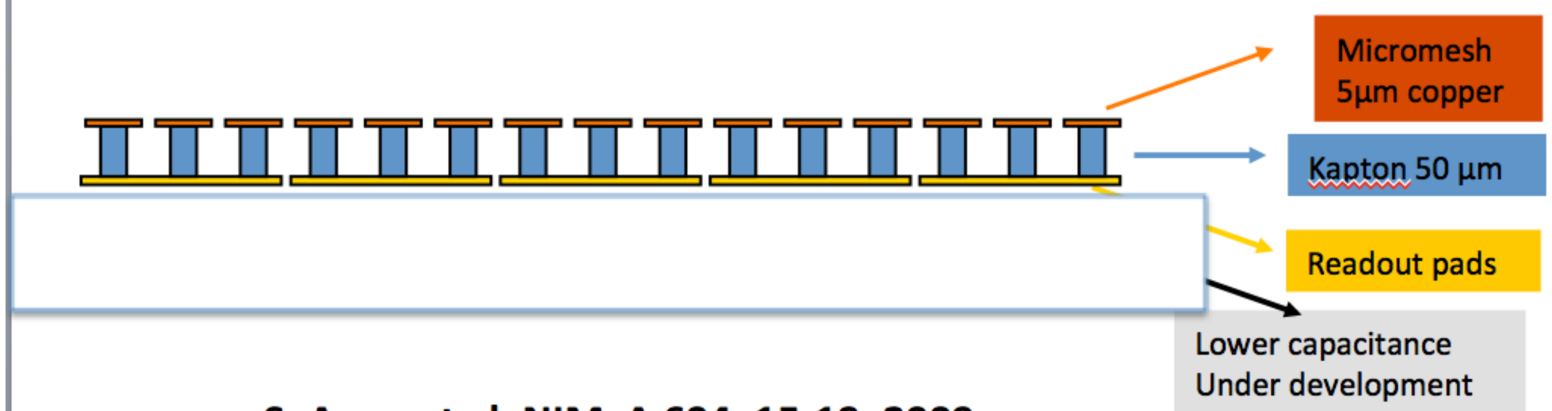


so far, tests in high drift field->10kV/cm,200 micron gap
->~350 pico sec per photoelectron

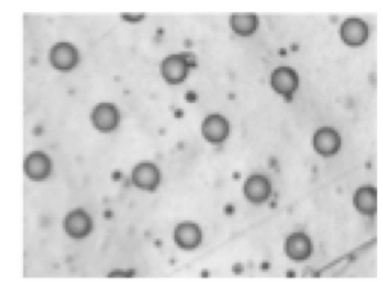
<u>however</u>, at these high drift fields we also have preamplification gain
-> effective ~factor 2 reduction in diffusion limit
->need ~50-60 pe/MIP
MgF2/CsI->~80pe/cm

This initial test used Microbulk technology for amplification structure.
Potential time jitter reduction with higher pitch.
Used Ne-Ethane (10%). CF4 possibly will yield lower jitter.
210 V in 200 micron “drift region” led to limited pre amplification gain.
440V across micro bulk in run shown below.
initial test with 10nm Al used as “pc” with very low (~10^-6) qe
n-photon ~ Cerenkov photon yield in final design

Microbulk technology



Pitch 100 µm,
Holes 30 µm



S. Aune et al. NIM A 604: 15-19, 2009
S. Andriamonje et al. JINST, 2010

✓Energy resolution (<13% FWHM @ 6 keV)
✓Low intrinsic background & better particle recognition
✓Low mass detector
✓Very flexible structure

×Higher capacity
×Fabrication process still improving
×Fragility / mesh can not be replaced

