2012 Project X Physics Study

06/16/2012

Winston Cones for a Cylindrical WCD

Stefano Perasso

Winston Cones: Pros and Cons

Why Use Winston Cones?

Reduce # PMTs (costs) without reducing the amount of collected light

Winston Cone ~50$

PMT ~3000$

Largest increase in light collection among the LCs considered for LBNE (up to a factor 3)

Already successfully used in UPW in other experiments (SNO, Borexino-CTF)

R&D for optimization

Concerns

Risk of Dregradation in UPW

Light Cones limit the PMT field of view

Light Collection position dependent

May affect the FV definition

May affect the detector response, hence the event reconstruction

Materials

Winston Cone Structure: plastic (acrylic) cone + metal coating

Metals for coating: Al, Ag

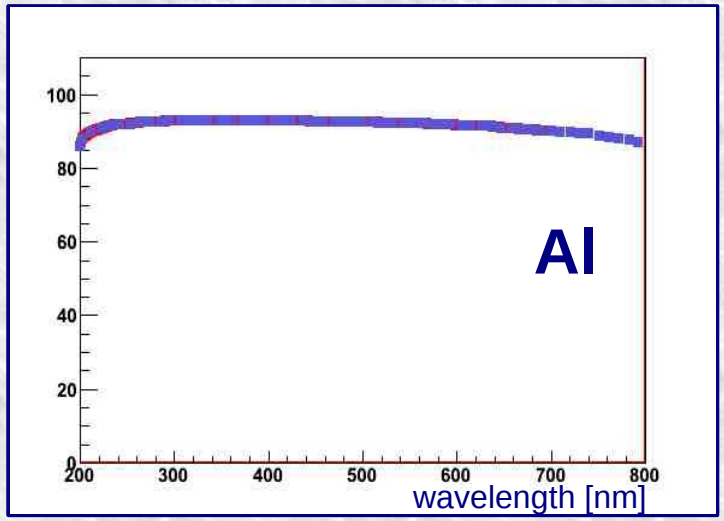
Compatibility with UPW

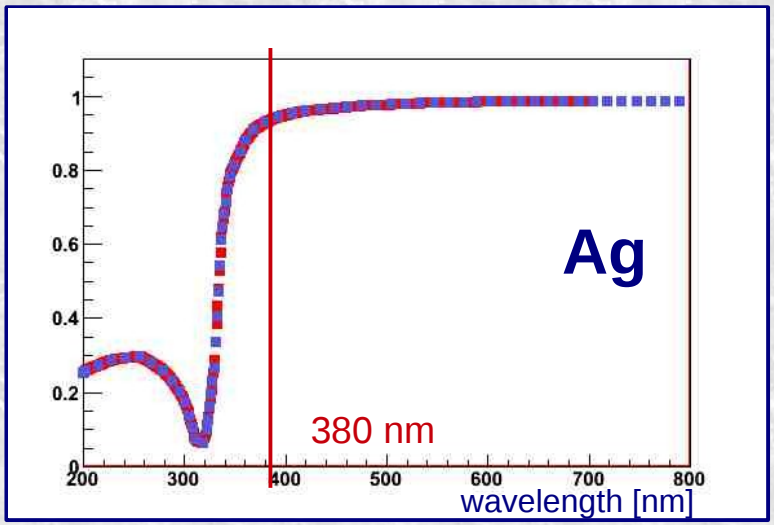
Ag compatible: already used for many years in Borexino – CTF

Al not compatible: need of additional protective coating (light absorption)

Al protective coating: different solutions under study (based also on SNO experience)

Reflectivity





Profile

- 2 profiles

  Off axis parabola (Winston Cones)

  Ellipsoidal

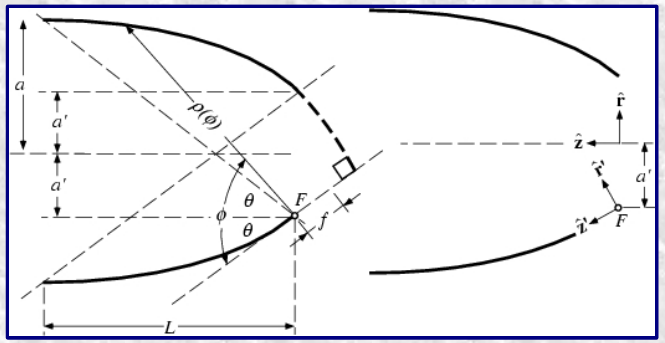
- Both are non imaging LCs

- Starting profile: Winston Cones

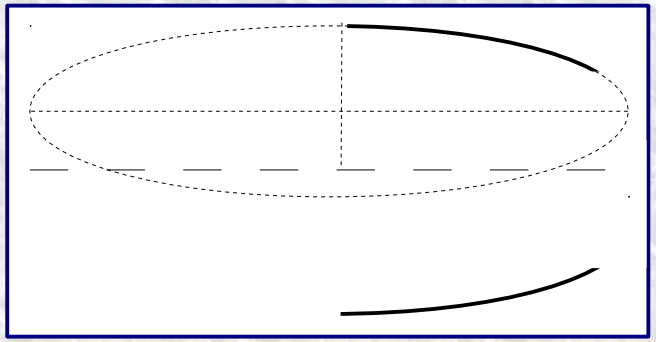
- Simulation shows that the ellipsoidal profile provides a more efficient light collection

