DRICH Simulation Update

Chandradoy Chatterjee

Updates

- ❑ **Simulation chain is working!**
- ❑ We can run dd4hep, juggler and evaluation script to characterize dRICH
- ❑ There have several debugging and intermediate refactoring steps to reach to the current config

The only step can be of interest (and probably discussion in future?)

- ❑ During the ATHENA proposal we had been using PhotonCounter class to describe the photon interaction property and filling the collection class. This has been changed substantially in the later phase. Now SiPMs are like SiPM tracker. That was causing loss of photons entering into the Collection Class.
- ❑ The remedy was to add the Geant4 option fStopandKill to kill the photon as soon as it arrives at the sensor active material and not to propagate it any further.
- ❑ After that description also the sensor surface definition became compatible.

```
Detector        INFO  +++ Patching names of anonymous shapes....
DDG4            INFO +++ Imported 358 global values to namespace:DDG4
Geant4Kernel         OutputLevel:  2
Geant4Kernel         UI:          UI
Geant4Kernel         NumEvents:    10
Geant4Kernel         NumThreads:   0
DDG4            INFO +++  List of sensitive detectors:
DDG4            INFO +++  DRICH                    type:tracker      --> Sensitive type: ('Geant4TrackerWeightedAction', {'HitPositionCombination': 2, 'CollectSingleDeposits': False})
Geant4UI        INFO  +++ UI> Install Geant4 control directory:/ddg4/UI/
Geant4Kernel    INFO  ++ Registered global action UI of type dd4hep::sim::Geant4UIManager
Geant4UI        INFO  +++ MagFieldTrackingSetup> Install Geant4 control directory:/ddg4/MagFieldTrackingSetup/
Geant4Kernel    INFO  ++ Registered global action RunInit of type dd4hep::sim::Test::Geant4TestRunAction
Geant4UI        INFO  +++ RunAction> Install Geant4 control directory:/ddg4/RunAction/
Geant4UI        INFO  +++ EventAction> Install Geant4 control directory:/ddg4/EventAction/
Geant4Output2EDM4hep INFO  instantiated ...
Geant4UI        INFO  +++ EDM4hepOutput> Install Geant4 control directory:/ddg4/EDM4hepOutput/
DDSim           INFO ++++ Adding DD4hep Particle Gun ++++
DDSim           INFO Enabling the PrimaryHandler
Geant4UI        INFO  +++ GeneratorAction> Install Geant4 control directory:/ddg4/GeneratorAction/
Geant4UI        INFO  +++ Gun> Install Geant4 control directory:/ddg4/Gun/
Geant4UI        INFO  +++ hepmc4> Install Geant4 control directory:/ddg4/hepmc4/
Geant4UI        INFO  +++ InteractionMerger> Install Geant4 control directory:/ddg4/InteractionMerger/
Geant4UI        INFO  +++ PrimaryHandler> Install Geant4 control directory:/ddg4/PrimaryHandler/
Geant4UI        INFO  +++ TrackingAction> Install Geant4 control directory:/ddg4/TrackingAction/
Geant4UI        INFO  +++ SteppingAction> Install Geant4 control directory:/ddg4/SteppingAction/
Geant4UI        INFO  +++ ParticleHandler> Install Geant4 control directory:/ddg4/ParticleHandler/
DDSim.Helper.Filter INFO ReqFilt {'opticalphotons', 'edep0'}
DDSim           INFO getDetectorLists - found active detector DRICH type: tracker
DDSim           INFO Setting up SD for DRICH
DDSim           INFO       replace default action with : Geant4OpticalTrackerAction
Geant4UI        INFO  +++ DRICH> Install Geant4 control directory:/ddg4/DRICH/
Geant4UI        INFO  +++ DRICHHandler> Install Geant4 control directory:/ddg4/DRICHHandler/
DDSim.Helper.Filter INFO Adding filter 'opticalphotons' matched with 'DRICH' to sensitive detector for 'DRICH'
Geant4UI        INFO  +++ PhysicsList> Install Geant4 control directory:/ddg4/PhysicsList/
PhysicsList          +++ Dump of physics list component(s)
PhysicsList          +++ Extension name       FTFP_BERT
PhysicsList          +++ Transportation flag: 0
PhysicsList          +++ Program decays:      0
PhysicsList          +++ RangeCut:            0.700000
Geant4UI        INFO  +++ GlobalRangeCut> Install Geant4 control directory:/ddg4/GlobalRangeCut/
Geant4UI        INFO  +++ CerenkovPhys> Install Geant4 control directory:/ddg4/CerenkovPhys/
Geant4UI        INFO  +++ OpticalGammaPhys> Install Geant4 control directory:/ddg4/OpticalGammaPhys/
FieldSetup      INFO  Geant4 magnetic field tracking configured.
FieldSetup      INFO  G4MagIntegratorStepper:ClassicalRK4 G4Mag_EqRhs:Mag_UsualEqRhs
FieldSetup      INFO  Epsilon:[min:0.000050 mm max:0.001000 mm]
FieldSetup      INFO  Delta:[chord:0.250000 1-step:0.010000 intersect:0.001000] LargestStep 10000.000000 mm
```

