TOF MC Status

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Old TOF MC Status Review

1: TOF simulation program is mainly written by E.Choumilov

2: Optical photon transmission simulated in scintillator+LG+PMT is simulated by LTRANS, a Fortran package

3: Using parameterized table to do simulation, namely time and charge simulation

Need to be better

1: finite geometry of LTRANS

2: Not flexible to do modification

3: Not be able to do online simulation

4: PMT parameters need to be update

Outline of new TOF Geant4 software

1: Geant4 optical photon simulation

2: TOF Geant4 Introduction

3: new PMT +electronic simulation

4: MC software development status

5:Tuning work

5: To do list

Geant4 optical photon simulation

1: Geometry volume

Box, Bend, Twist, Polygon….

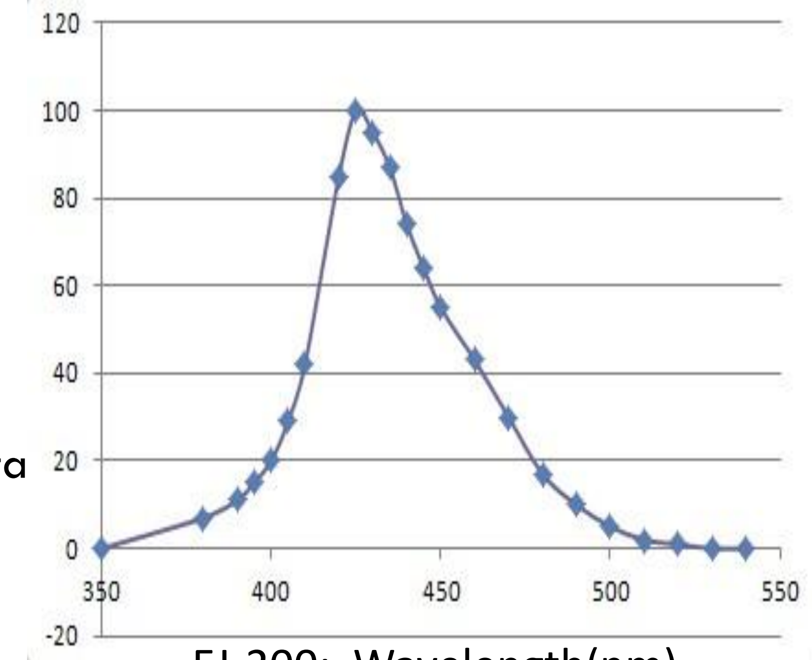
2: Scintillation process simulation:

Number of photon generate proportional to energy lost during step

Yield, emission spectrum sample from input data

Emission time spectrum of rise and delay(fast/slow) with exponentail time constant

Birk saturation constant can be added



EJ-200: Wavelength(nm)

```
TOFSc_Mt = new G4MaterialPropertiesTable();
TOFSc_Mt->AddProperty("FASTCOMPONENT", PhEnergyS, Sci_Fast, ENUMS);
TOFSc_Mt->AddProperty("SLOWCOMPONENT", PhEnergyS, Sci_Fast, ENUMS);// s
TOFSc_Mt->AddProperty("RINDEX",        PhEnergySI, Sci_RIND, ENUMSI);
TOFSc_Mt->AddProperty("ABSLENGTH",     PhEnergySI, Sci_ABSL, ENUMSI);

G4double DEDX=QEMAX*10000./MeV;
/  G4double DEDX=10000./MeV;
TOFSc_Mt->AddConstProperty("SCINTILLATIONYIELD",DEDX);
TOFSc_Mt->AddConstProperty("RESOLUTIONSCALE", 1.0);
TOFSc_Mt->AddConstProperty("FASTTIMECONSTANT",2.1*ns);
TOFSc_Mt->AddConstProperty("SLOWTIMECONSTANT",2.1*ns);
TOFSc_Mt->AddConstProperty("FASTSCINTILLATIONRISETIME",0.9*ns);
TOFSc_Mt->AddConstProperty("SLOWSCINTILLATIONRISETIME",0.9*ns);
//TOFSc_Mt->AddConstProperty("YIELDRATIO",0.8);
TOFSc_Mt->AddConstProperty("YIELDRATIO",0.0);
TOFSc_M->SetMaterialPropertiesTable(TOFSc_Mt);

// Set the Birks Constant for the scintillator
TOFSc_M->GetIonisation()->SetBirksConstant(0.0116*mm/MeV);
```

3: photon transmission in medium

The optical property of material medium can be define as a function of photon energy

photon absorption and propagation in medium according to the Material table

Wavelength shifting(WLS)+ Rayleigh scattering + Mie scattering is optional

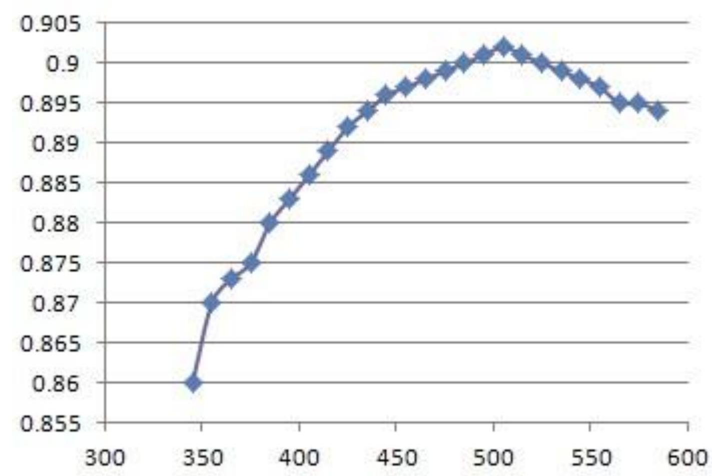
```
const G4int ENUMSI = 3;
G4double PhEnergySI[ENUMSI]={
 2.386*eV,2.886*eV,3.447*eV,
};
G4double Sci_RIND[ENUMSI]={
1.58, 1.58, 1.58,
};
G4double Sci_ABSL[ENUMSI]={
400.*cm, 400.*cm, 400.*cm,
};
```

4: Boundary process

Dielectric-Dielectric: total internal reflection , Fresnel refraction, Fresnel reflection

Dielectric-Metal: absorption , reflection, diffuse reflection

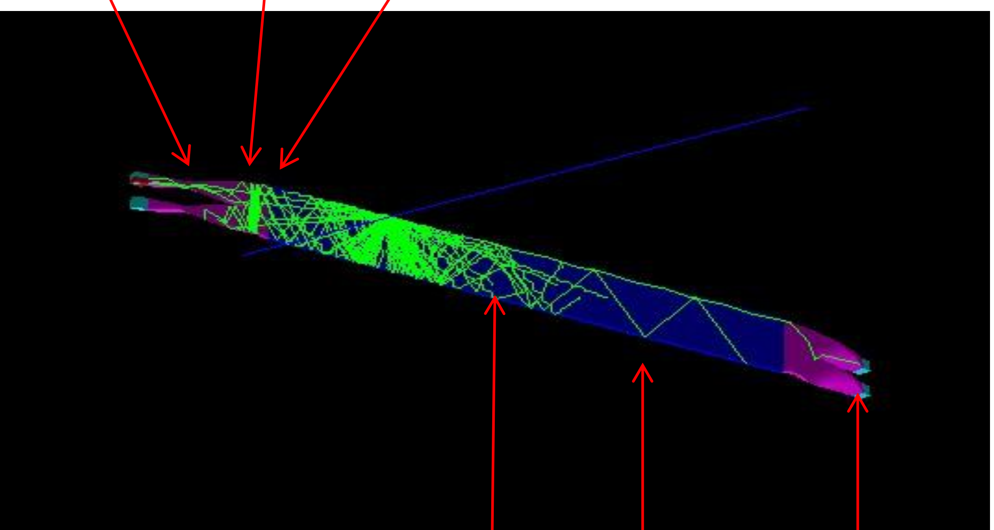
Volume bounary with the concept of Surface , allows for different feature depending on photon direction and photon energy

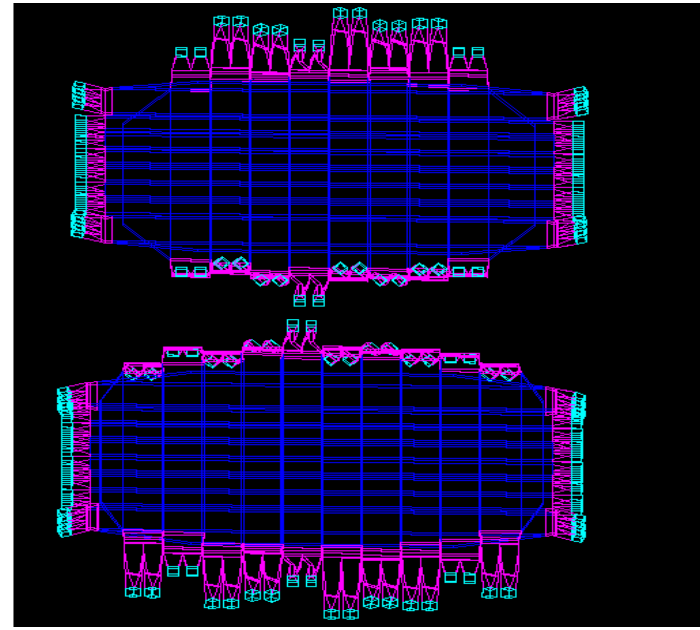


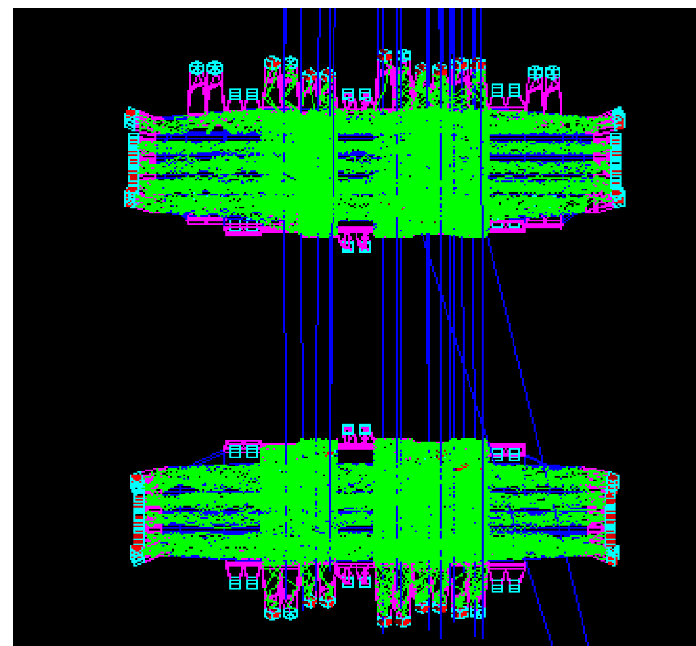
Al mylar reflection: Wavelength(nm)