→ switch to ellipsoidal profile

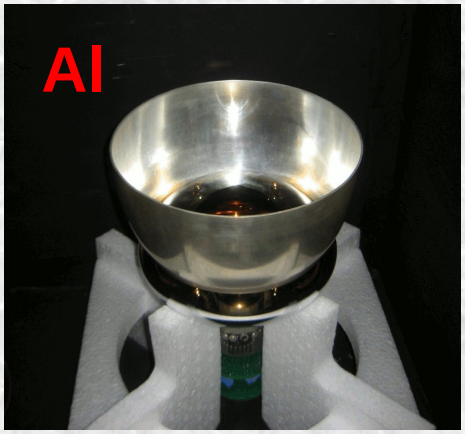
Winston Cone



Ellipsoidal Cone



First prototypes



Profile: Winston Cone

Metal Coat: Al

60° opening angle

Rmin at the edge of Photocathode guaranteed by Hamamatsu

Profile: Winston Cone

Metal Coat: Ag

60° opening angle

Rmin at the edge of Photocathode guaranteed by Hamamatsu

Profile: Ellipsoidal

Metal Coat: Al + coating

60° opening angle

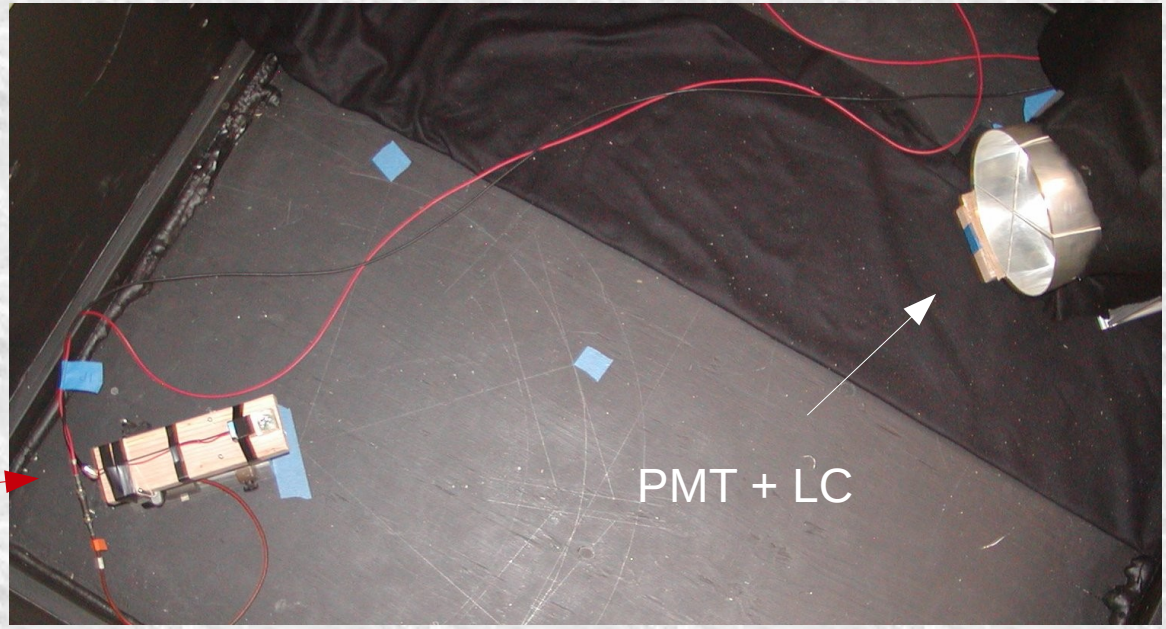
Wider rmax (16.5”)

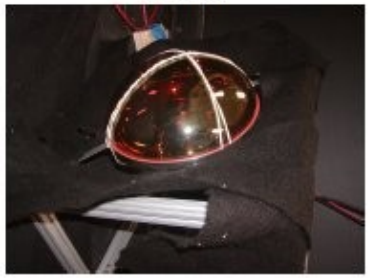
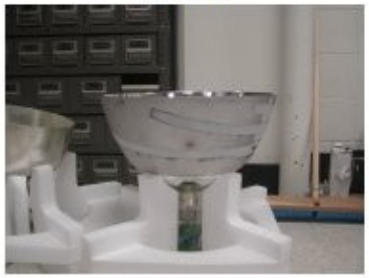
Rmin at the equator

Tests at UPenn

Optimal Configuration:
Source facing the PMT

Cherenkov Light Source



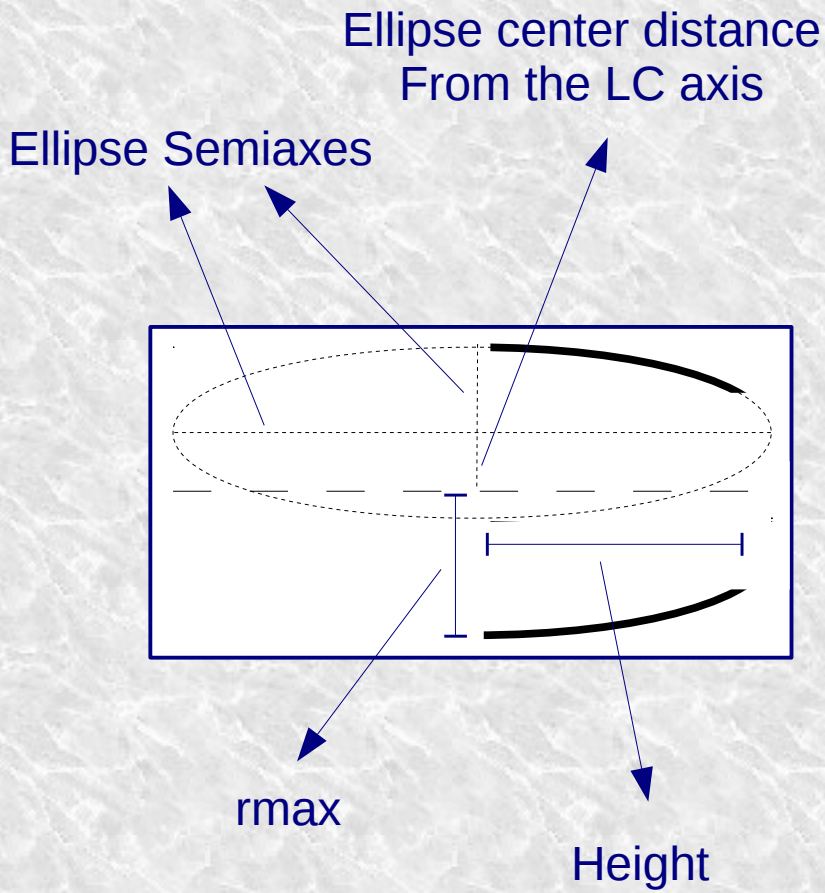
WC type	None	Aluminum	Silver	Wide
				
Rel. Eff.	1.0 (±0.01)	1.45 (±0.01)	1.43 (±0.02)	3.05 (±0.03)
TTS σ	1.49 ns (±0.05)	1.45 ns (±0.05)	1.49 ns (±0.05)	1.72 ns (±0.06)