Few words on the sensor surface incompatibility

For boundary description G4 uses three descritptions
a. dielectric_dielectric
b. dielectric_metal
c. dielectric_dichoric (not relevant for us)

For the dielectric_metal the photon is not transmitted (user provides two ref. indices real and imaginary of the metal surface to ensure the probability of absorption and reflection). During the athena proposal we studied this and taking into account the gas-reisin (5%) and reisin-Si (15%) reflections and assuming the QE provided by Hamamatsu has already accounted these effects in it we found a dielectric_dielectric description (gas-window boundary) is best. And as gas is having almost identical refractive index wrt to window of SiPM is reasonably good and agrees with the calculation from first principle. We computed for Aerogel; for the integrated wavelength of 350 to 600 we get around 70 photons produced by aerogel (QE and Safety factor set to 1).
For the dielectric_metal these number reduced to factor 2. Which was also observed by Alexander in his SA MC sim.

Therefore, for ATHENA sim we stick to dielectric_dielectric description of the boundary.

Before the update of the NPSIM we were not able to see any photon with dielectric_dielectric description and now once we have added the fStopandKill we are seeing exactly factor 2 loss in dielectric_metal and compatible numbers with dielectric_dielectric.

EPIC dRICH geometry compared to ATHENA

The ECCE dRICH radiator length was shorter compared to the ATHENA radiator length.
Number of photons are of concern. → We have increased the rad. Length by 20 cm (compared to ecce) however the rad. Length is not yet final.
Different geometries will be studied soon in terms of dRICH performance. → Requires functioning full simulation chain.

All Units are in cm!