TOF Geant4

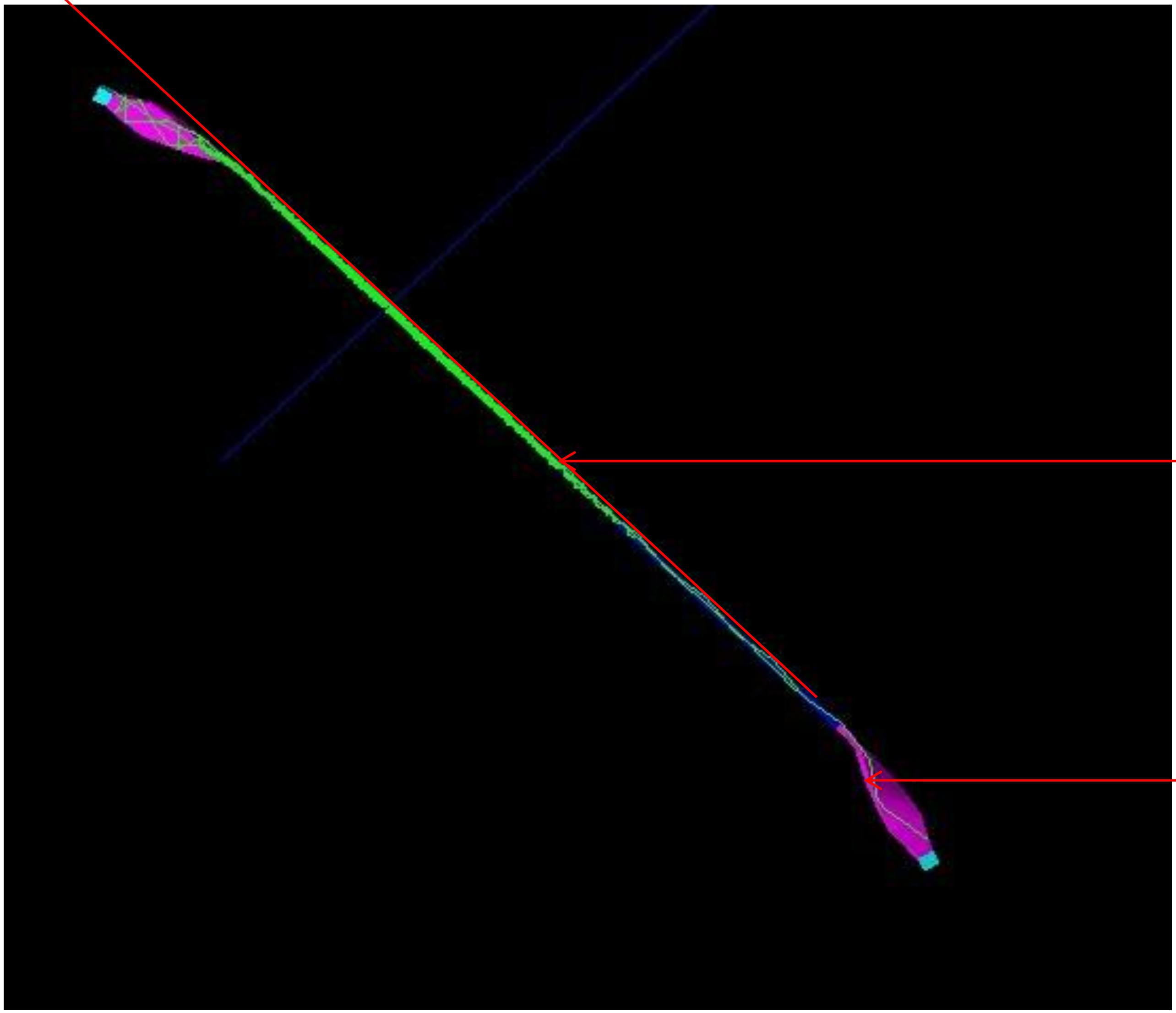
Gemetry







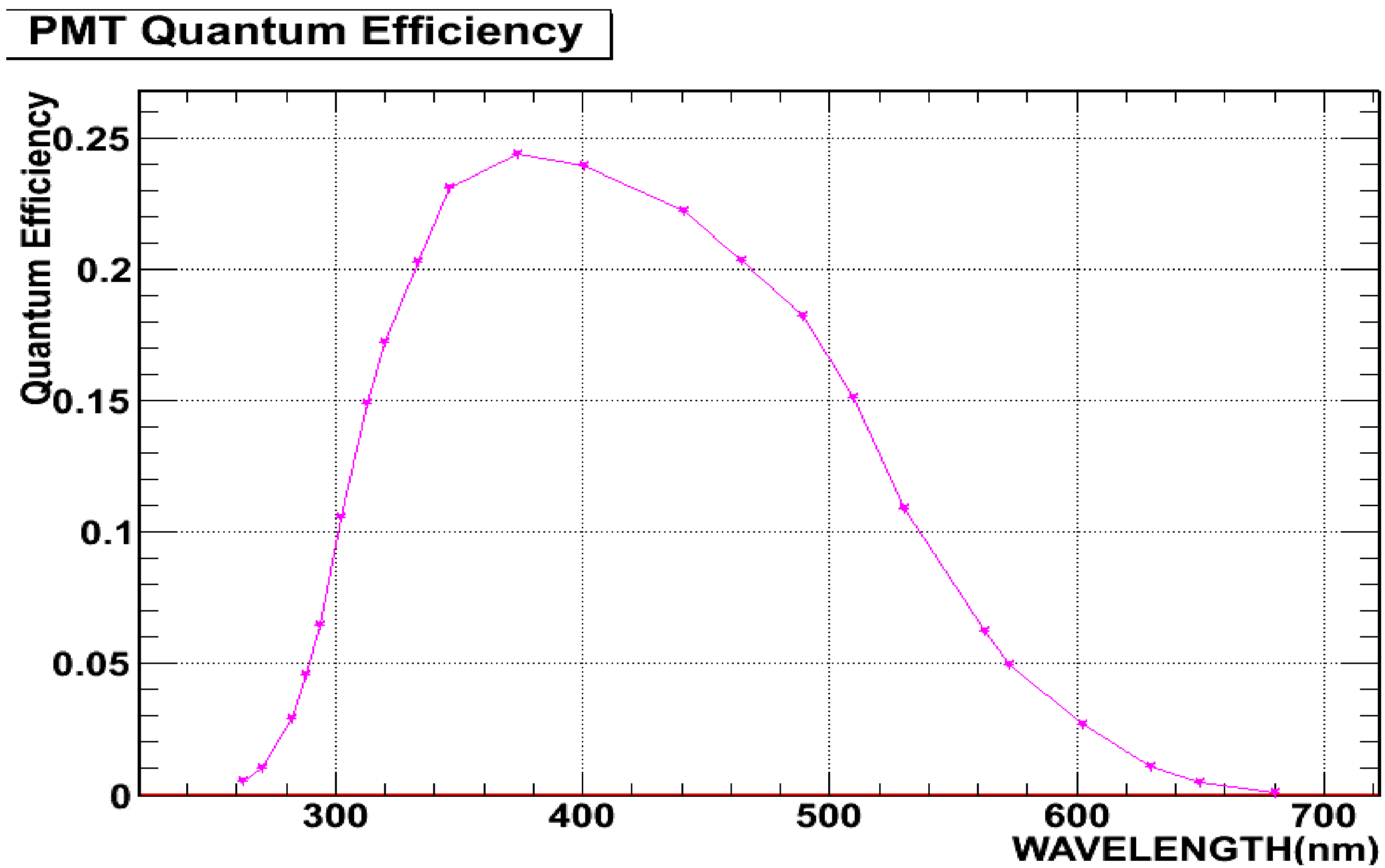
Al Skin: Vacuum gap (n=1)+Al wrap



Scintillator(EJ-200)
n=1.58

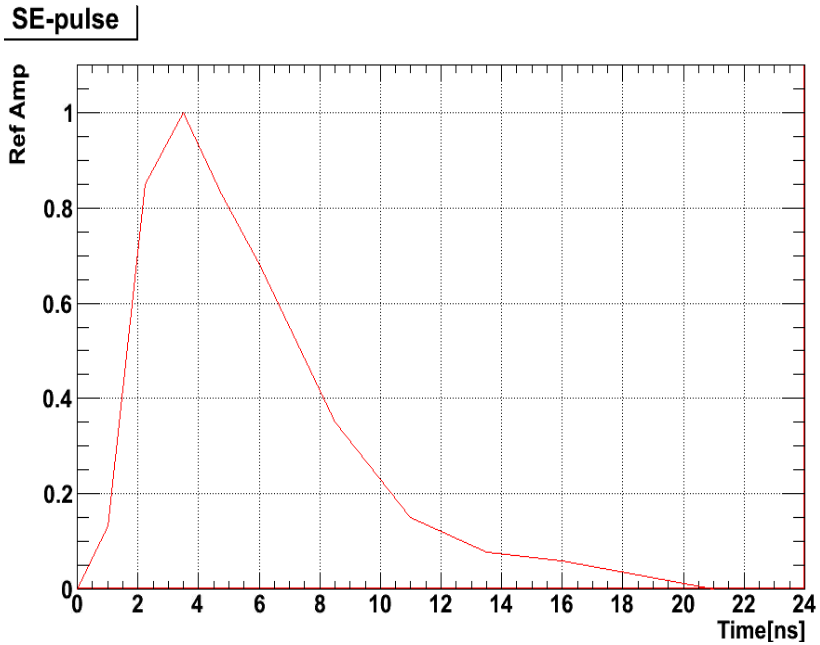
Light guide(PMMA)
n=1.49

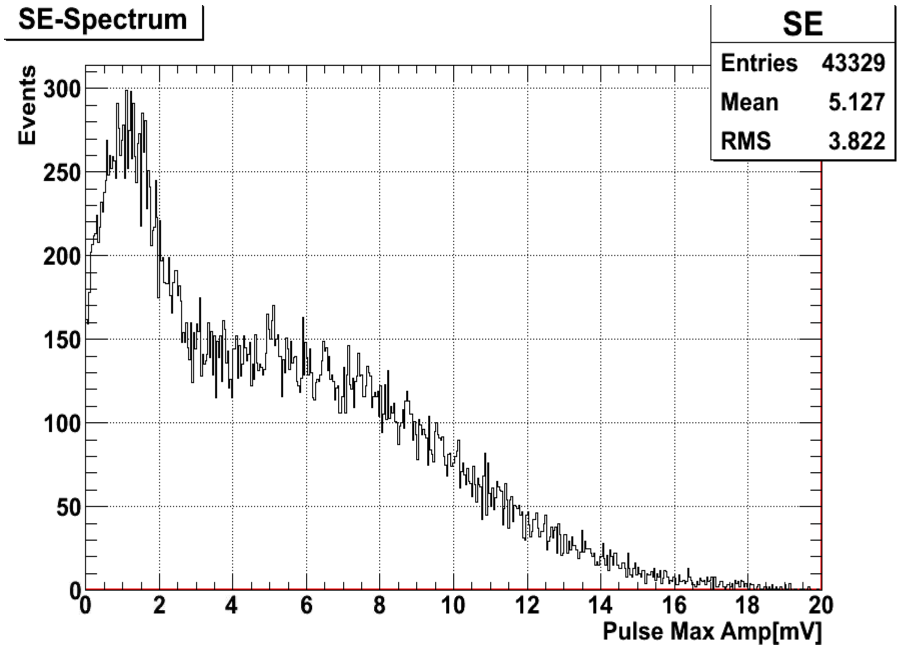
PMT Quantum efficiency simulation



Hamamatsu PMT R5946 quantum efficiency

Single electron pulse + spectrum

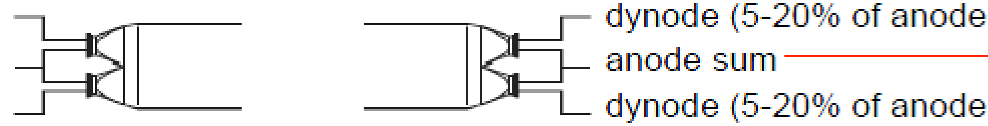




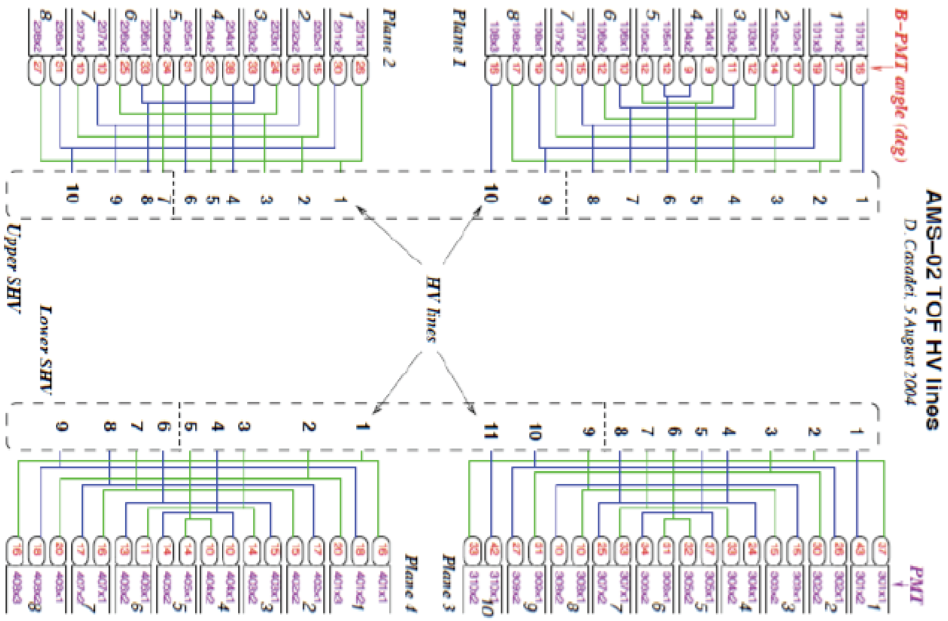
SE Pulse shape:

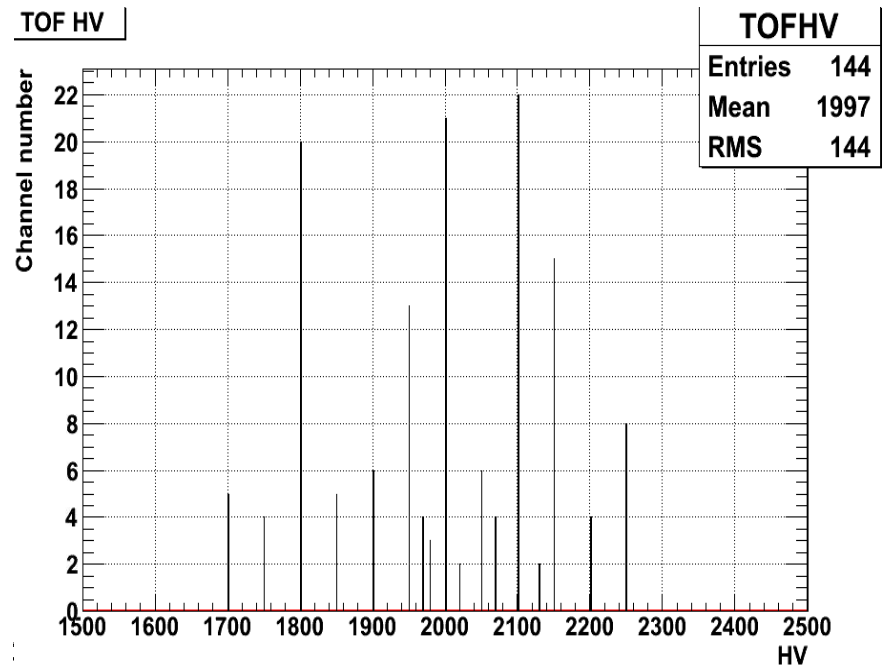
SE spectrum

Unbalance of HV for same side PMTs



- Each counter must be able to operate with only one PMT powered in each side.

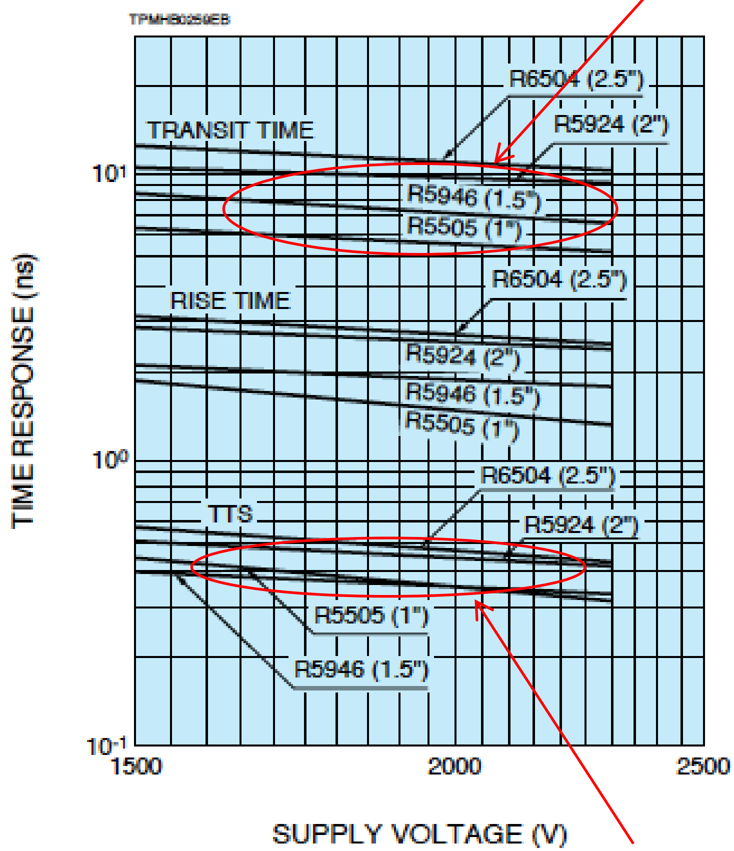


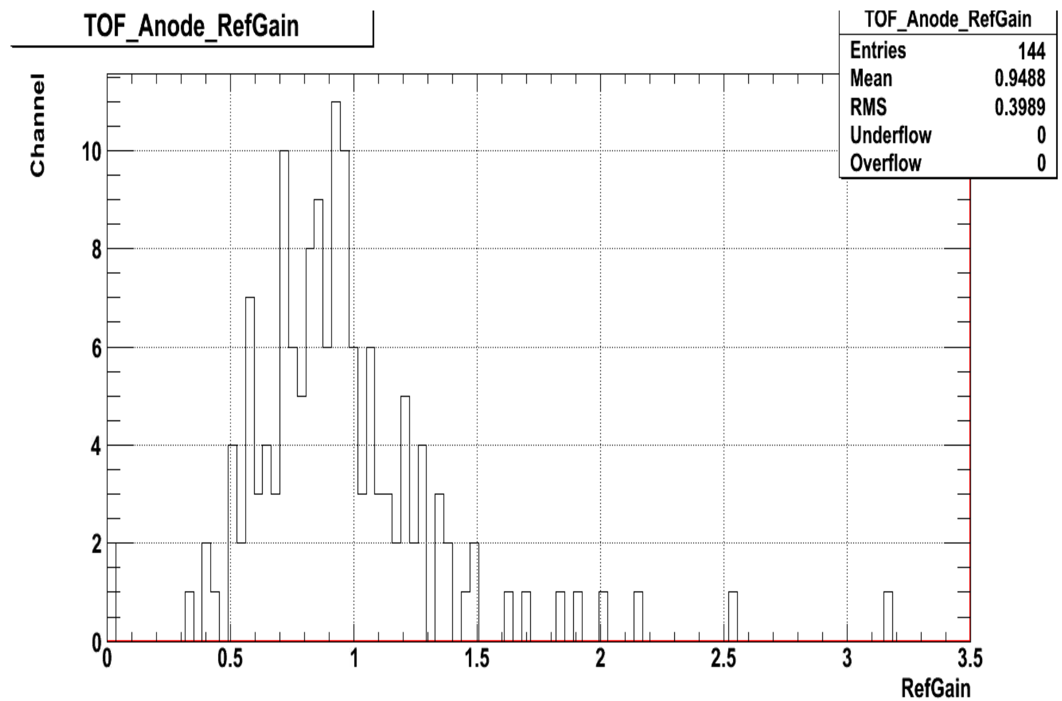


PMT HV Setting

PMT Transmit Time +Gain Unbalance

Fig.3: Typical Time Response **Transmit Time=7.16 pow(hv/2000.,-0.567);**





Anode gain for all pmt

Transmit time Spread 0.357*pow(hv/2000.,-0.412)

TOF MC Software Status

1:TOF Geant4 new source and update code for AMSsoft

New geant4 simulation code and connect to AMSsoft: TofSimUtil.h TofSimUtil.C g4tof.h g4tof.C

New PMT and electronic simulation code: Tofsim02.h Tofsim02.C Tofdbc.h Tofdbc.C

Update file:

geant4.h gvolume.h linkdef.h mccluster.h ntuple.h root.h commom.h

geant.C geant4.C g4physics.C gmat.C amsgeom.C gvolume.h mcluster.C event.C root.C job.C

2:New class

TOFMCPmtHitR: record each detect photon's information for further analysis: arriving PMT time, transmit time ,energy, …

3: New Database file

TofGainPMag_v1.dat : TOF PMT Anode and Dynode Gain + HV setting+LT HT SHT setting

TofGeant4_v1.dat: using for tuning of Geant4 TOF

4:How to use newest Gean4 TOF simulation (icc/gcc))

1: TOF new PMT+ new electronic simulation

setenv TOFNEWSIM 1(before compile): Tofsim02.C instead of tofsim02.C

2: Datacard: TOF new Geant4 online simulation

G4FFKEY.TFNewGeant4=1 MISCFFKEY.G4On=1

If you unsetenv TOFNEWSIM before compile, and switch off TFNewGeant4, old parameterize table and old simulation will be used without affect present simulation

Tuning work in progress

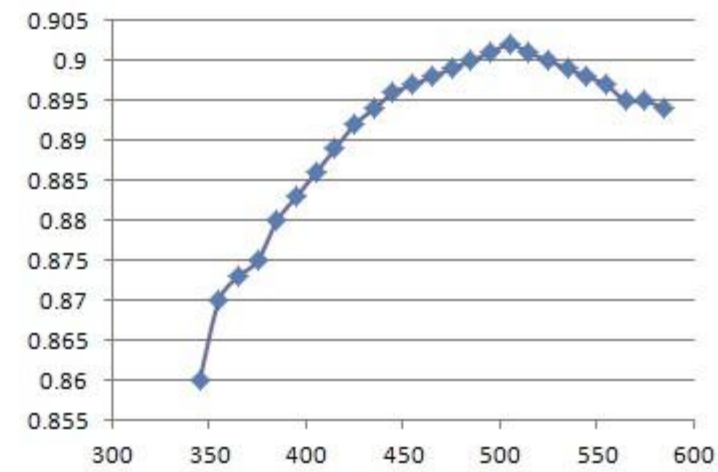
Test Three Finish Model of LG+SC surface

1: dielectric_metal

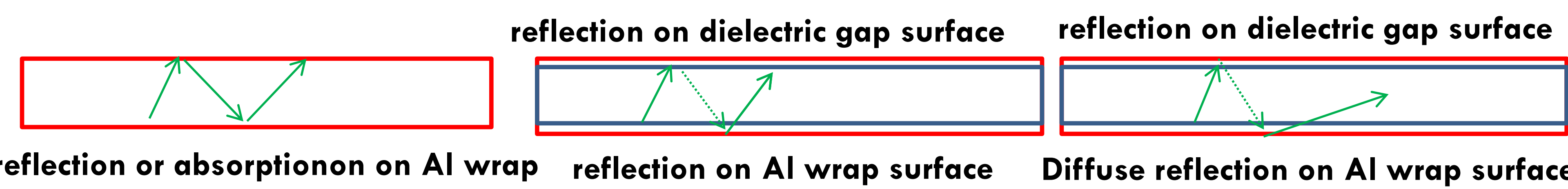
2: polishbackpaint

3: groundbackpaint

4: newbackpaint(based on 2+3)



Al mylar reflection: Wavelength(nm)