LC Shape Optimization for a 200 kton Cylindrical WCD

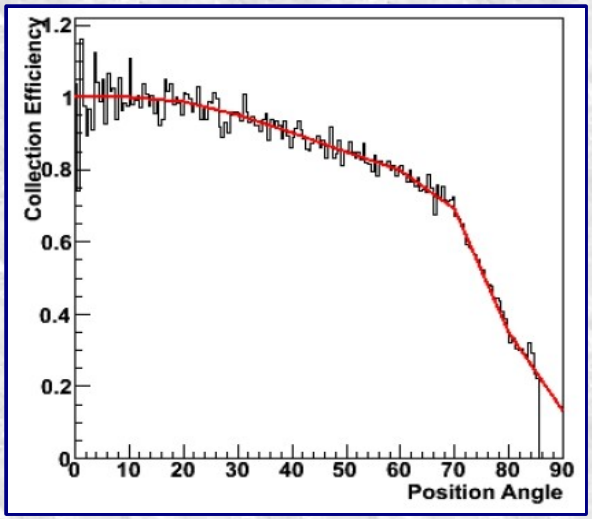
LC Profile Optimization

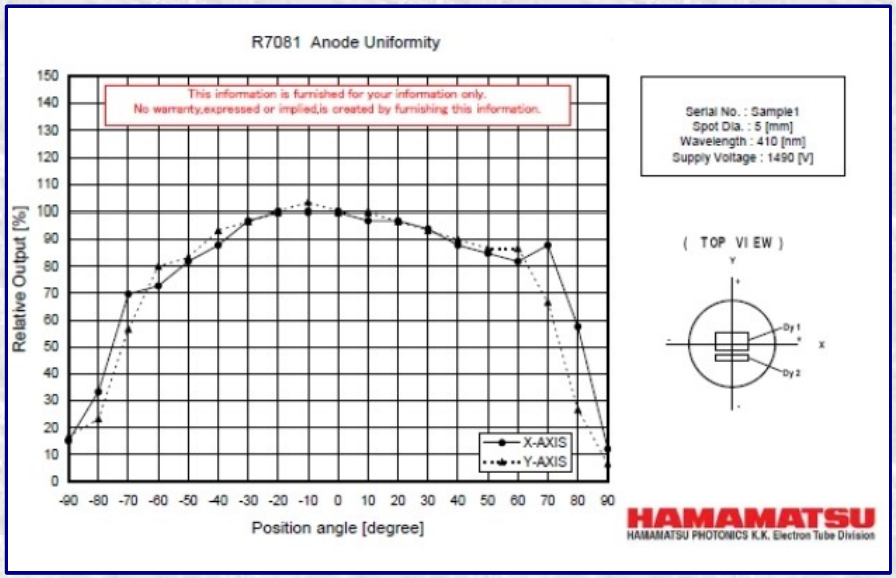
- Shape optimization done through simulations
  - Tuning of the ellipsoidal parameters
- Simulation program: WCSim

  Geant4 based LBNE WCD MC program
- 2 stage simulation
  - Identification of the best LC profile
  - Check of its impact on the detector response



Simulation of the PMT photocathode



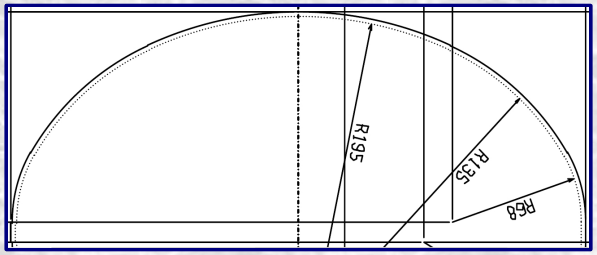


- Included in the simulation:

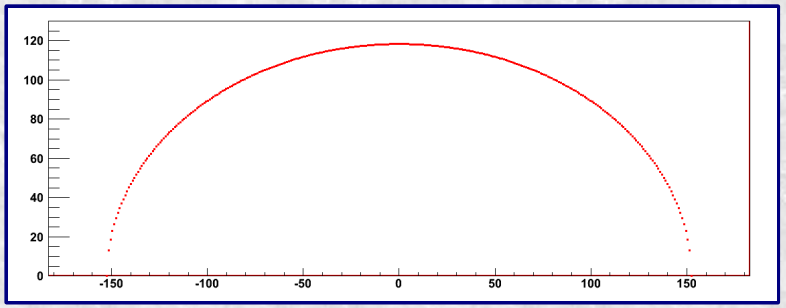
  QE vs position angle on the photocathode

  PMT photocathode elliptical profile

From Specs (Hamamatsu)



In WCSim



Criteria for Selecting the Best Profile

- Gain as independent on incident angle as possible
- Reflected light as little as possible
- Opening angle as high as possible

  Avoid shadow effect at large incident angles → negative effect for events at the FV boundaries
- LBNE Constraint: Gain > 1.4

  BUT simulations show that the detector response is not worsened if this condition is not strictly met

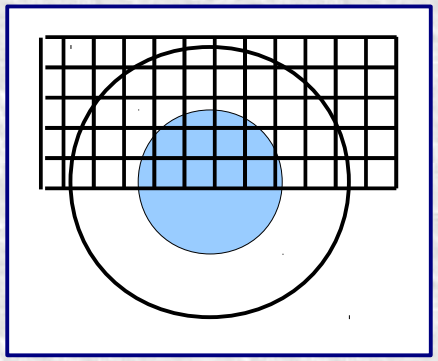
LBNE Benchmark
Reproduce SK photocoverage