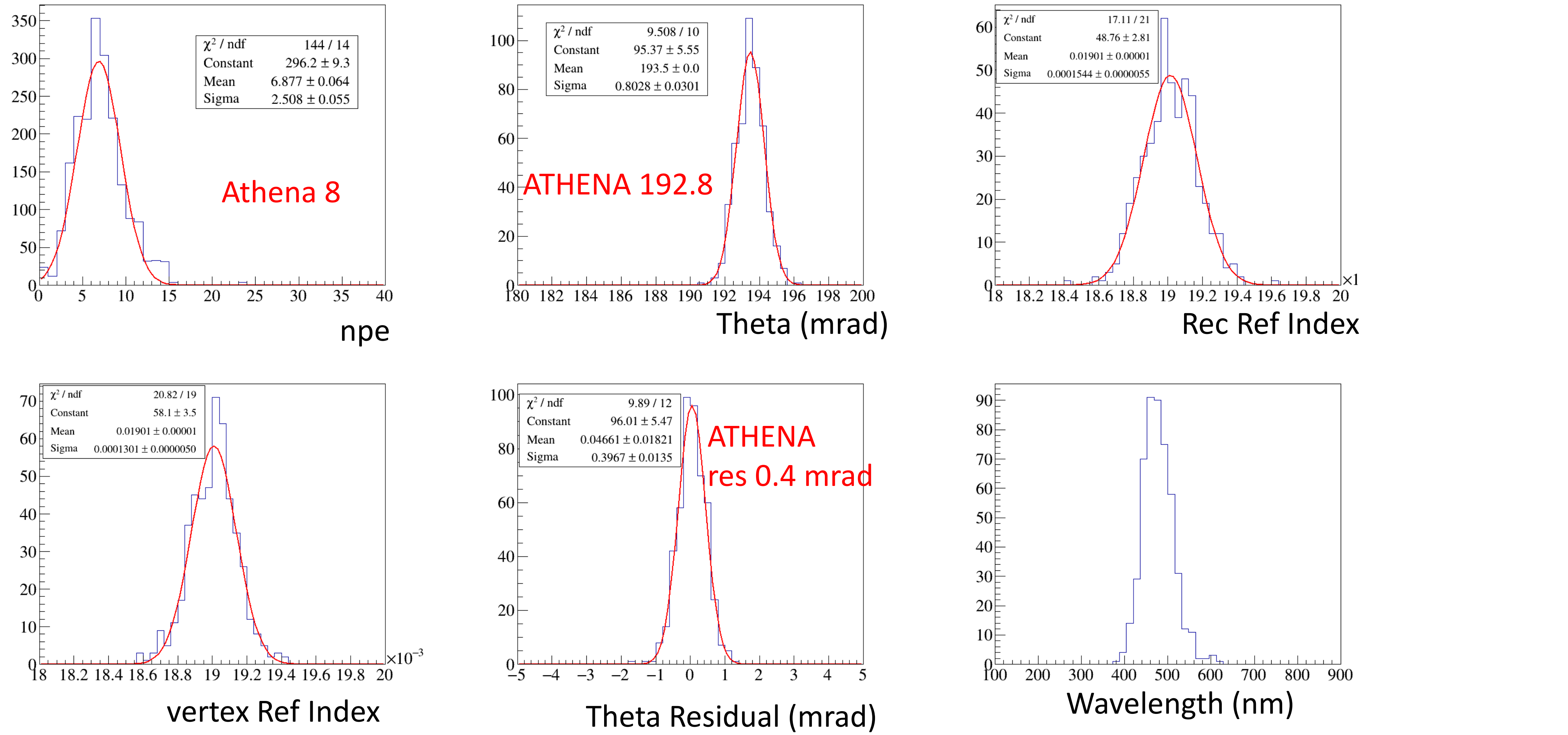
ATHENA

DRICH_Length	=	140.000
DRICH_SnoutLength	=	4.000
DRICH_SnoutSlope	=	0.667
DRICH_aerogel_thickness	=	4.000
DRICH_create_irt_file	=	0.000
DRICH_debug_mirror	=	0.000
DRICH_debug_optics	=	0.000
DRICH_debug_sensors	=	0.000
DRICH_num_px	=	8.000
DRICH_rmax0	=	126.667
DRICH_rmax1	=	129.333
DRICH_rmax2	=	220.000
DRICH_rmin0	=	8.273
DRICH_rmin1	=	16.062
DRICH_sensor_pixel_pitch	=	0.320
DRICH_sensor_pixel_size	=	0.300
DRICH_sensor_size	=	2.580
DRICH_sensor_thickness	=	0.050
DRICH_wall_thickness	=	0.500
DRICH_window_thickness	=	0.100
DRICH_zmin	=	190.000

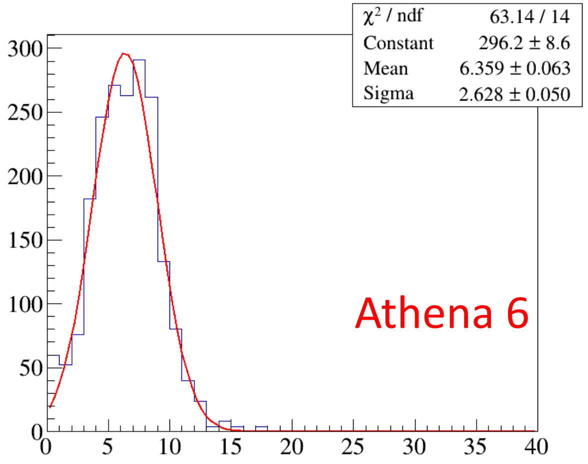
EPIC (current version after increasing the radiator length of ecce)