1: dielectric_metal

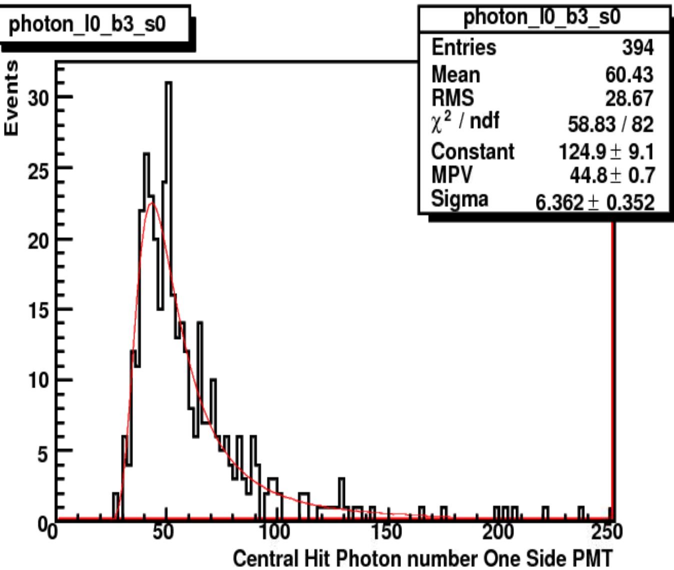
2: polishbackpaint

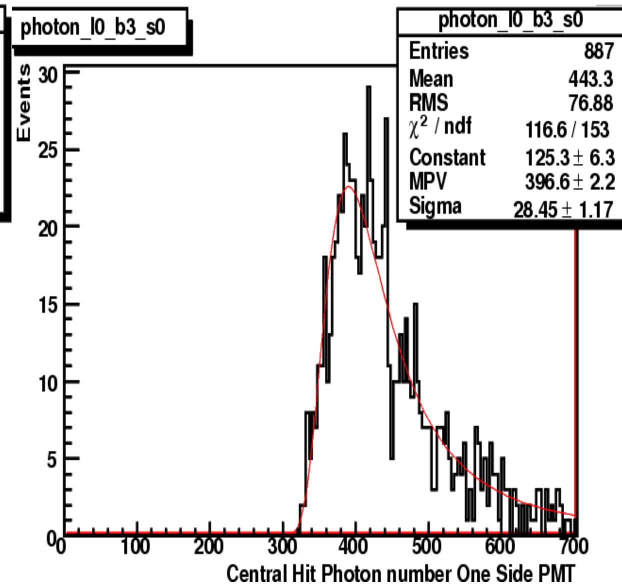
3: groundbackpaint

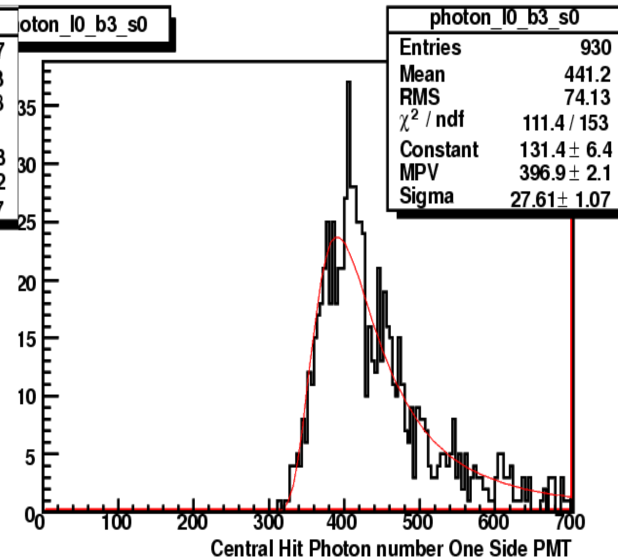
Newbackpaint: 2+3+dielectric surface absorption

Proton Photon Electron Number Comparison

Typical Bar one side Photon Number in Geant4 simulation







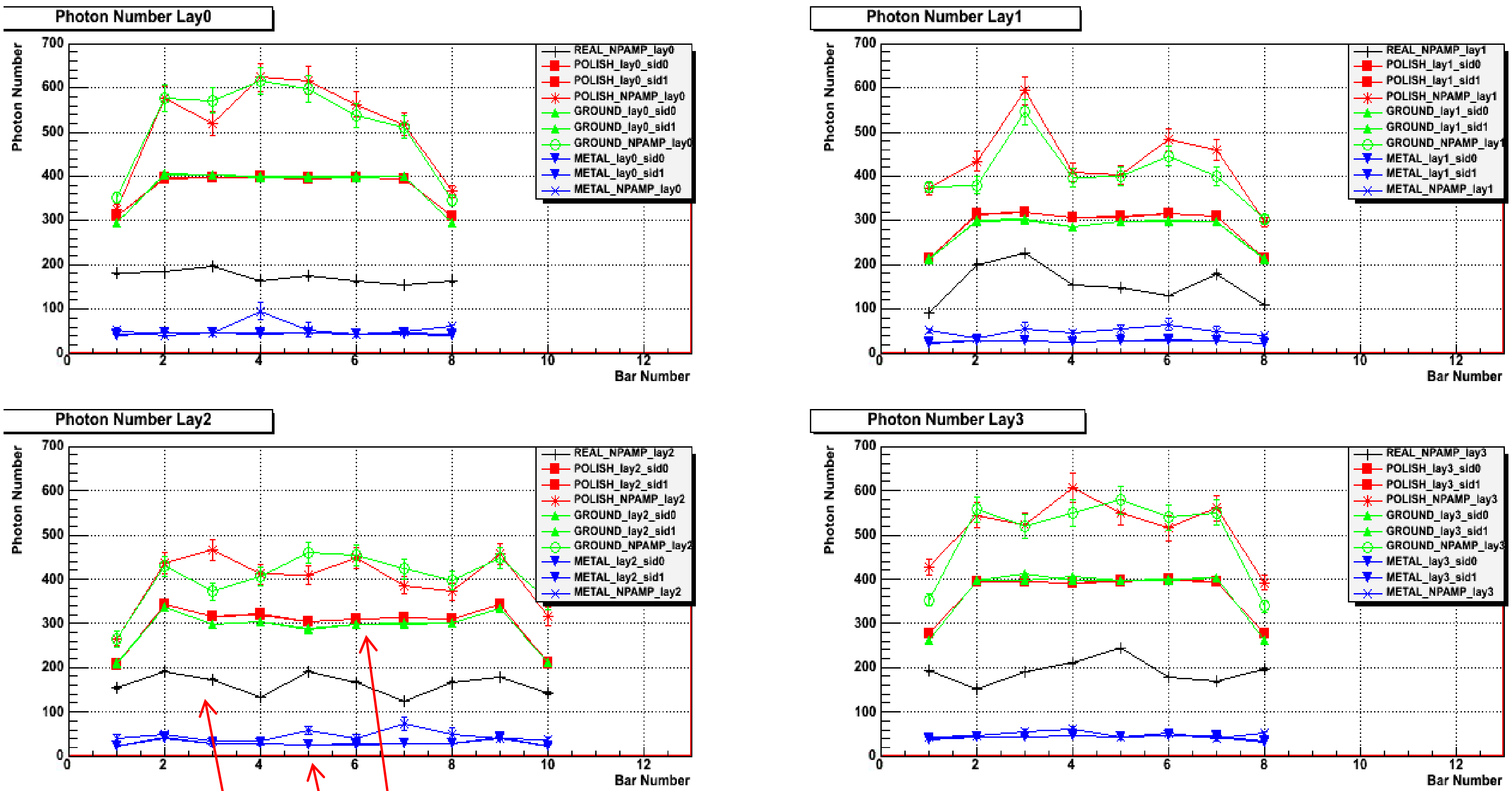
1: dielectric_metal

2: polishbackpaint

3: groundbackpaint

MC +ISS Proton Photon Electron

$$N_{phe} = \frac{1}{\sigma_R^2} \text{ wth R} = \frac{Q_N - Q_P}{Q_N + Q_P}$$



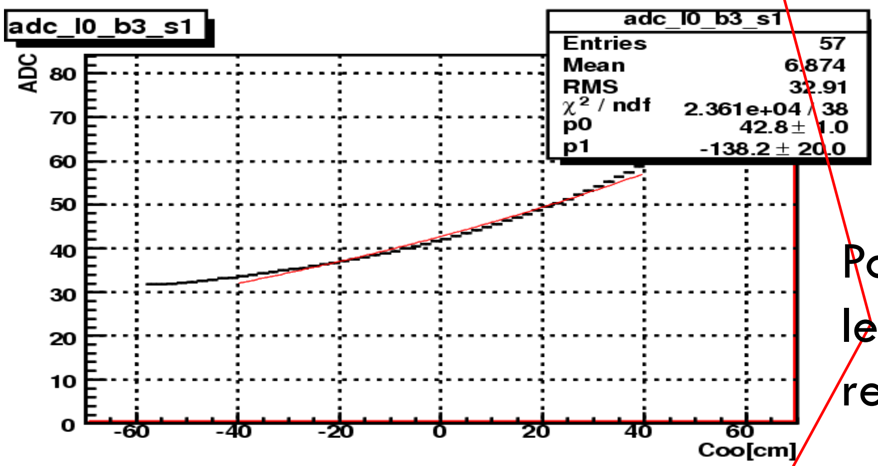
ISS photon number is about 200 for central region

dielectric_metal Finish --photon number is 50 much lower(Model Abandon)

Gap Model--photon number is 300 much higher but can used for further tuning

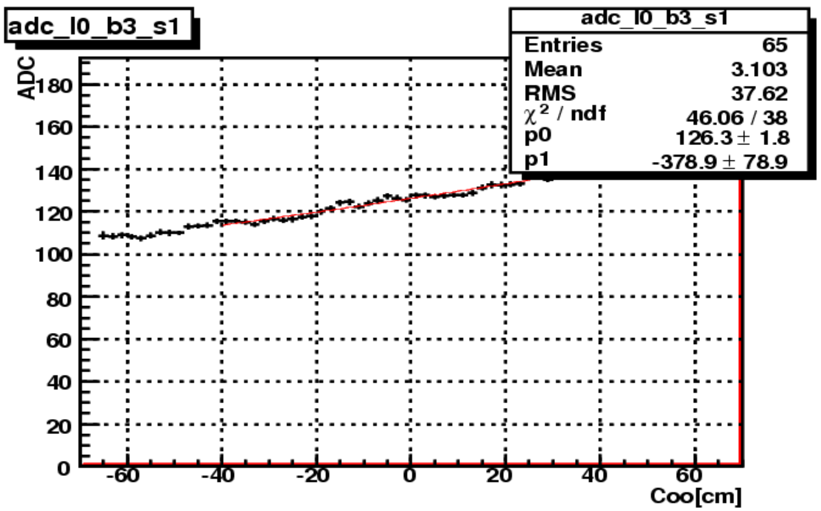
Amplitude Attenuation

ISS Typical Attenuation length is about 150cm



Polishbackpaint Model attenuation length is larger than ISS data,which relate to dielectric surface quality

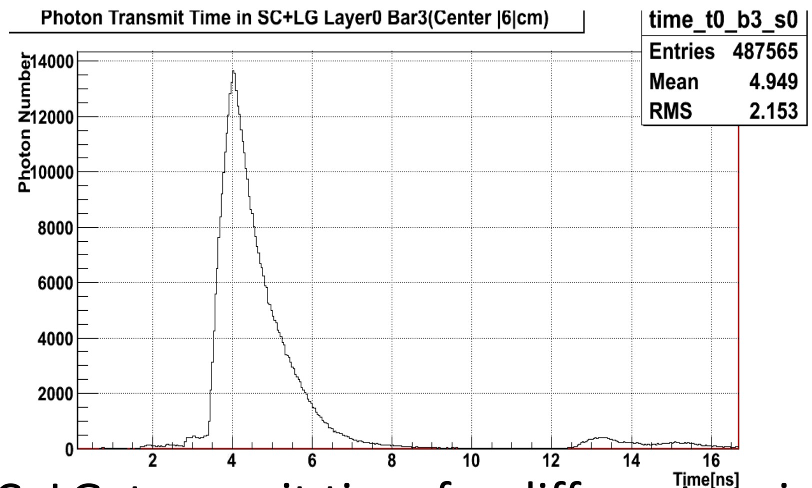
Polishbackpaint Model MC Typical Attenuation length is about 350cm

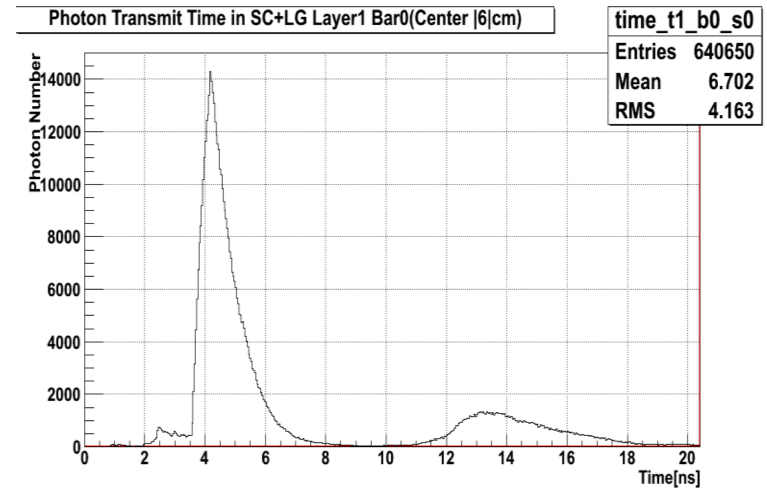


LG+SC dielectric surface absorption parameter need to adjust

Photon Transmit Time in SC+LG

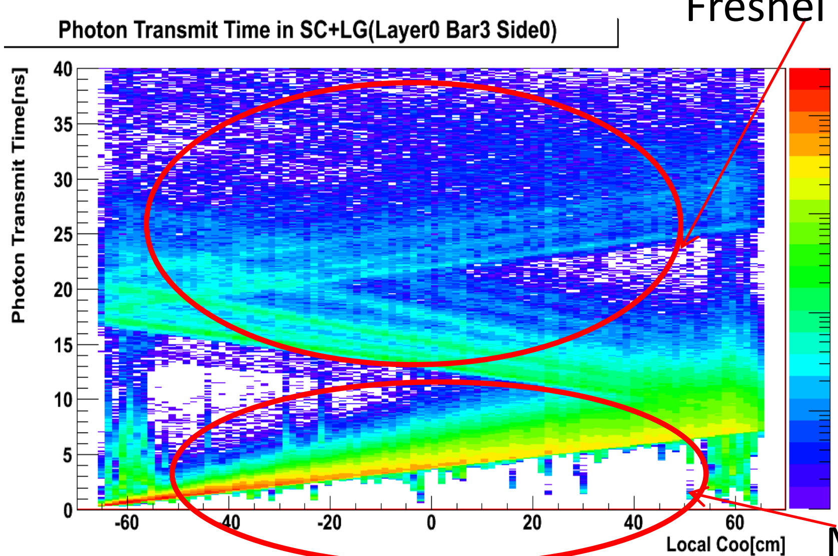
Typical SC+LG transmit time in Central region