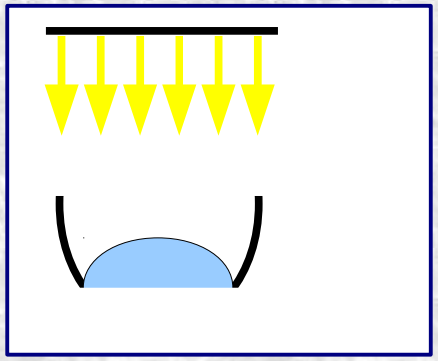
20% photocoverage

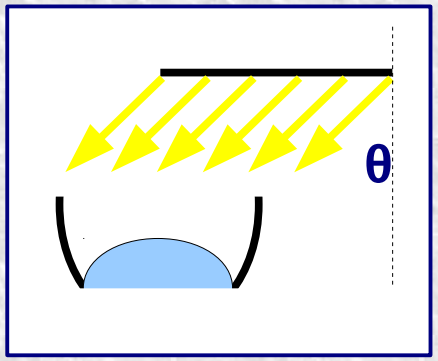
Use high-QE PMTs
→ 14% photocoverage

Use LCs
→ 10% photocoverage

LC Profile Optimization







- One single PMT

  w/ and w/o Light Cone

- Define a fine grid on half of it, ~1 m above

- Shoot N photons downwards from every vertex on the grid (fixed θ)

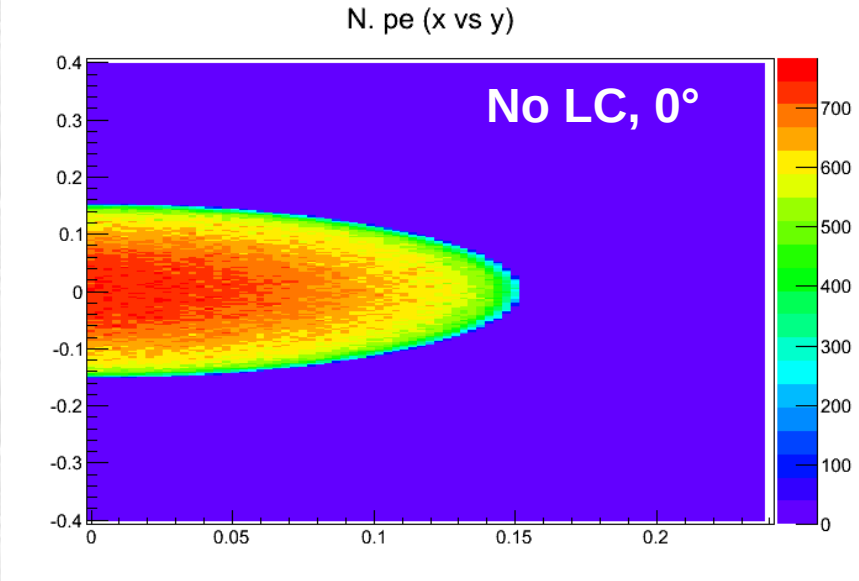
- Repeat for different θ (0° → 80°; step: 10°)