DRICH_Length	=	120.000
DRICH_SnoutLength	=	20.000
DRICH_SnoutSlope	=	0.487
DRICH_aerogel_thickness	=	4.000
DRICH_create_irt_file	=	0.000
DRICH_debug_mirror	=	0.000
DRICH_debug_optics	=	0.000
DRICH_debug_sensors	=	0.000
DRICH_num_px	=	8.000
DRICH_rmax0	=	95.000
DRICH_rmax1	=	104.744
DRICH_rmax2	=	180.000
DRICH_rmin0	=	8.490
DRICH_rmin1	=	15.332
DRICH_sensor_pixel_pitch	=	0.320
DRICH_sensor_pixel_size	=	0.300
DRICH_sensor_size	=	2.580
DRICH_sensor_thickness	=	0.050
DRICH_wall_thickness	=	0.500
DRICH_window_thickness	=	0.100
DRICH_zmax	=	315.000
DRICH_zmin	=	195.000

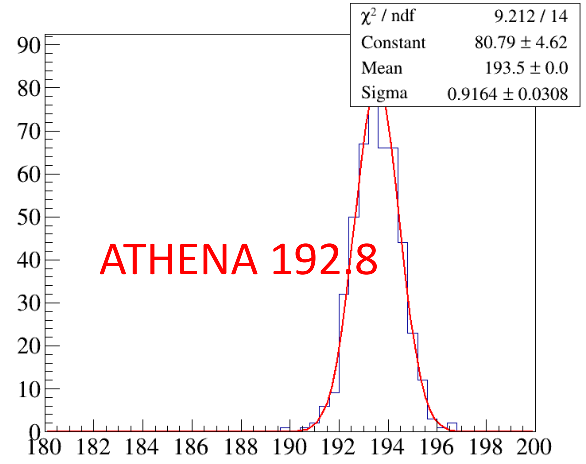
EPIC dRICH Aerogel (eta 1.5)



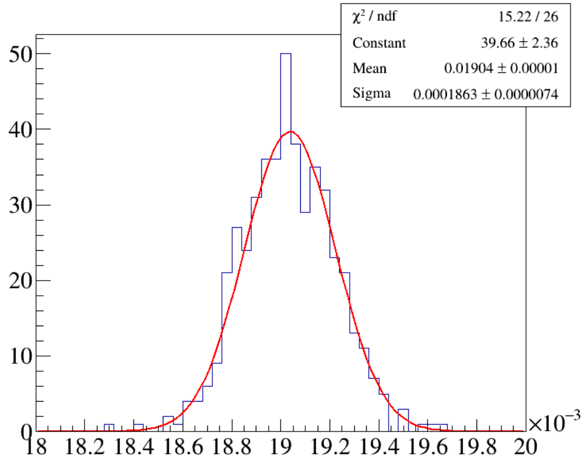
EPIC dRICH Aerogel (eta 3.0)