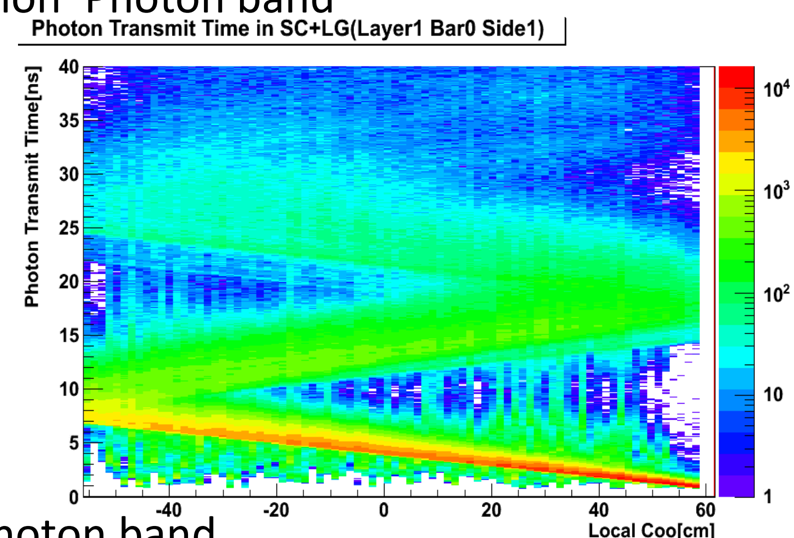




Typical SC+LG transmit time for different region

Fresnel Reflection Photon band

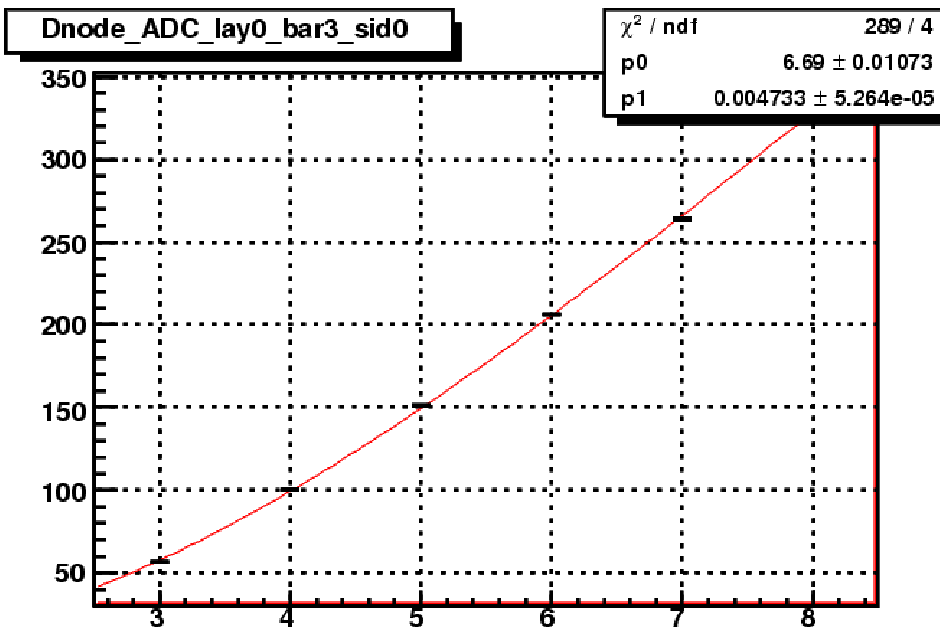


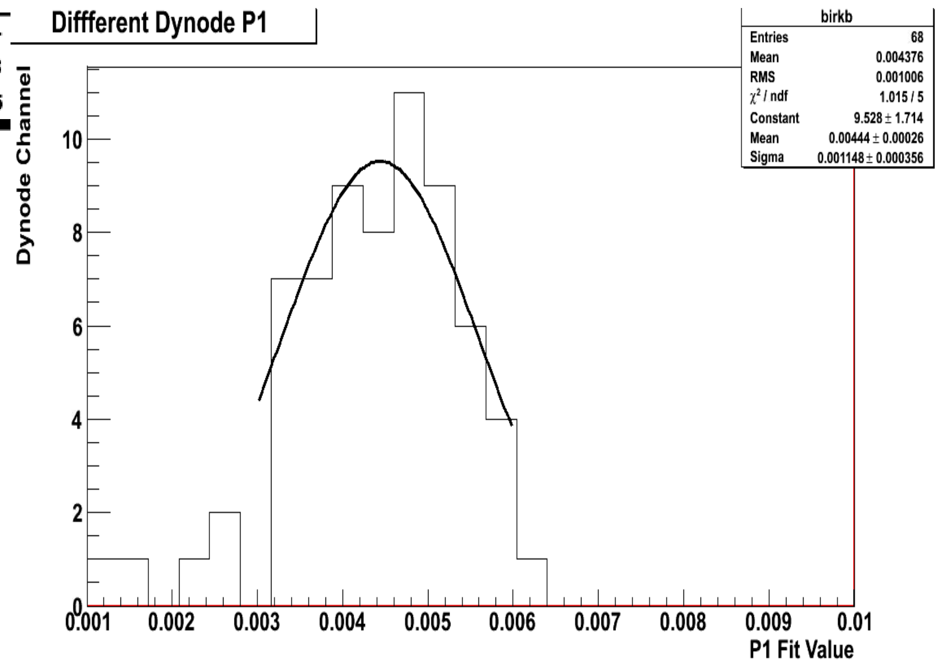


Main Photon band

Birk's law for light yield saturation

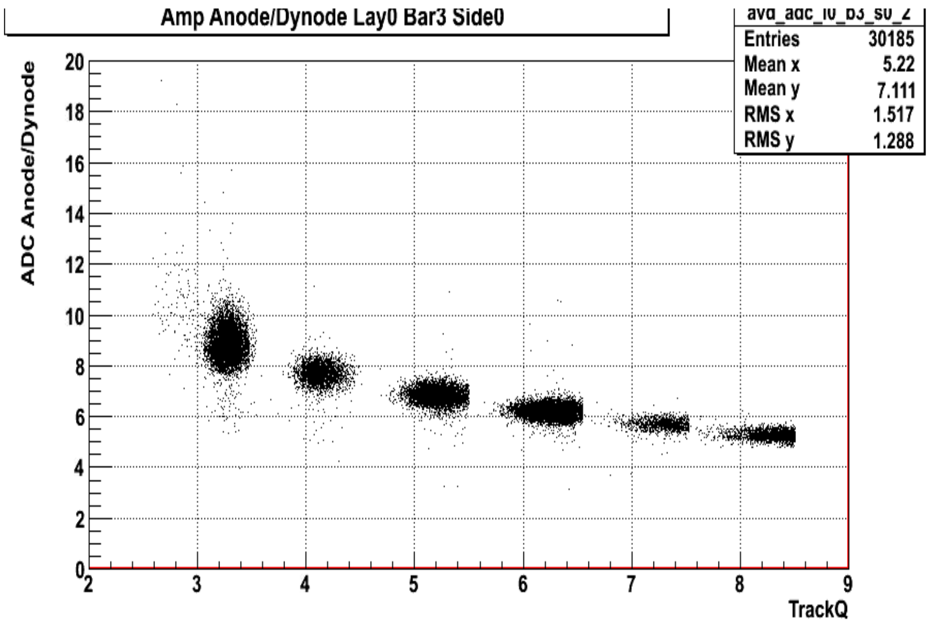
$$Q = P0Z^2/(1+P1Z^2)$$

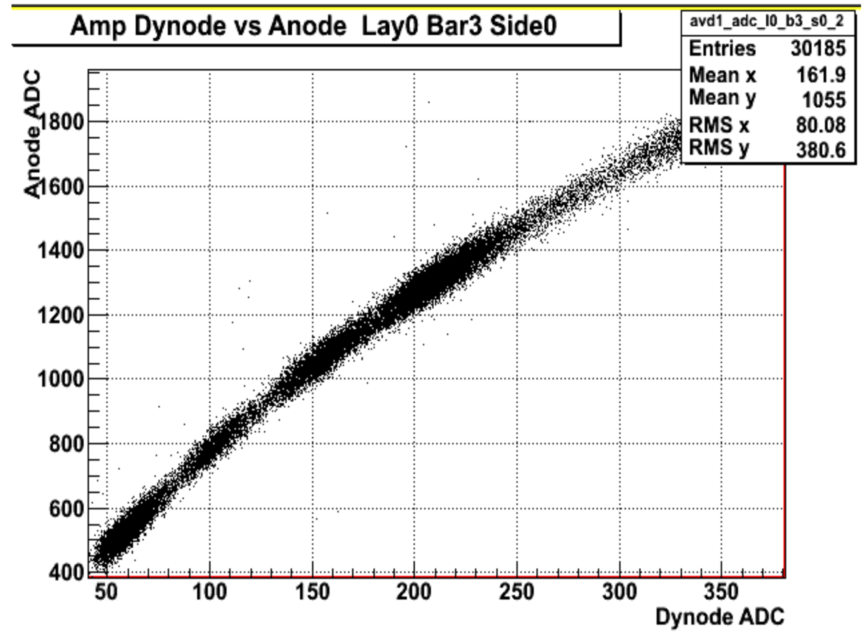




Birk's Law $\frac{\mathrm{d}E}{\mathrm{d}x} = \frac{\frac{dE}{dx}}{1+kB\frac{dE}{dx}}$ kB=0.0222mm/MeV

Anode Saturation





Need to do

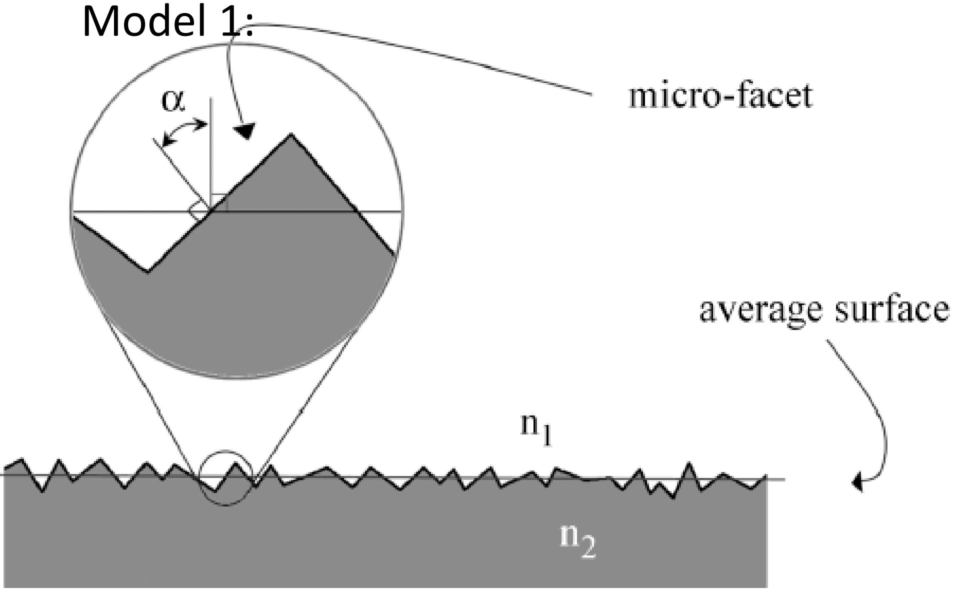
Photon Electron number tuning

Relate to photon electron number loss:

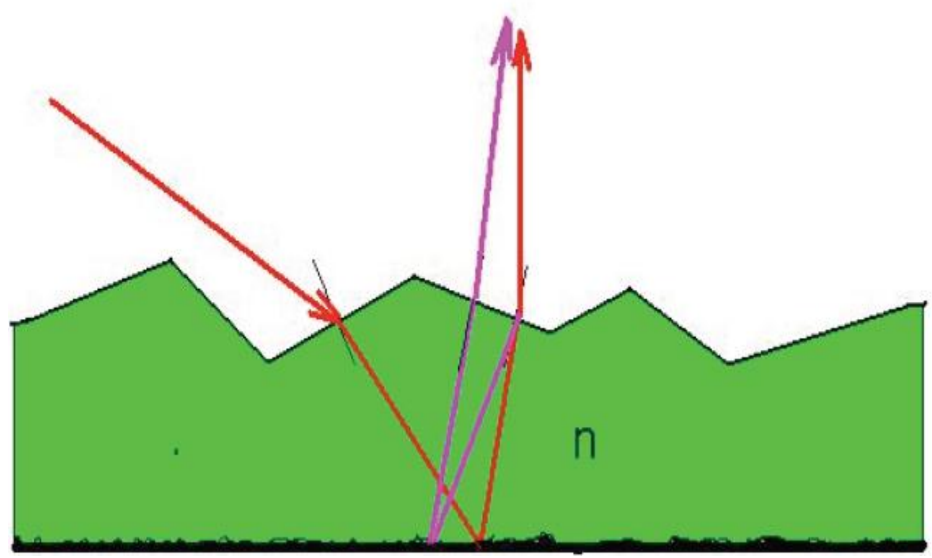
1: dielectric surface-> sensitive to attenuation length

2: LG and Scintillator glue->sensitive to global photon efficiency

Model 1:

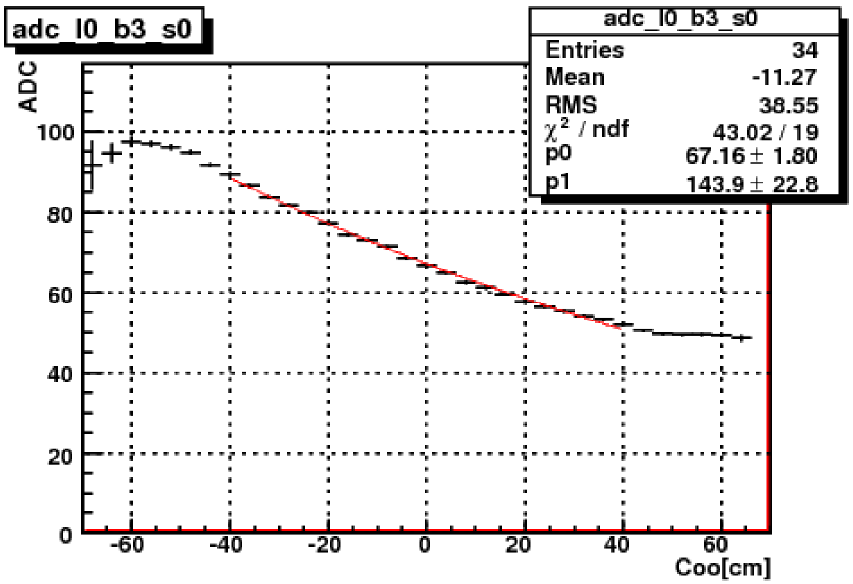


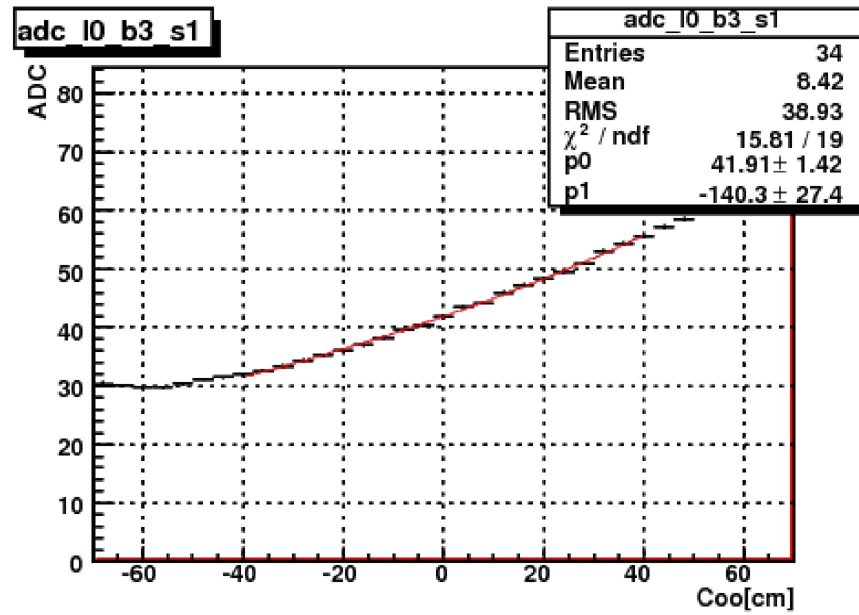
Model---Polishbackpaint



Tuning Surface According to attenuation length

Polishbackpaint Alpha=7.0deg





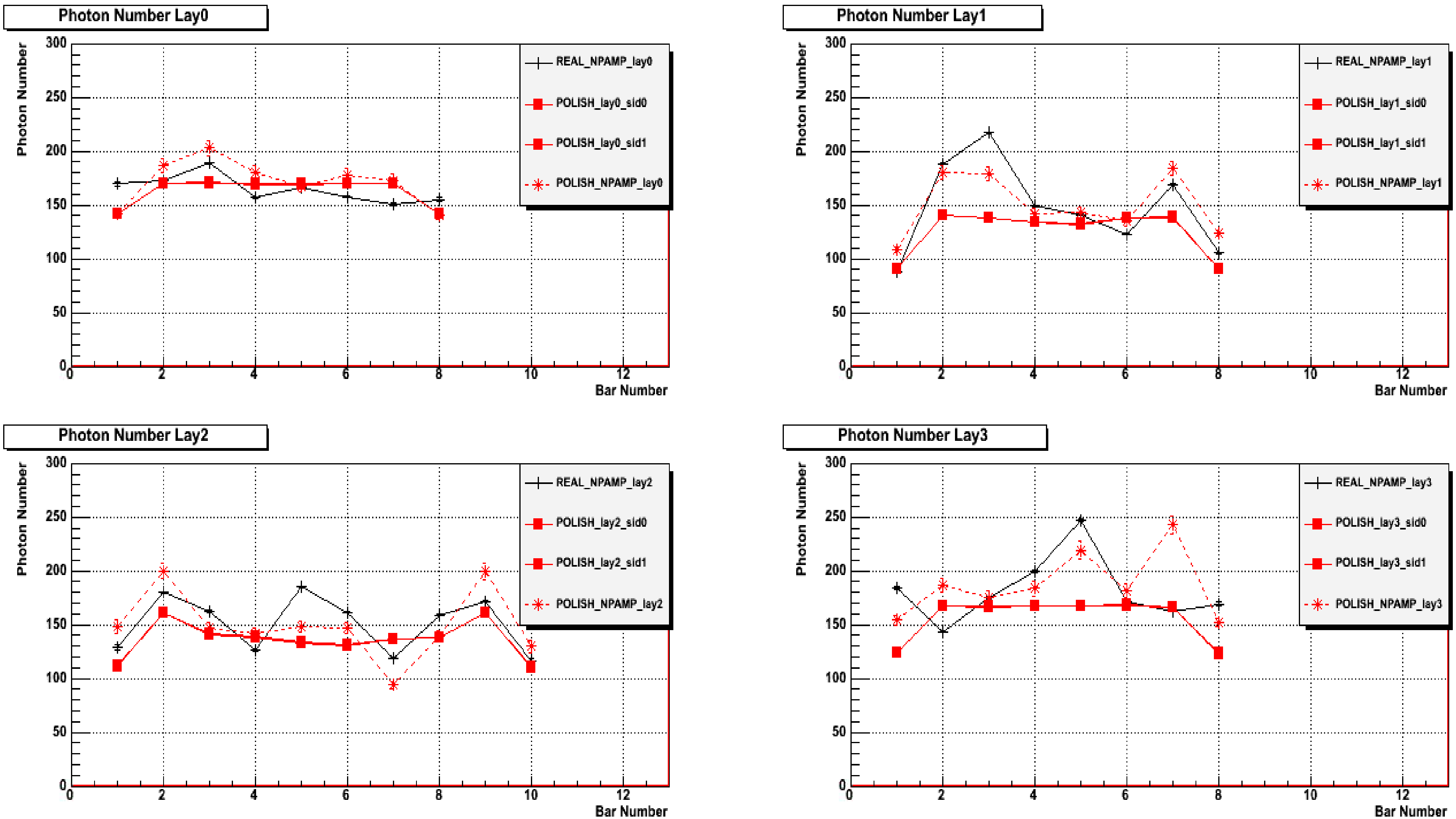
Tuning Surface the same attenuation length as real data

Then Tunning Proton Photon Number

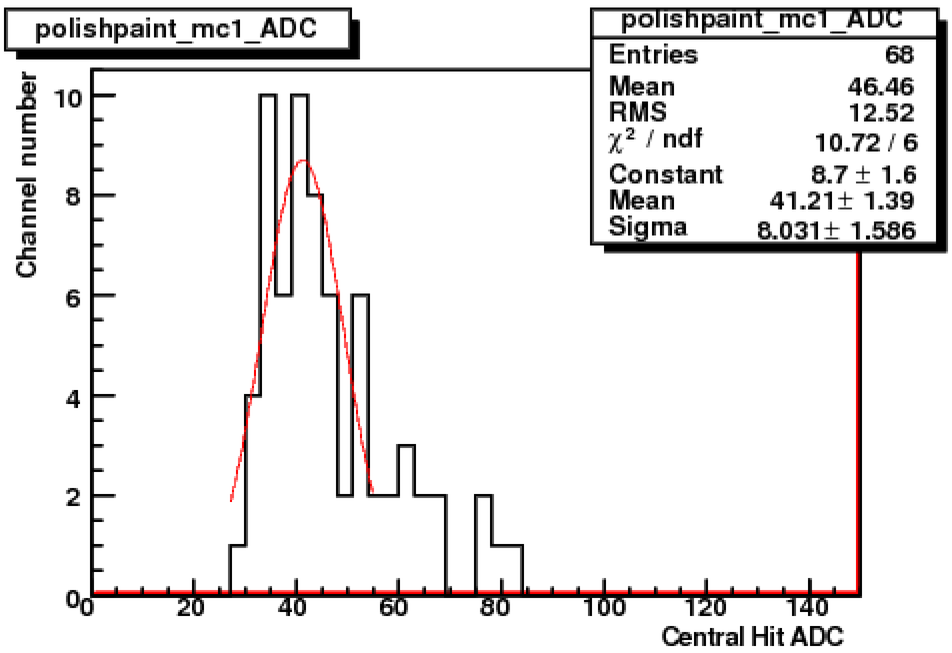
$$N_{phe} = \frac{1}{\sigma_R^2} \text{ wth } R = \frac{Q_N - Q_P}{Q_N + Q_P}$$