Detector design

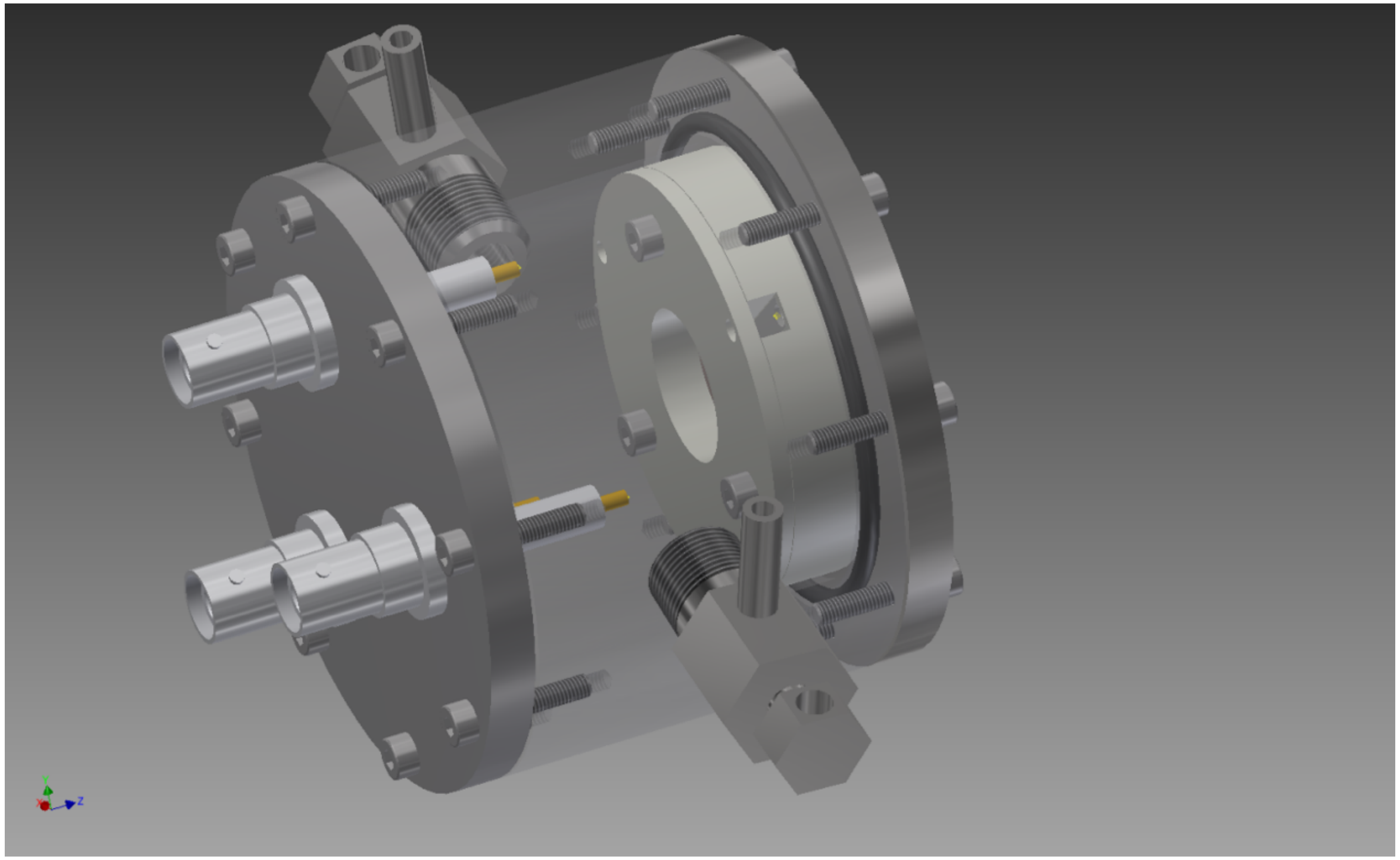
First tests with UV lamp / laser ➔ quartz windows