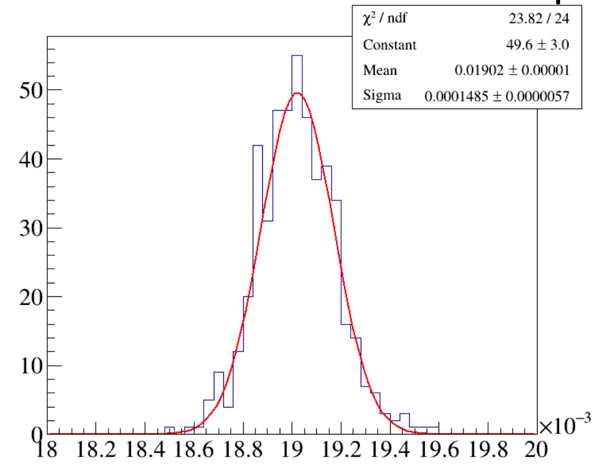
npe



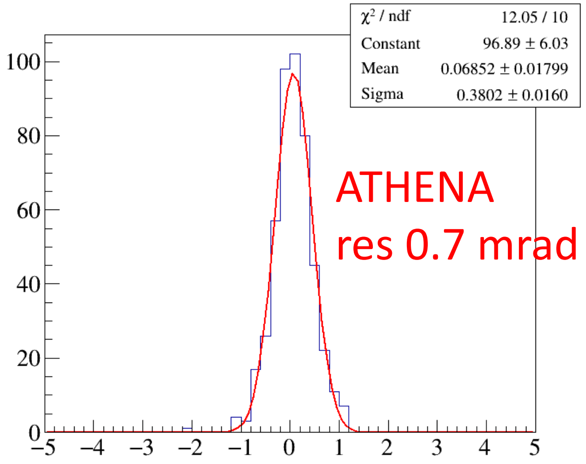
Theta (mrad)



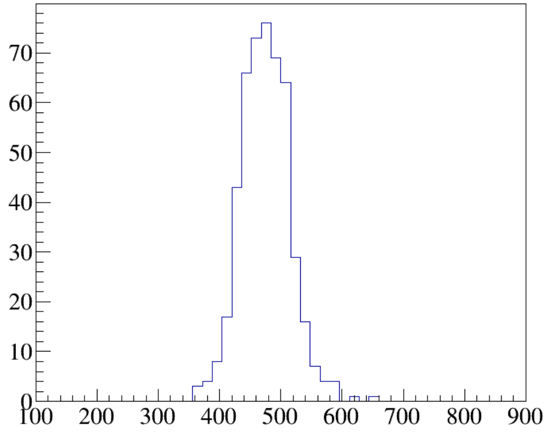
Rec Ref Index



vertex Ref Index



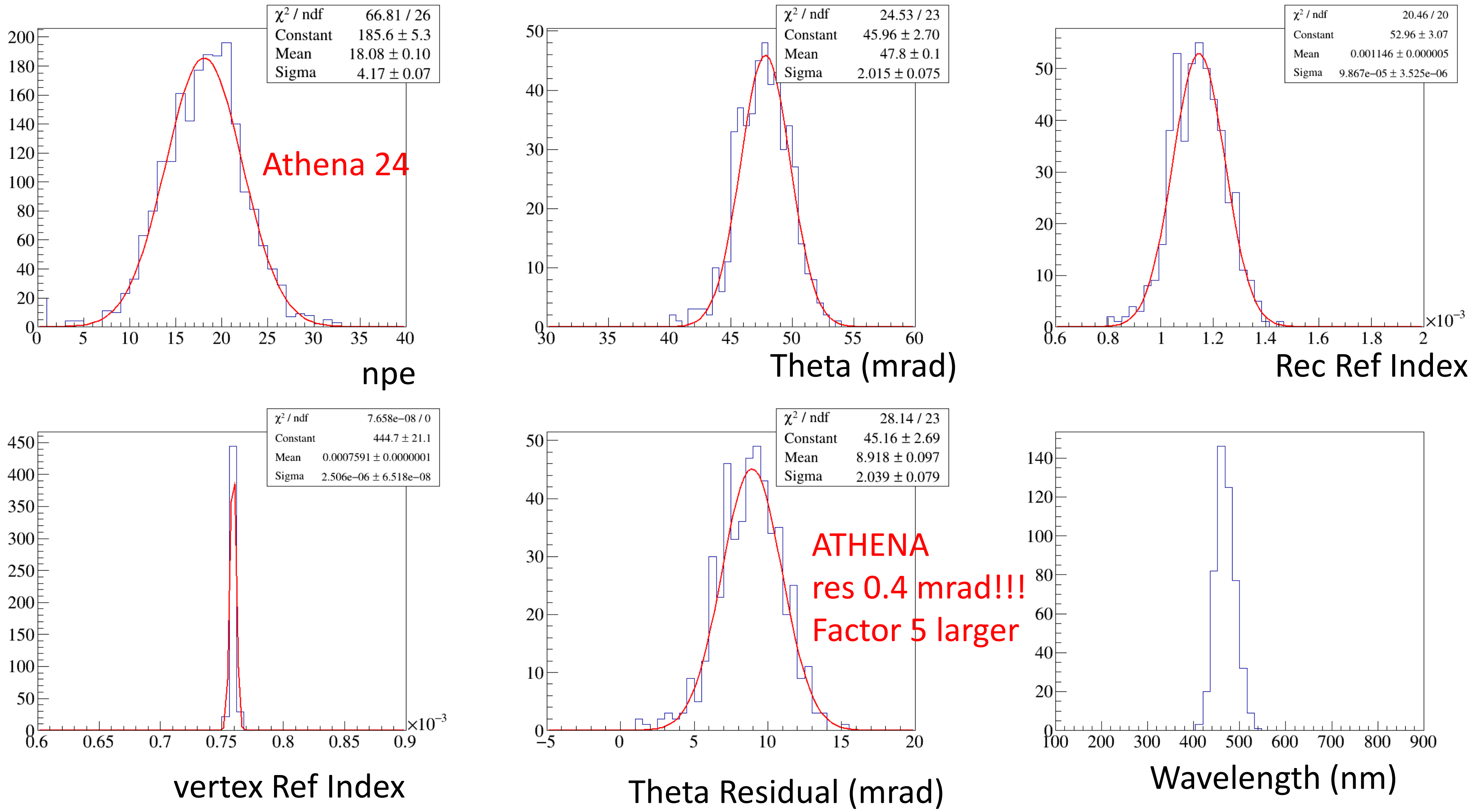
Theta Residual (mrad)