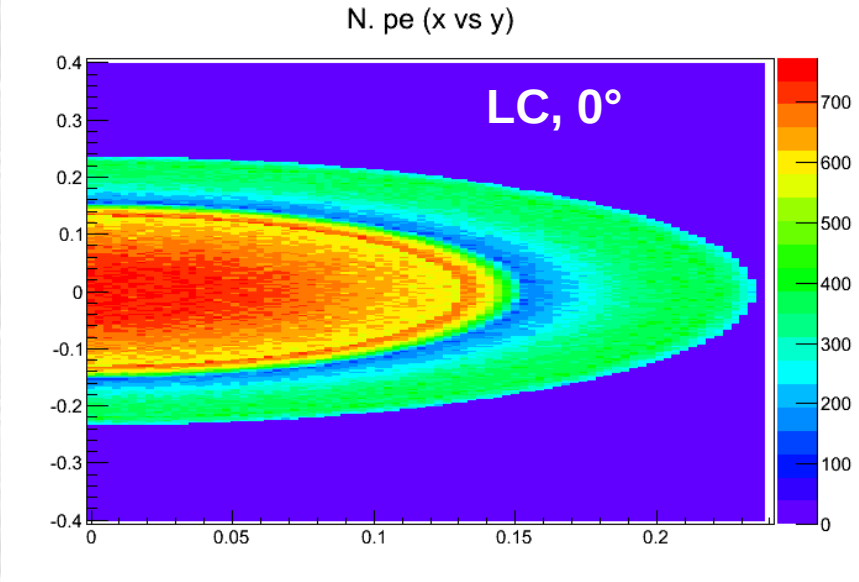
- For every angle compute

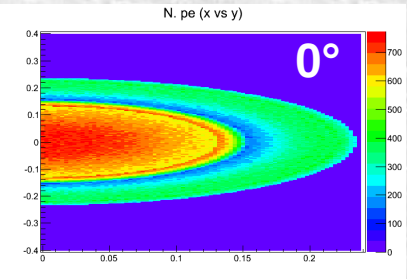
  Gain

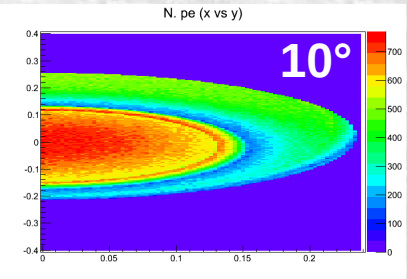
  Reflected Light

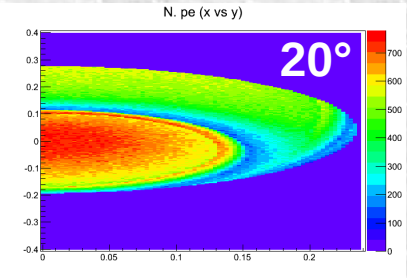
PMT scan

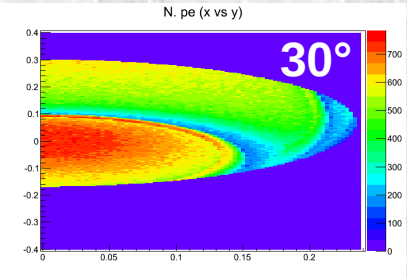

N. pe (x vs y)
No LC, 0°

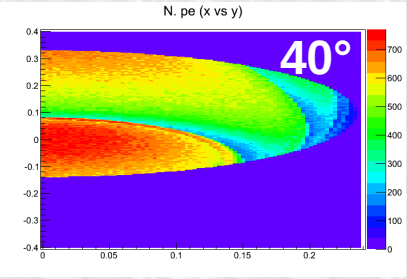

N. pe (x vs y)
LC, 0°

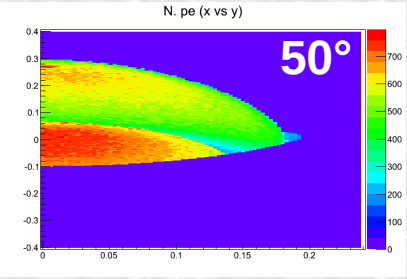

N. pe (x vs y)
0°

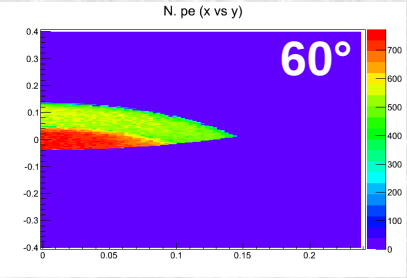

N. pe (x vs y)
10°

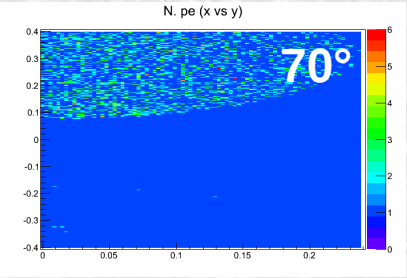

N. pe (x vs y)
20°


N. pe (x vs y)
30°

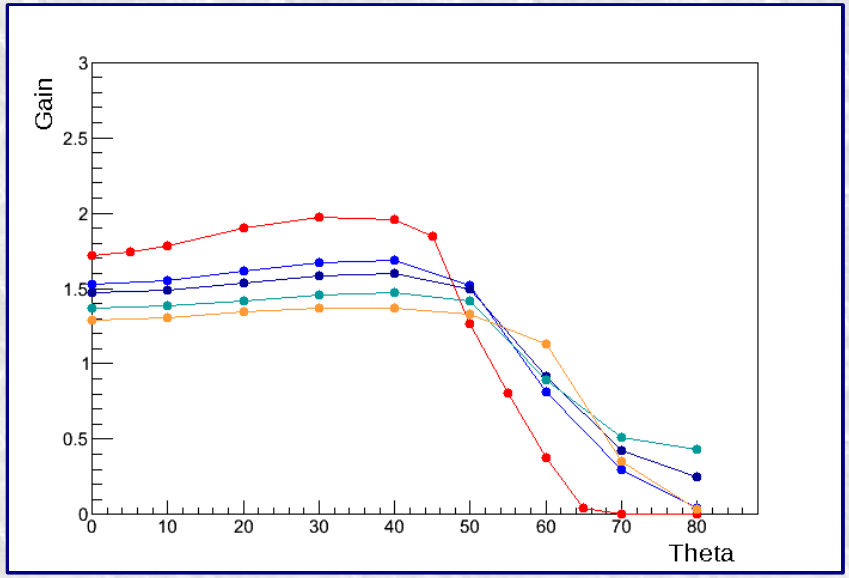

N. pe (x vs y)
40°

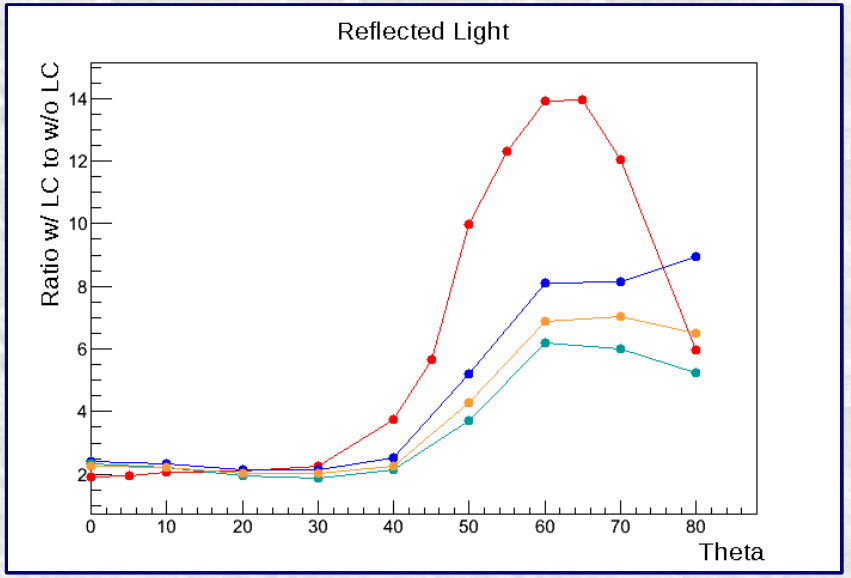

N. pe (x vs y)
50°


N. pe (x vs y)
60°


N. pe (x vs y)
70°

Gain and Reflected Light vs Incident Angle

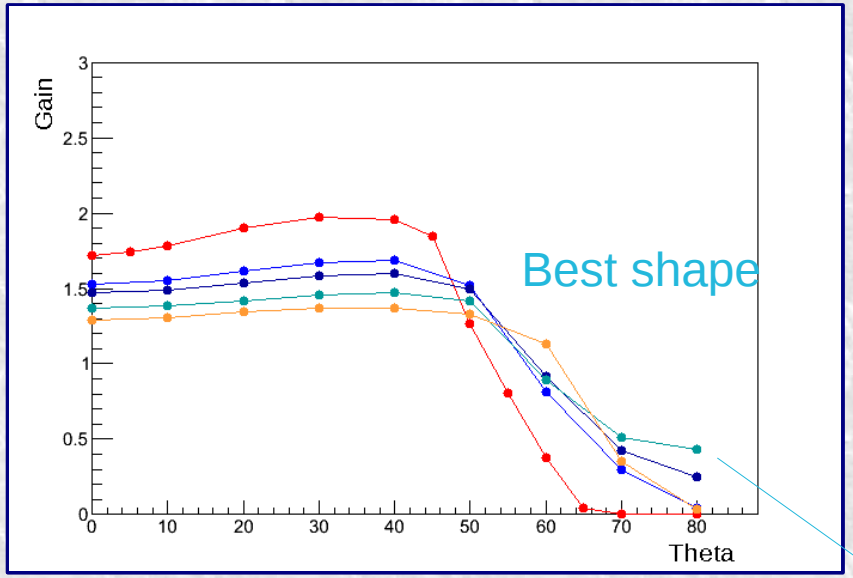