Microbulk Micromegas ø 1cm

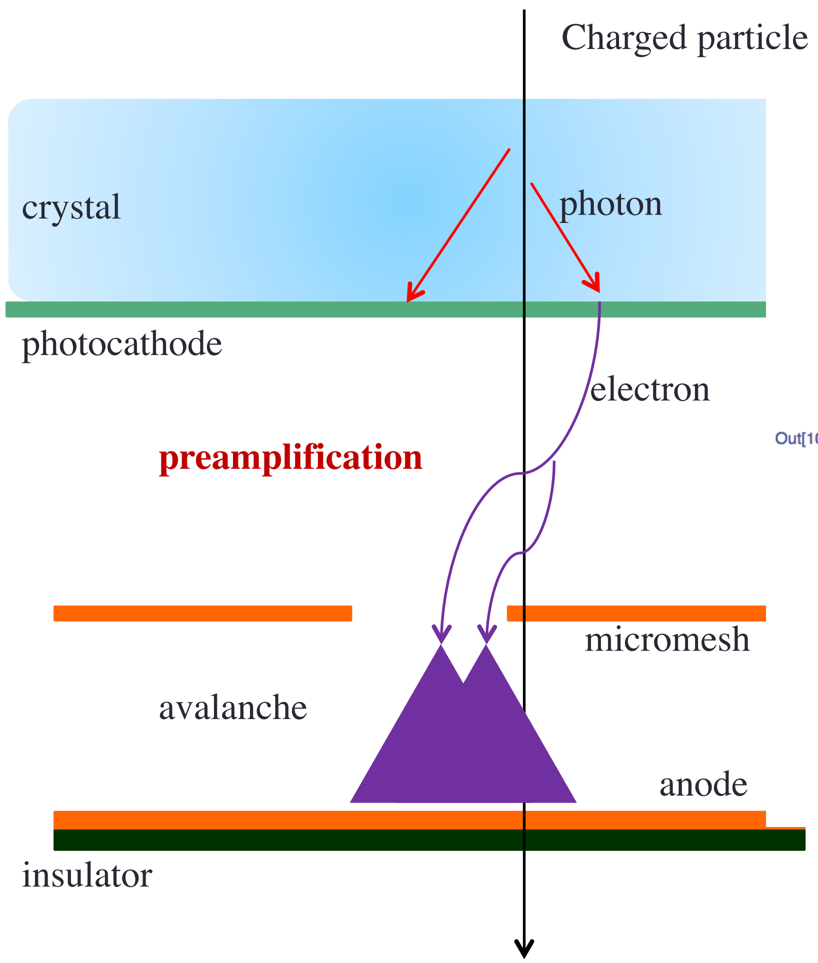
- ➢ Possibility to deposit CsI on the mesh surface
- ➢ Capacity ~ 35 pF

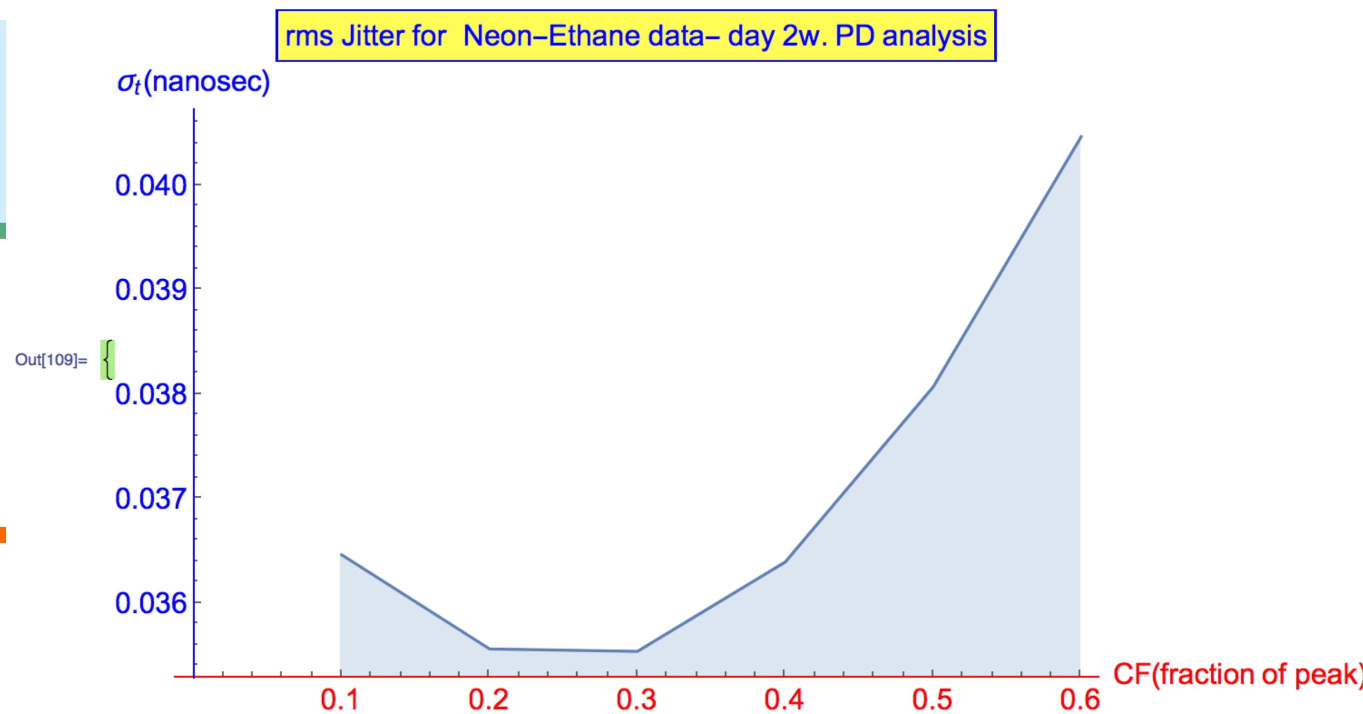
Ensure homogeneous small drift gap + contacts