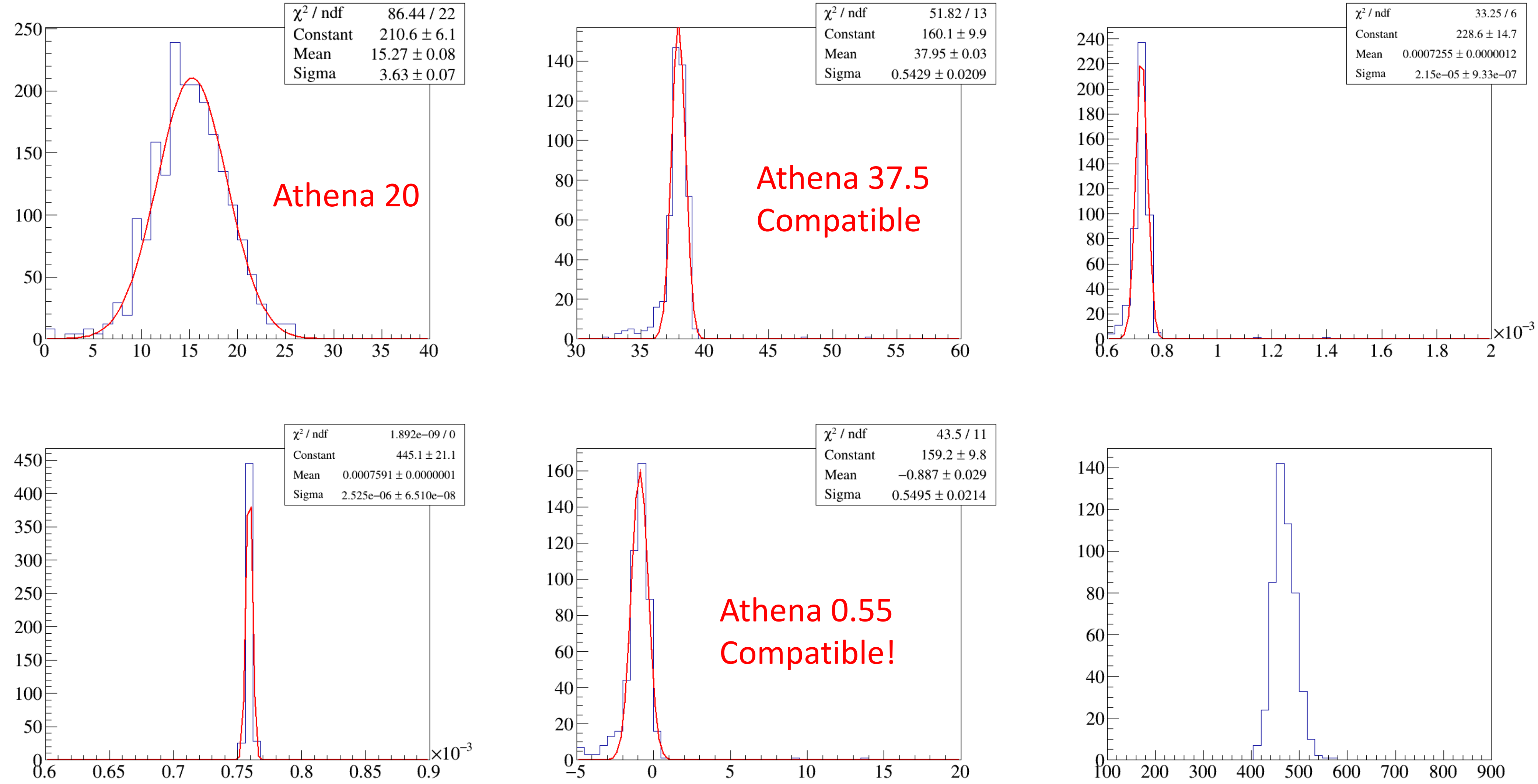
Wavelength (nm)