Black Photon number NP ISS

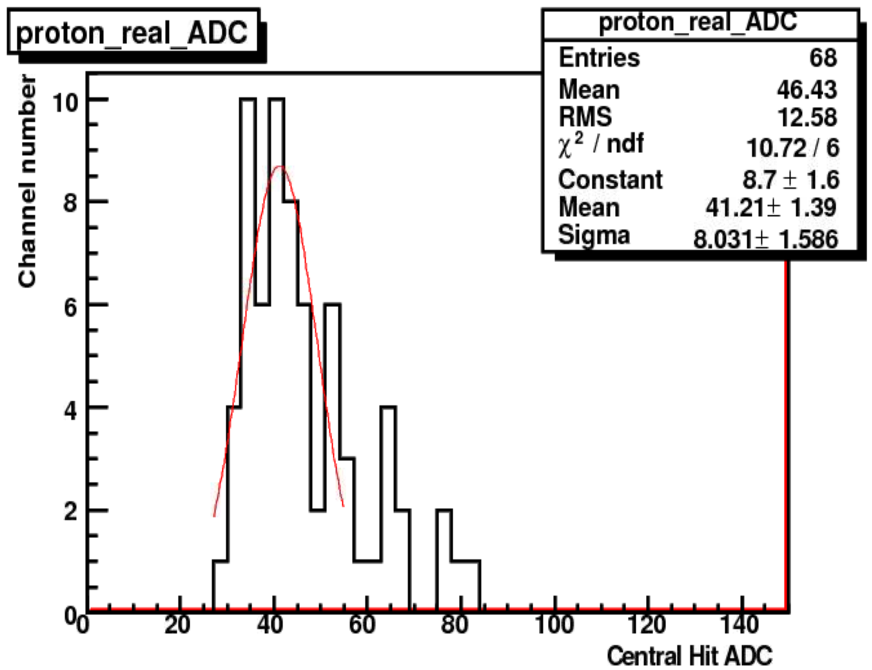
Red Photon number NP MC



The Same Proton MIP ADC as ISS data



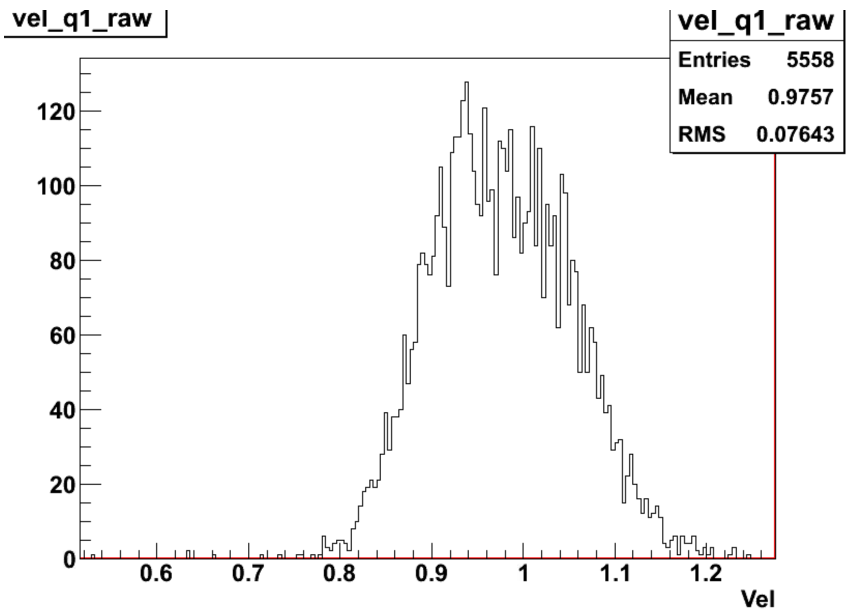
MC



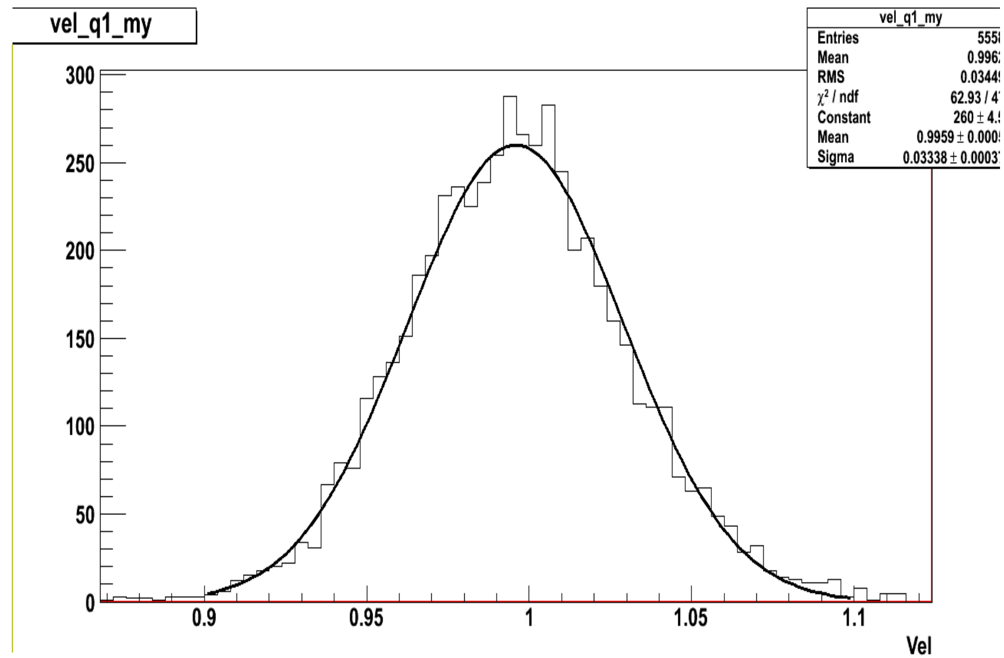
ISS data

MC Proton Velocity Resolution

Rigidity=20GeV **Present LT=0.3-0.4 MIP**



Before Slewing Calibration



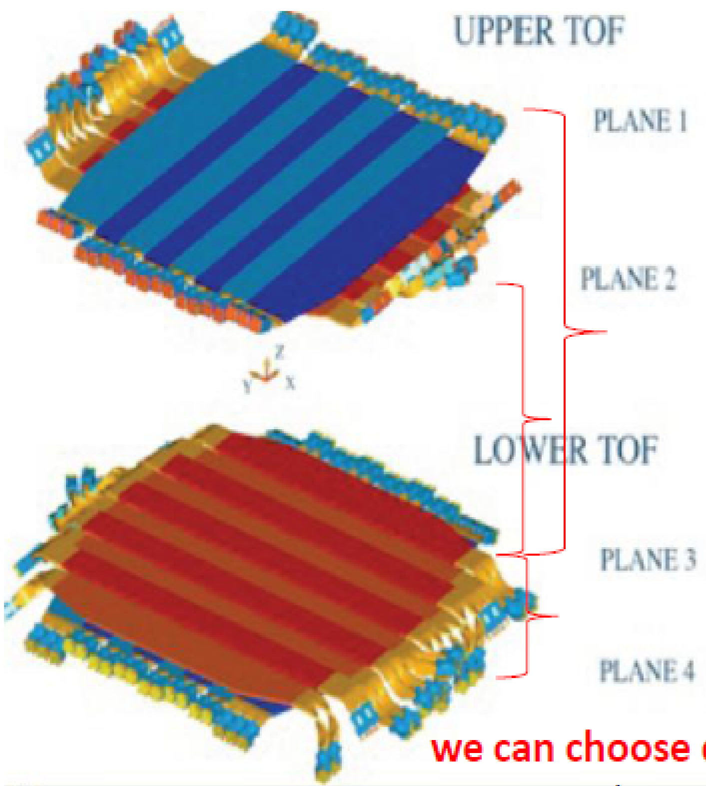
After Slewing calibration

Resolution is about 0.0334, much better than real data(0.04)

My Slewing Calibration

for two different fixed Layers:

$$ {}_{ij}^{2}(S_{1libo}\ \dots) = \sum_{ibar\,jbar \in ilay\,jlay} \ \sum_{event \in ibar\,jbar} \{-\frac{l_{ij}}{v} - [\left(\frac{t_{m1}+\frac{S_1}{\sqrt{A_1}}+t_{m2}+\frac{S_2}{\sqrt{A_2}}}{2}\right)_i - \left(\frac{t_{m1}+\frac{S_1}{\sqrt{A_1}}+t_{m2}+\frac{S_2}{\sqrt{A_2}}}{2}\right)_j + C_i - C_j\ ]\ \}^2/Never $$



for four Layers: $$\chi_j^{\,2} = \frac{\sum_{ilay=0-3}^{ilay!=jlay} \chi^2_{\ ij}}{3}$$

Minimization to get four Layers' Parameters:

$0lay$: $S_{1l0b0}\ S_{2l0b0}\ S_{1l0b1}\ \dots.\ C_{l0b0}\ \ C_{l0b1}\dots$

$1lay$: $S_{1l1b0}\ S_{2l1b0}\ S_{1l1b1}\ \dots.\ C_{l1b0}\ \ C_{l1b1}\dots$

$2lay$: $S_{1l2b0}\ S_{2l2b0}\ S_{1l2b1}\ \dots.\ C_{l2b0}\ \ C_{l2b1}\dots$

$3lay$: $S_{1l3b0}\ S_{2l3b0}\ S_{1l3b1}\ \dots.\ C_{l3b0}\ \ C_{l3b1}\dots$

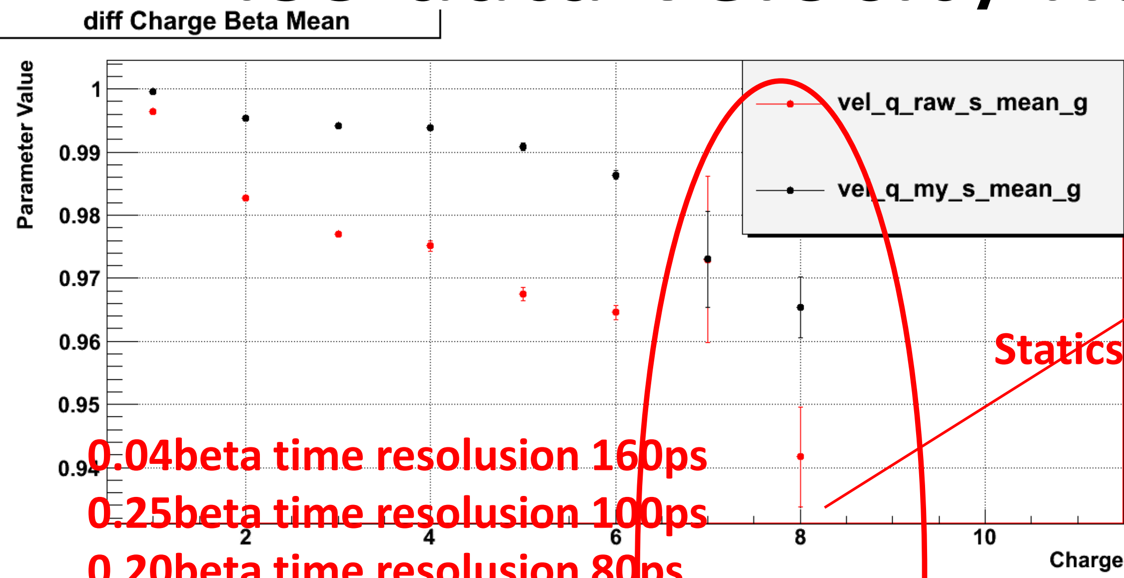
2×(8+8+10+8) S (8+8+10+8) -1 C

Choose one Bar Constant as fixed value

we can choose different layer as reference to do minimization

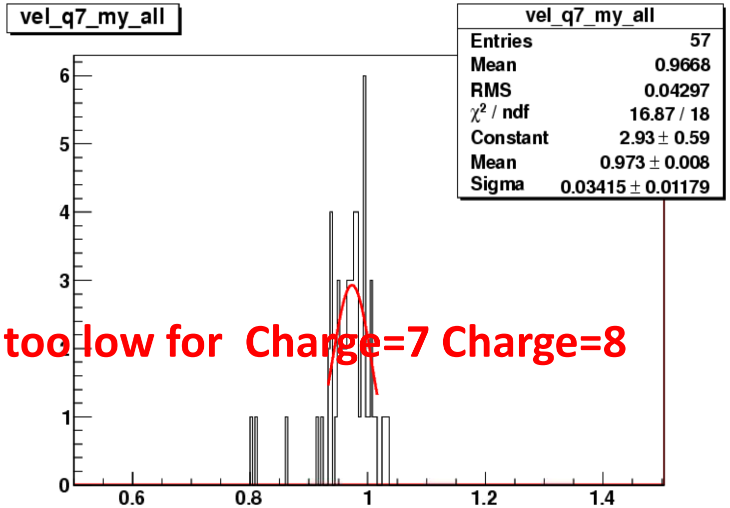
For example using layer2 as ref: $\chi_2^{\,2} = (\chi_{20}^{\ 2}+\chi_{21}^{\ 2}+\chi_{23}^{\ 2})/3$