Stainless steel chamber for sealed mode operation



Started with semi-transparent pc concept so far, 3 test runs at IRAMIS, Saclay





0.1	0.0364597
0.2	0.0355588
0.3	0.0355354
0.4	0.0363913
0.5	0.0380673
0.6	0.0404614

Several potential benefits:

cost @ scale
elimination of Landau jitter

Calibration of N_photoelectrons

good collaboration with Thomas Gustavsson of IRAMIS
improvements in noise environment around TiSa laser
end of April runs with single pe sensitivity

Method 1 from bench calibration:

Estimation of number of photo-electrons:

Measurement @ IRAMIS: signal ~1300 mV

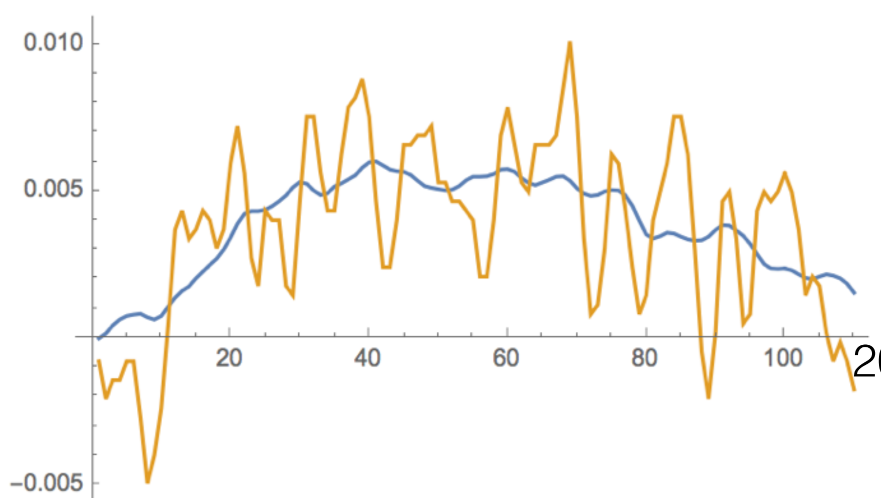
Measurement with pulsed lamp @ SEDI: signal ~600 mV
Measurement with candle @ SEDI: <signal> ~30 mV

So, we concluded that we had around 20 photo_electrons at the lab and around 50 with the laser.

method (2) from/200 optical attenuator data

Effect of filtering on a typical waveform.