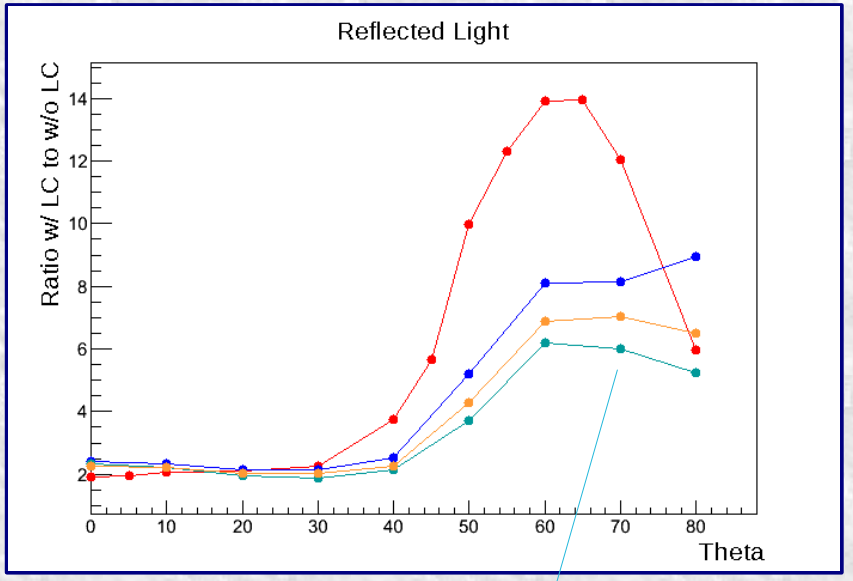


Gain = npe_{tot}(LC) / npe_{tot}(noLC)

This computation of the gain
Includes only direct light
No reflected light → good gain

Gain and Reflected Light vs Incident Angle





Gain = npe_{tot}(LC) / npe_{tot}(noLC)

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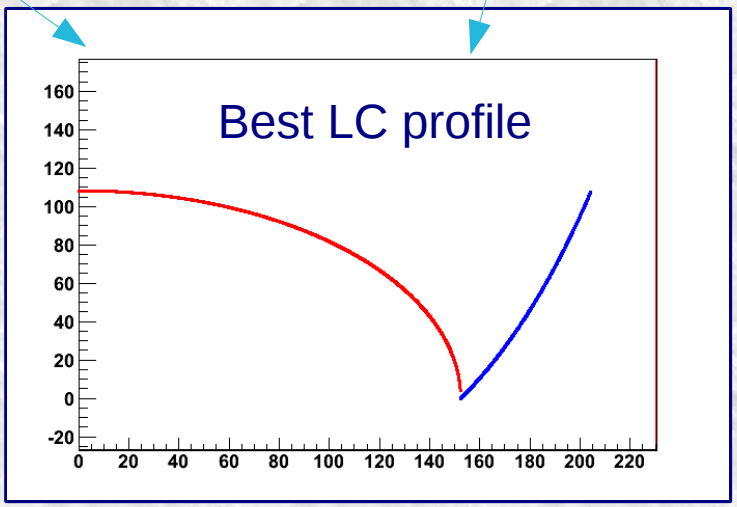
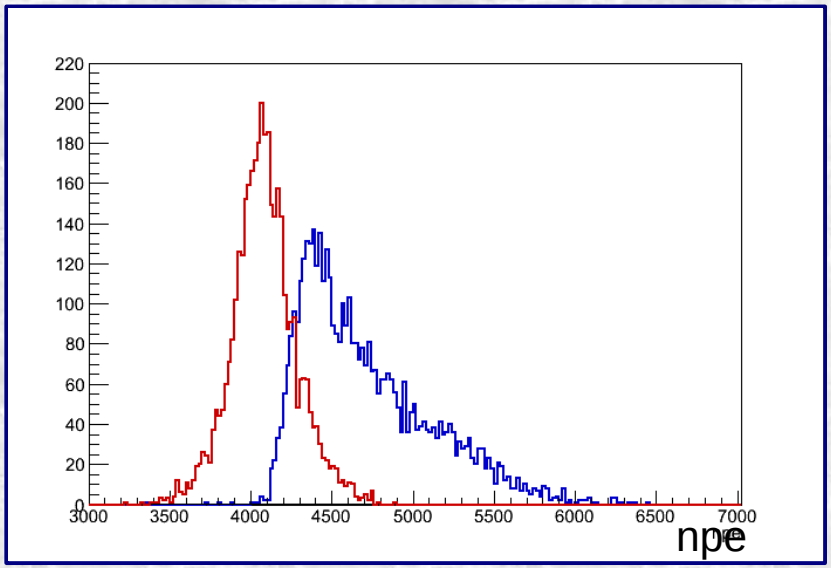
No reflected light → good gain



2nd Stage: Impact on Detector Response

- Evaluate the impact of the best LC on the detector response
- Effects on event reconstruction: check
  - Energy vs event position
  - Timing
  - PID
- Compare 2 configurations
  - 14% photocov w/o LC (benchmark) and 10% photocov w/ LC
- Samples used
  - 1 GeV mu- and e-, isotropic direction, uniform distribution on the FV

