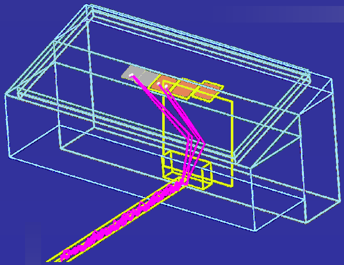


Analysis Progress from Geant 4 Simulation Studies

Executive summary:

Our reconstruction code uses photon directional vectors in the bar
and time/path in bar from measured PMT pads
based on Ivan's Geant 4 simulation.

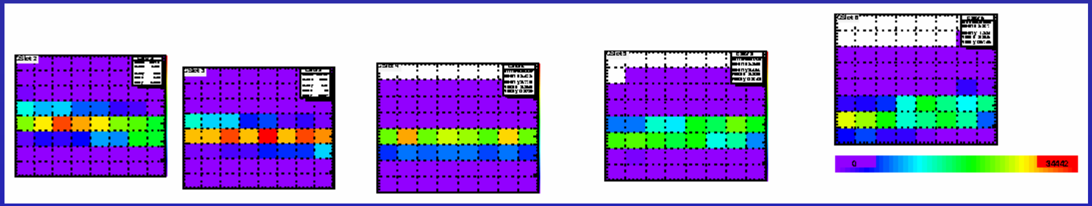
Ivan defined how Cherenkov angle and directional cosines are determined.

Revisited that definition, made some changes and created new set of angles.

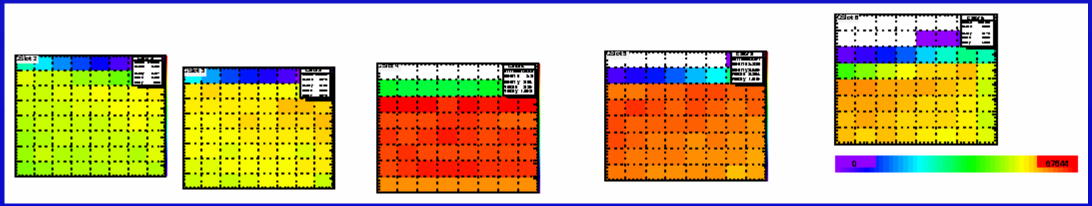
thetaC(pixel) resolution improves by ~2mrad.

Two methods for determining angles, paths, time, directional cosines:

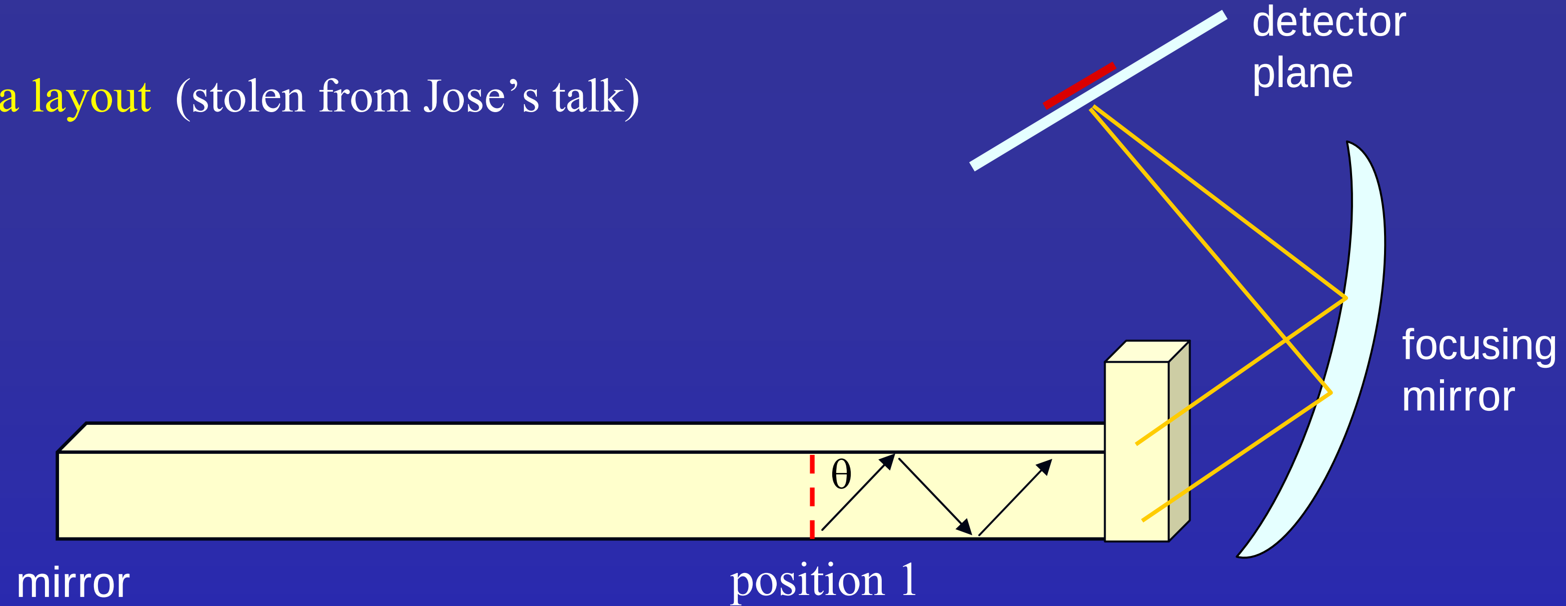
1. "variable lambda"
   standard Geant 4 simulation. Cherenkov photons are generated along the particle track in the bar; photons propagated forward and backward, all physics processes, all propagation properties, all detection efficiencies; used for checks, true paths, times. Seems to work as advertised, keep that method unchanged for now.