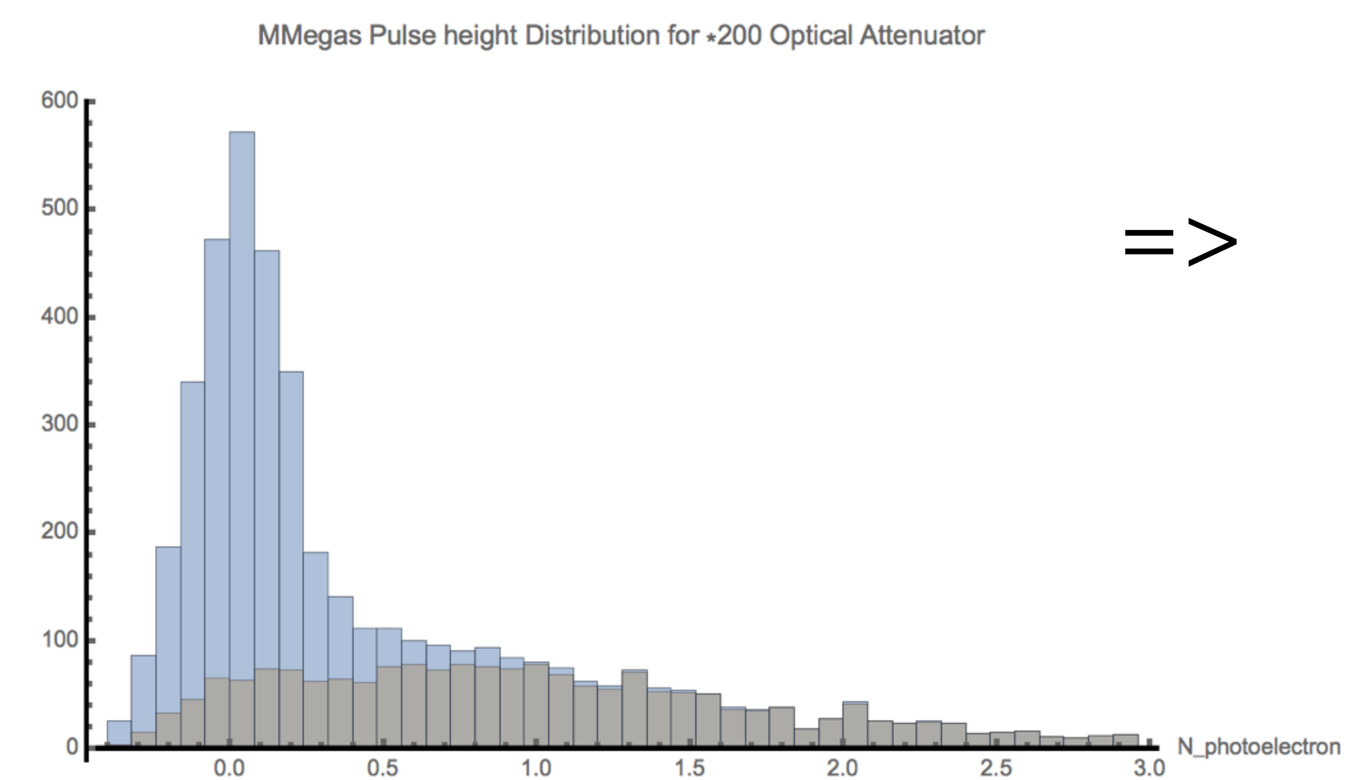
```
ListPlot[{v1fil[[1]], Take[(v2[[1]] - inbase1[[1]]),
```



200 psec bins->

<=

single pe data are pretty noisy
looks like digital noise dominates
next time need higher sampling
also setting scope to lower scale would have reduced this