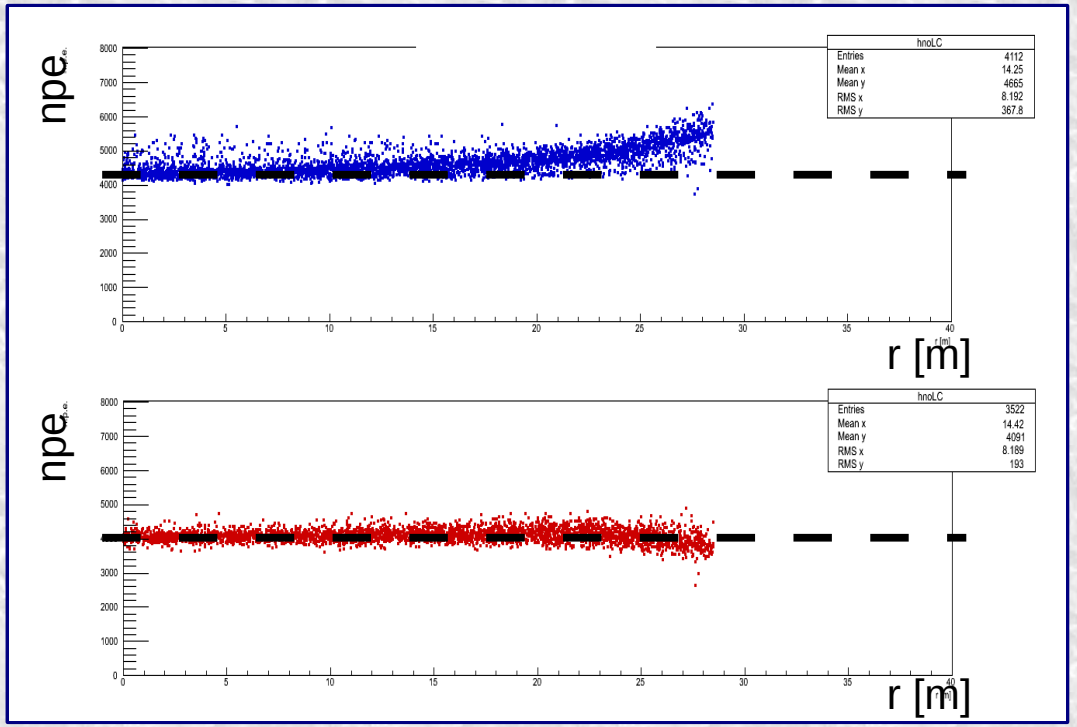
Light Collected vs Event Position



RMS/Mean

7.8% - no LC

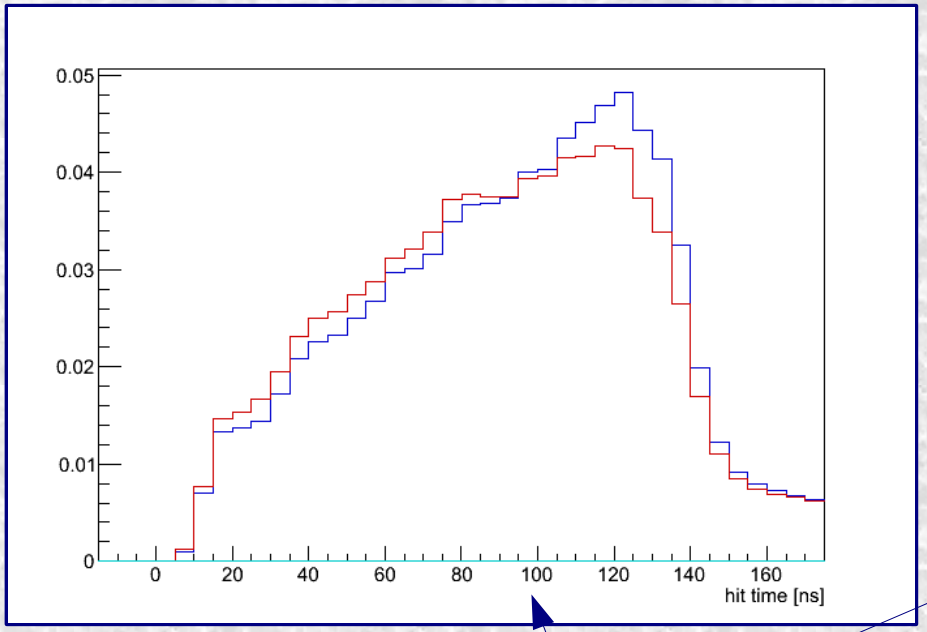
4.7% - LC

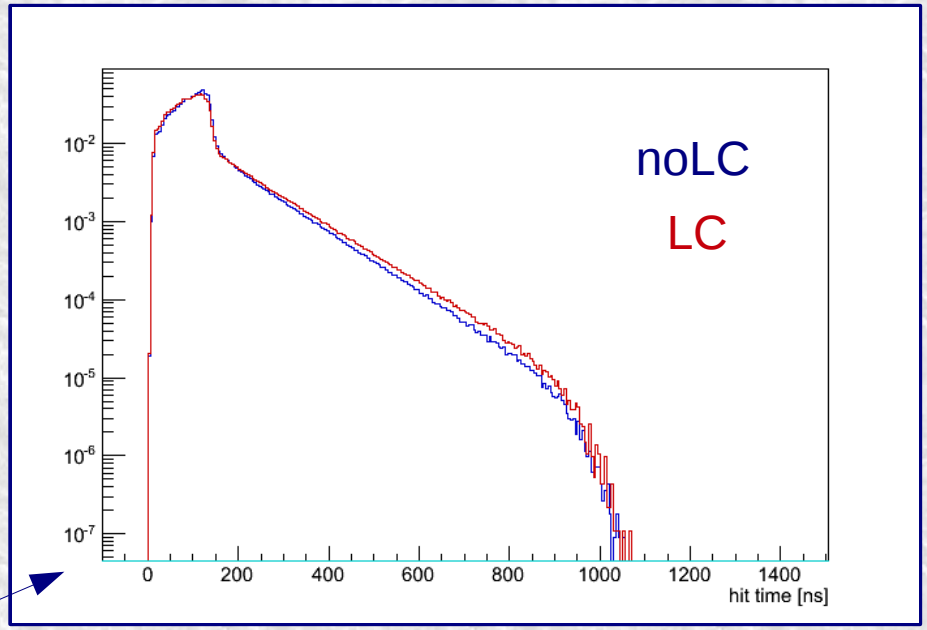


Npe_{LC} / $Npe_{no\ LC}$ = 0.87

Gain < 1.4

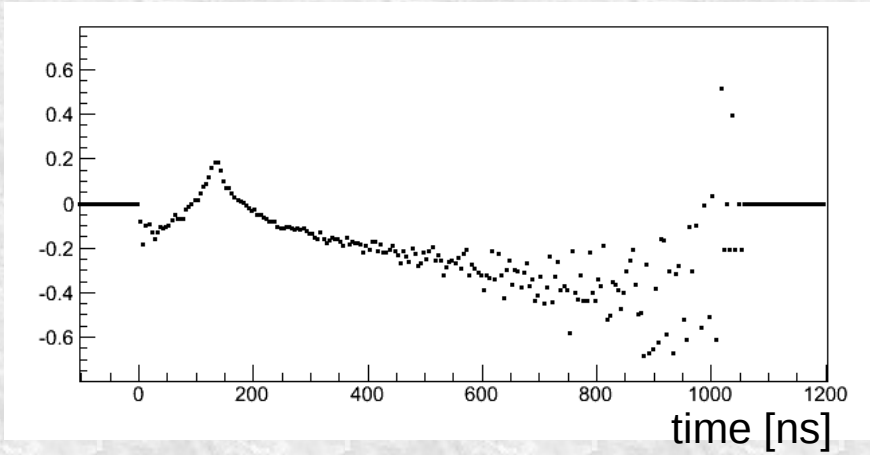
Timing





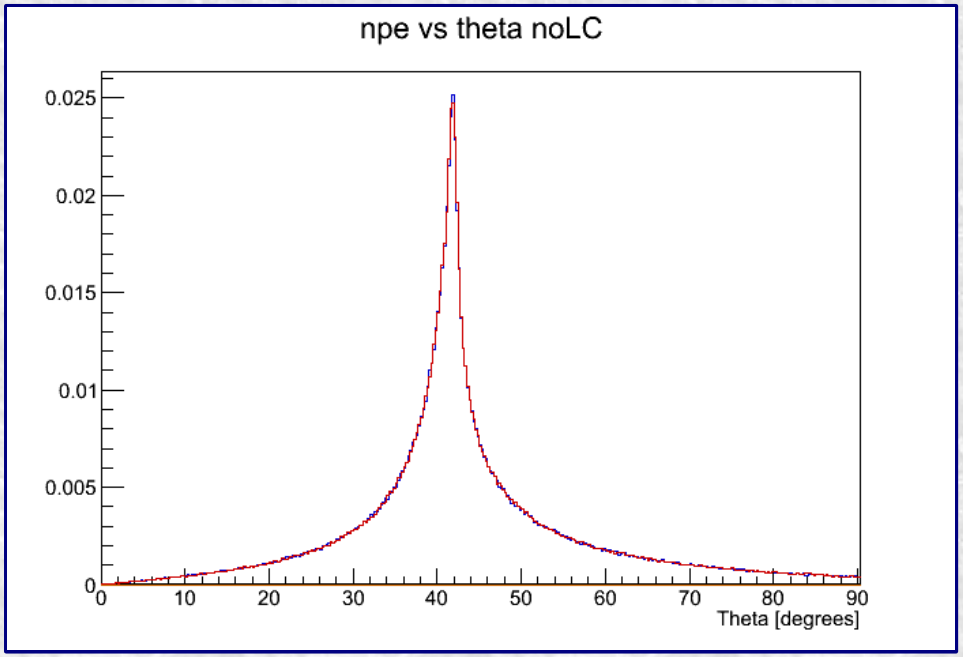