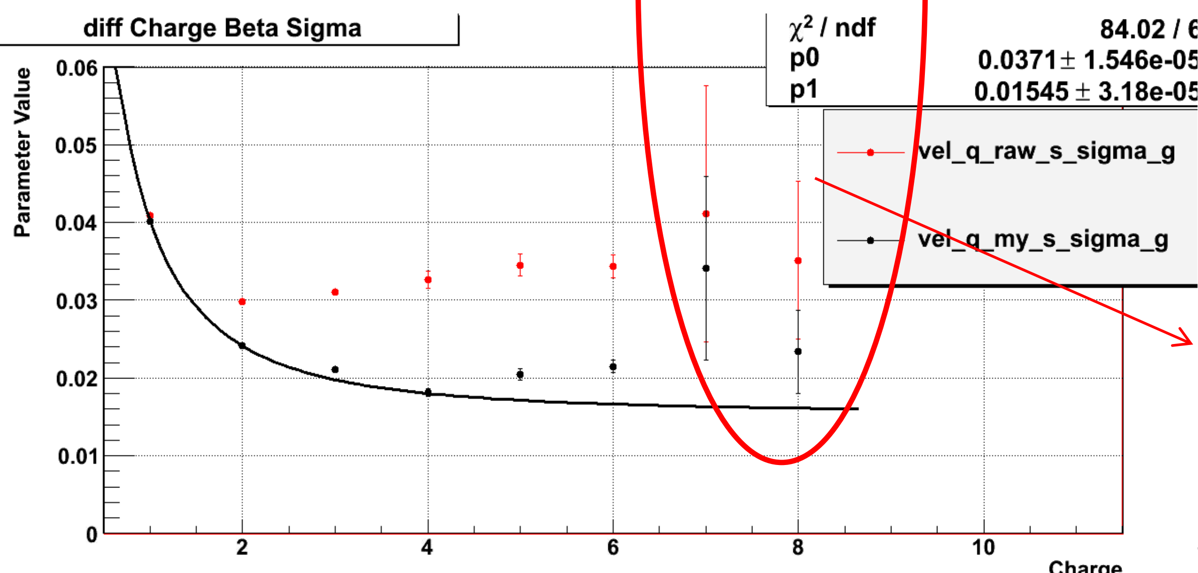
ISS data Velocity Resolution

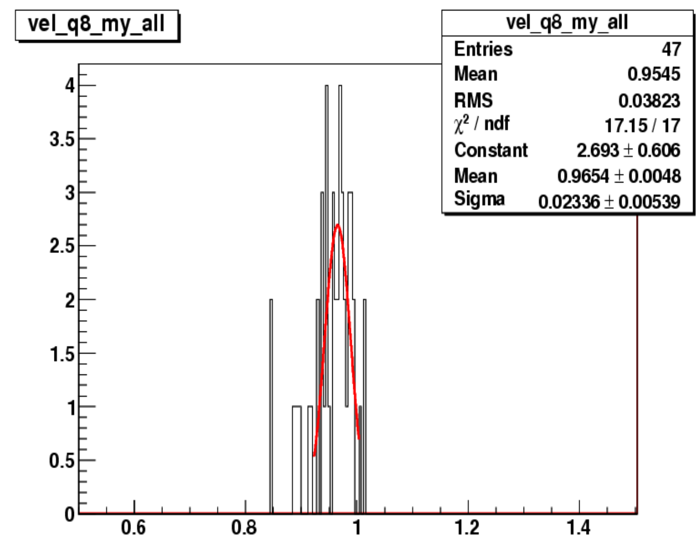


0.04beta time resolution 160ps
0.25beta time resolution 100ps
0.20beta time resolution 80ps

Statics is too low for Charge=7 Charge=8





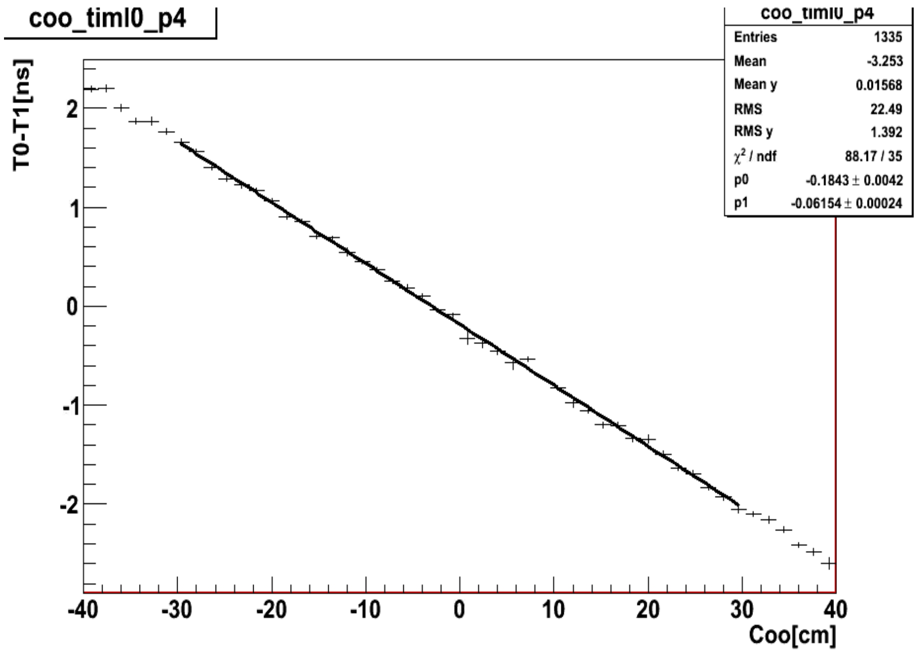


Red official same Slewing Calibration Result

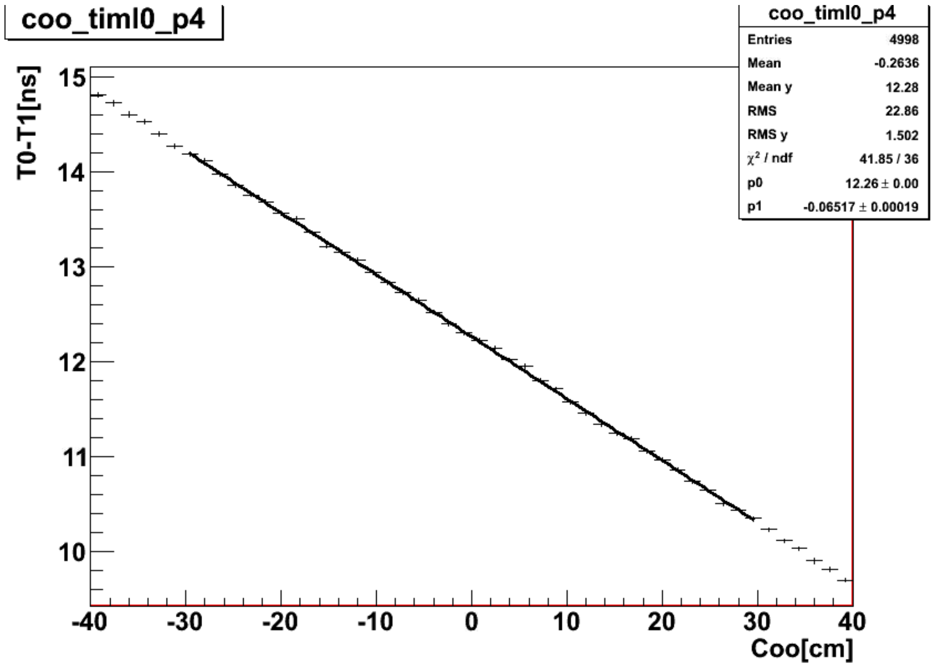
Black my different Slewing Calibration Result

Typical Velocity of photon in SC

Typical light speed in SC of lay0 bar4



MC



ISS data

MC is 1./0.06154=16.2cm/ns

ISS data is 1./0.06517=15.3cm/ns

!!! Old MC velocity=17.8cm/ns

Summary and to do list

1: New TOF Geant4 can simulate each photon transmit in TOF and reconstruction from detect photon

both Geant4 part(material, geometry,process….) and electronics is ready(different PMT gain, PMT transmit time,SE…), code is ready for all. which successfully put and test in AMSsoft

2: Tuning Attenuation Length and photon number already done

3: MC MIP ADC tuning is also done. (SE-amp)

4: The resolution of MC Beta is a little better than Real data, need to tune

4: Time Calibration for MC should be better done by TOF Group. And also Charge and Coo calibration for MC.

7: AMSsoft TOF online simulation is slow(about 15-20s/event ---20GeV proton), Next have to get Fast simulation table with the help of TOF Geant4.

Tuning Introduction

datacard option

```
TFMCFFKEY.seamref=1.; //(24)PMT single electron spectrum ref to  5mV
TFMCFFKEY.seamres=0.9;//(25)PMT single electron spectrum resolution Rms/Mean
TFMCFFKEY.selampec=0.2;//(26)PMT single electron low amplitude fraction
TFMCFFKEY.selamref=0.2;//(27)PMT single electron low Amp/normal Amp
TFMCFFKEY.pheffref=1.; //(28)photon ref eff uncertainty //absorption by gap(due to quality of polish)+glue(Sci-LG)+quantum effeciency uncertainty[0 4]

TFMCFFKEY.refmodel=1; //(29)(1)new polishbackpaint (2)polishbackpaint (3)groudbackpaint (4)unified dielectric_metal
TFMCFFKEY.absorp=0.; //(30)Sci-facet absorption prob[0,1]//MD-1
TFMCFFKEY.reflobsig=0.;//(31)Sci-facet lob-diffuse angle sigma//MD-1234
TFMCFFKEY.reflamber=0.;//(32)Sci-facet Lambertian reflection prob[0 1]//MD-1234
TFMCFFKEY.reflob=0.;   //(33)Sci-facet lob-diffuse reflection prob[0 1]//MD-1234
TFMCFFKEY.refbac=0.;   //(34)Sci-facet back-reflection prob[0 1]//MD-1234
TFMCFFKEY.refskin=1.;  //(35)Al-skin reflection ref prob//small angle more possible reach Al surface//may affect final fast slow fraction [0 1./0.902]//MD-1234
TFMCFFKEY.refpolish=1.;//(36)Al-skin polish quality 1->Total mirror 0->diffuse//MD-1

TFMCFFKEY.birk=0.0116; //(37)scintillator Birks Constant de/dx/(1+a*de/dx) mm/MeV
TFMCFFKEY.phancut=0.1;// (38)cos(Angle 85deg) verticle direction photon cut
TFMCFFKEY.phtrlcut=5.;// (39)photon transmit track length cut //5m
TFMCFFKEY.phstepcut=2.;//(40)photon max steplength cut//2*m
//TFMCFFKEY.maxphcut=160000;//(41)max photon allow 0(inf) proton 20000ph*4cm*0.25(QE)
TFMCFFKEY.maxphcut=0;
//---
FFKEY("TFMC",(float*)&TFMCFFKEY,sizeof(TFMCFFKEY_DEF)/sizeof(integer),"MIXED");
```

MC Analysis class

```
class TofMCPmtHitR {
public:
   int     Idsoft; ///< Idsoft  LBSP---L=Layer(0-3) B=Bar(0-9) S=Side(0-1) P=PMT(0-2)
   int     ParId;   //photon parent id
   float   TimeG;   //< time of photon in pmt (nsec)
   float   TimeT;   //< time of photon delay in SC+LG (nsec)
   float   Ekin;    //< photon energy (eV)
   float   Length;  //< photon transmit length in SC+LG
   float   Pos[3];  //< photon arrving pos
   float   Dir[3];  //< photn  arrving dir
   float   TimeP;   //transmit time in PMT
   float   Amp;     //SE amp

   TofMCPmtHitR(){};
   TofMCPmtHitR(AMSTOFMCPmtHit *ptr);
   virtual ~TofMCPmtHitR(){};
ClassDef(TofMCPmtHitR,1)       //TofMCPmtHitR
#pragma omp threadprivate(fgIsA)
};
```