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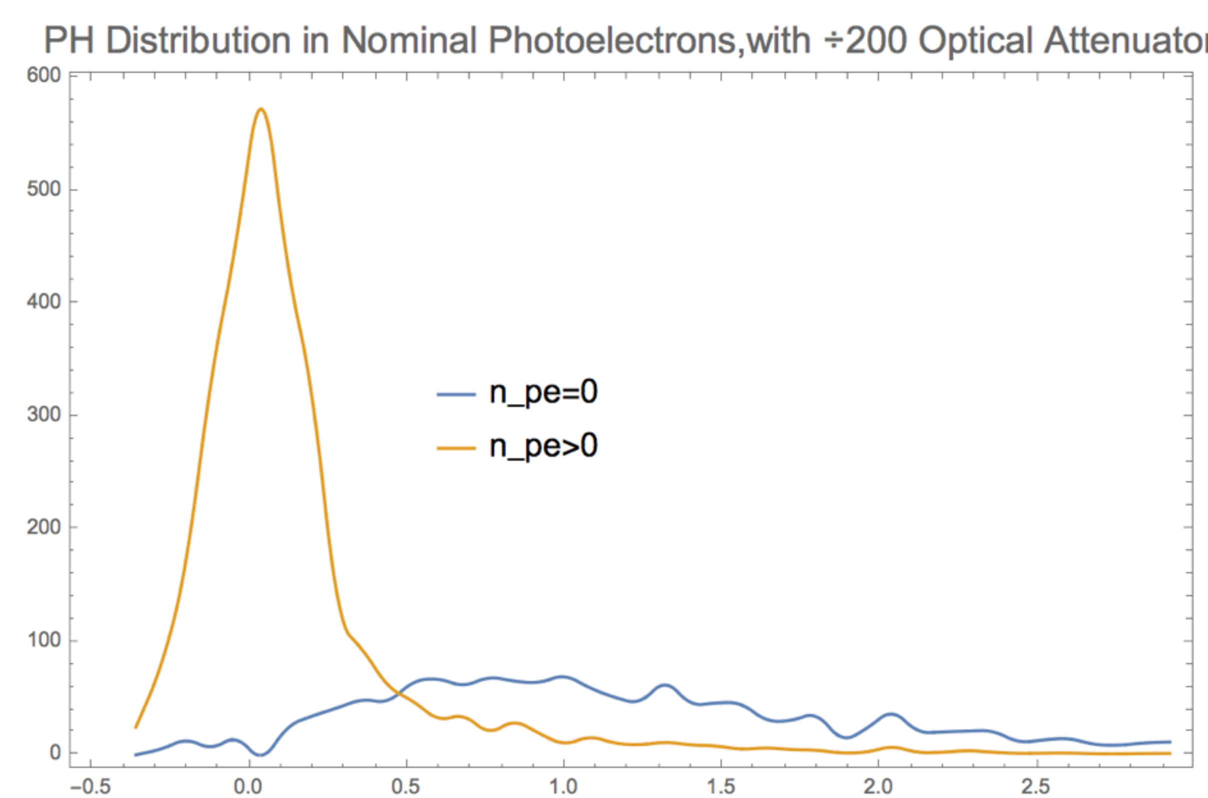
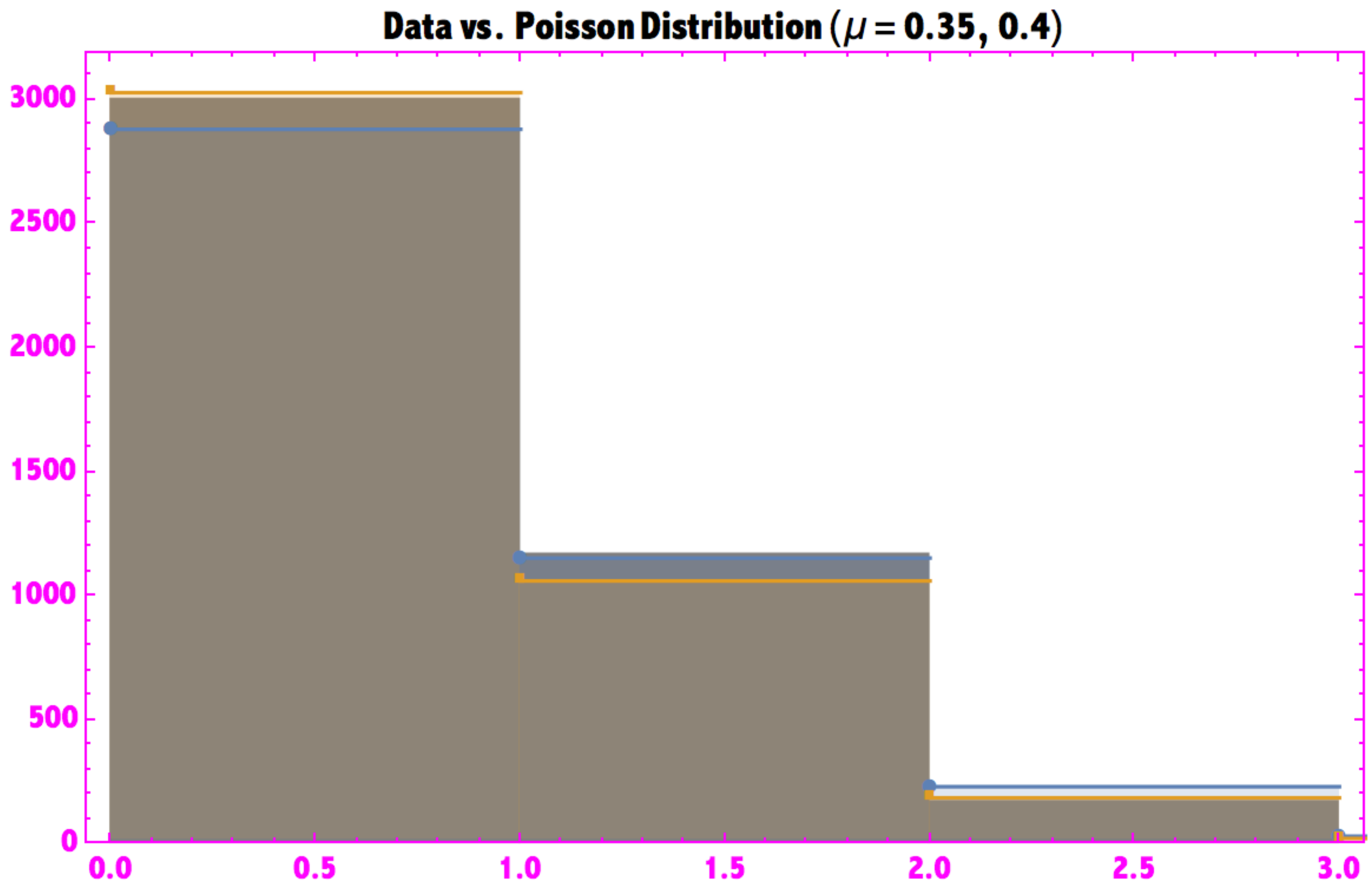