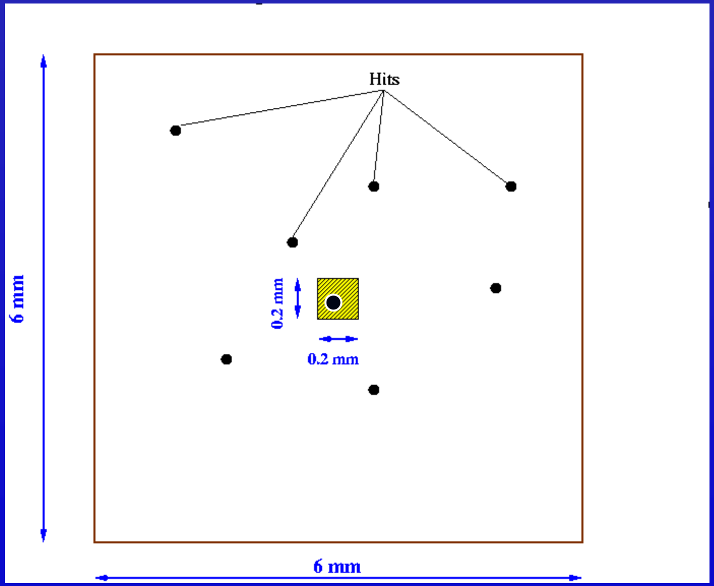


2. "fixed lambda"
   single photons are produced at one point in the bar; each photon is only propagated in forward direction if it points into a region of phase space where it would hit a PMT via the short path. Define range of photon polar and azimuth angles from PMT coverage. No "Cherenkov" properties, detection efficiencies set to 100%; used in data analysis. Found a couple of issues that cause some problems.



Fixed lambda layout (stolen from Jose's talk)