EPIC dRICH gas (eta 1.5)

ATHENA 37.8!!!
10 mrad off!



EPIC dRICH Gas (eta 3.0)



Number of photons produced

$$N = 2\pi L\alpha \int_{\lambda_1}^{\lambda_2} \left(1 - \left(\frac{\beta_t(\lambda)}{\beta}\right)^2\right) \frac{d\lambda}{\lambda^2}$$

$$= 2\pi L\alpha \int_{\lambda_1}^{\lambda_2} \left(1 - \left(\frac{1}{n_b(\lambda)}\right)^2\right) \frac{d\lambda}{\lambda^2} \qquad \beta \simeq 1$$

$$= 2\pi L\alpha \int_{\lambda_1}^{\lambda_2} \sin^2\theta \frac{d\lambda}{\lambda^2}$$

$$= 2\pi L\alpha \sin^2\theta \int_{\lambda_1}^{\lambda_2} \frac{d\lambda}{\lambda^2}$$

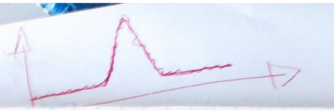
$$= 2\pi L\alpha \sin^2\theta \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) \qquad \theta_{sat} \sim 200\text{mrad}$$

$$= 2\times 3.14 \times 3\times 10^7 \,(\text{nm}) \times \frac{1}{137} \times (0.0028 - 0.00153)(\text{nm})^{-1}$$

X0.04

$$= 6.98 \quad 10^{-6} \times 10^7$$

$$= 69.8$$



EXPECTED NUMBER OF CHERENKOV PHOT

IN THE WAVELENGTH 325 nm to 900 nm

FOR DRICH WITH 130 cm Radiator CEff

AT Momentum of 20 GeV/c, 60 GeV/c

$$N = 2\pi L\alpha \int_{\lambda_1}^{\lambda_2} \left(1 - \left(\frac{\beta_t(\lambda)}{\beta}\right)^2\right) \frac{d\lambda}{\lambda^2}$$

- At saturation we have

We are left with

$$N = 2\pi L\alpha \int_{\lambda_1}^{\lambda_2} \sin^2\theta \frac{d\lambda}{\lambda^2}$$

Assuming, the theta at saturation is ~40

Therefore, $\sin^2\theta \sim 0.0016$

$\lambda_1 \sim 325$, $\lambda_2 \sim 900$

$$N = 2\pi L\alpha (0.0016) * \left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$= 2*3.14*1.2\,10^9 * \frac{1}{137} * (0.0016) * [0.002$$

$$= 2*3.14*1.2\,10^9 * \frac{1}{137} * 0.0016 * 0.0020$$

$$= 1.76\,10^{-7}\,10^9 \sim 176$$

At 20 GeV $\theta \sim 37$ mrad

$$N = 2\pi L\alpha * 0.00136 * \frac{0.0020}{137}$$

$$= 2*3.14*1.2\,10^9 * 0.00136 * \frac{0.0020}{137}$$

$$= 160$$