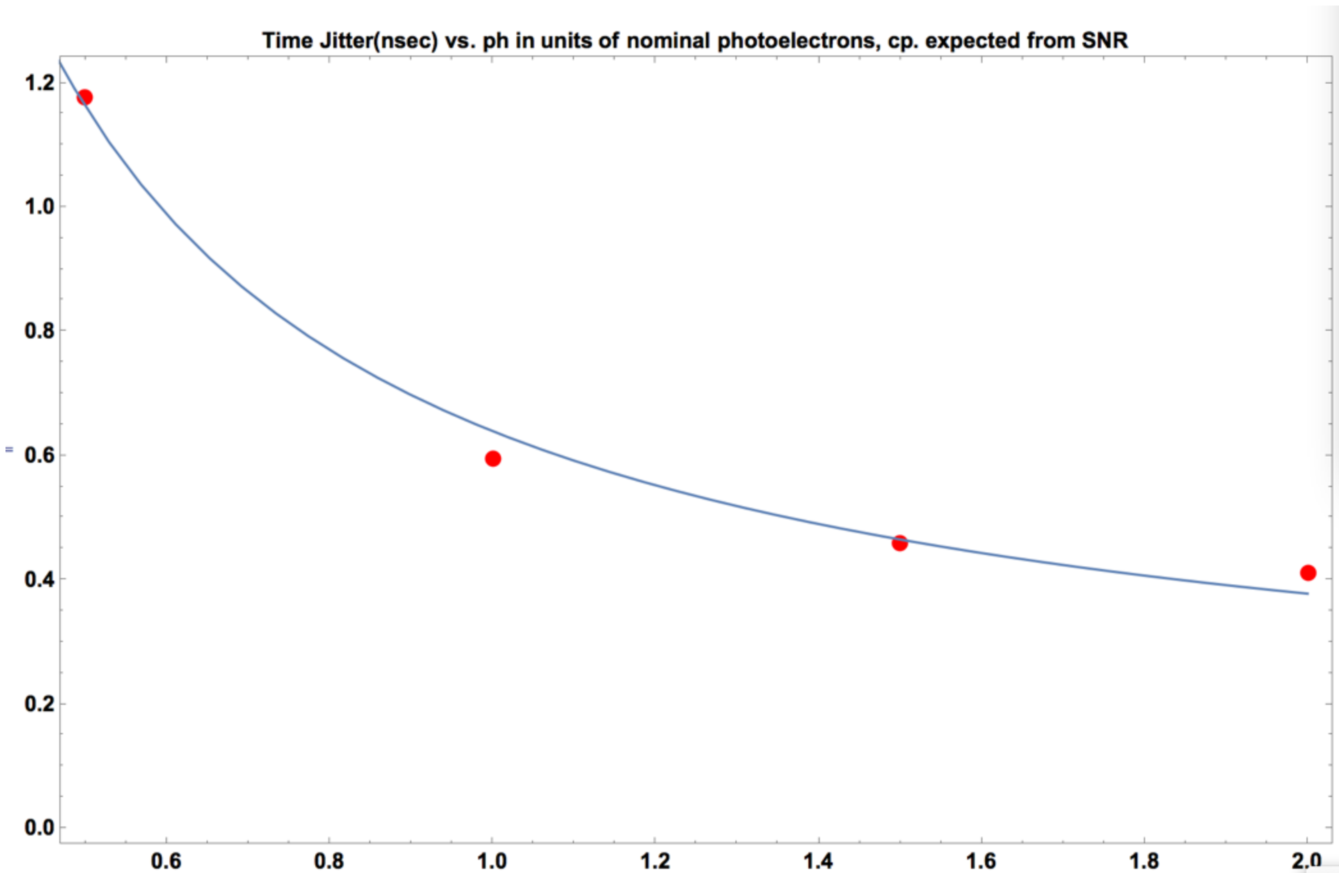
Photostatistics from attenuator data



This plot shows extracted N_pe distribution
It is compared to expectation for mean of 0.35 and 0.4

correcting for the /200 attenuator we find N_pe~60 for normal running with no attenuator
We consider this to be consistent with the ~50 result obtained by Thomas

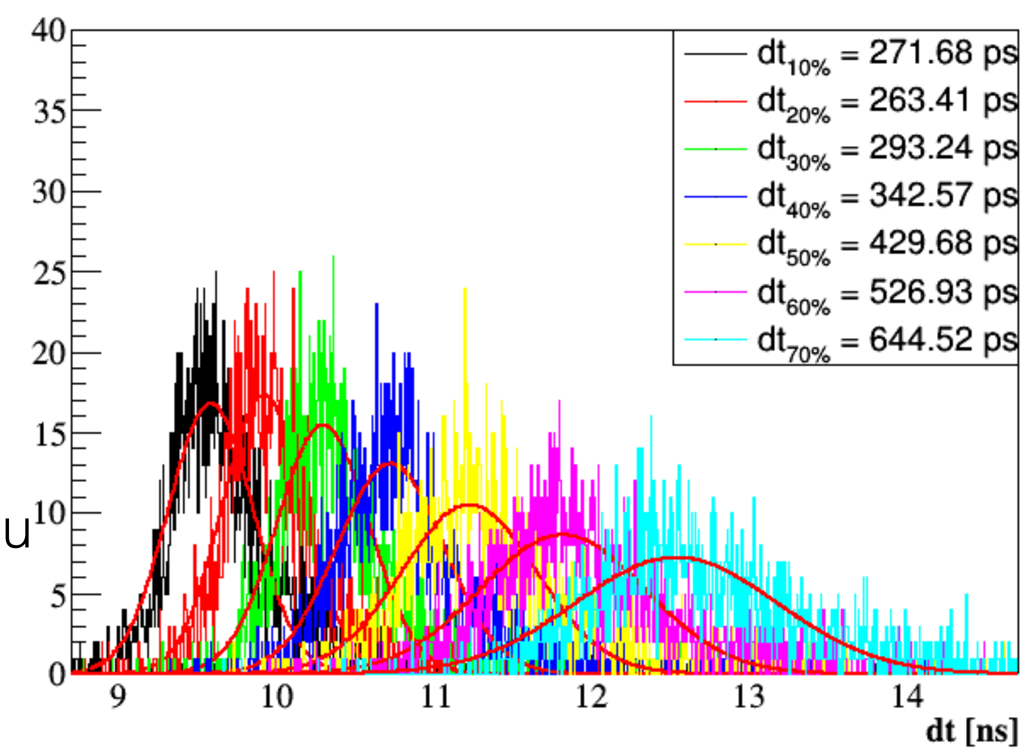
Jitter on Single pe



using the same timing algorithm
as I used for jitter at ~50 pe
we are noise dominated as shown
here.

more aggressive fitting/filtering
is giving closer to expected diffusion
dominated jitter @1pe
ie ca.~260 psec

Thomas Papaevangelu
->



Plans

- possibly another 1-2 runs w. Saclay chamber for cosmetic purposes-> write up proof of concept

- parallel development here at CERN of other test structures

- expect to have full, charged particle detector assemblies for beam tests at end of summer

- many interesting issues to follow proof of concept: gas & field configuration optimization, rate effects, photocathode development , possible benefits of reflective photocathode, etc.