t_{hit} -TOF

(noLC – LC) / noLC

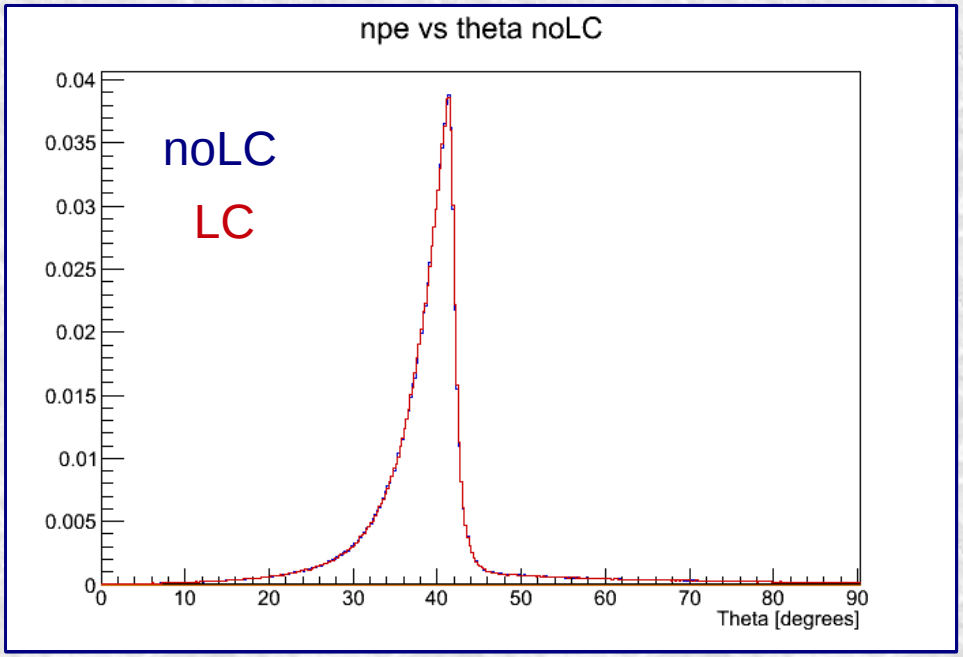


PID

electrons



muons



npe vs angle wrt particle direction

What's still to be done?

- Check the impact on the detector response at the MeV level
- Have a prototype produced
- Test the prototype in collaboration with the UPenn group