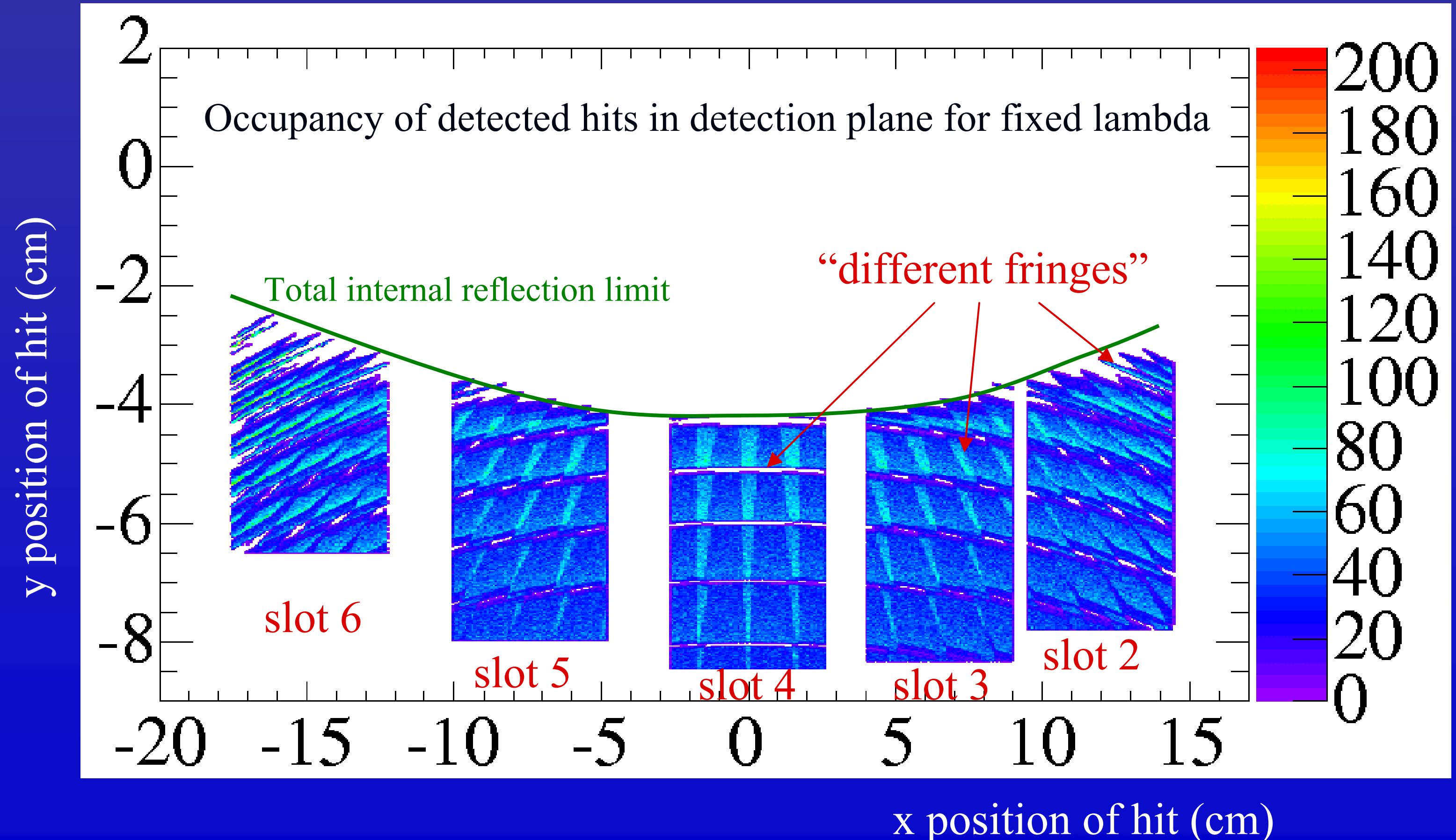
Fixed lambda analysis

- produce all photons in position 1
- produce all photons at bottom, center of bar
  (azimuth: 0…130deg, polar: cos(42)…cos(52))
- propagate only forward going photons that
  point to PMT (polar, azimuth angle cuts)
- assume 100% detection efficiency
- consider only photons that hit close to center
- average angles and paths of those photons to
  calculate pad angle/path assignments

However, some pads do not have good coverage and will not have any numbers assigned.

Two reasons for that:

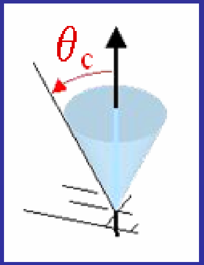
- part of detection plane cannot be hit due to total internal reflection limit (no problem)
- optics of photon propagation cause "fringes", phase space areas that are preferred or impossible to reach for a photon from a fixed (x,y,z) production point (problem)



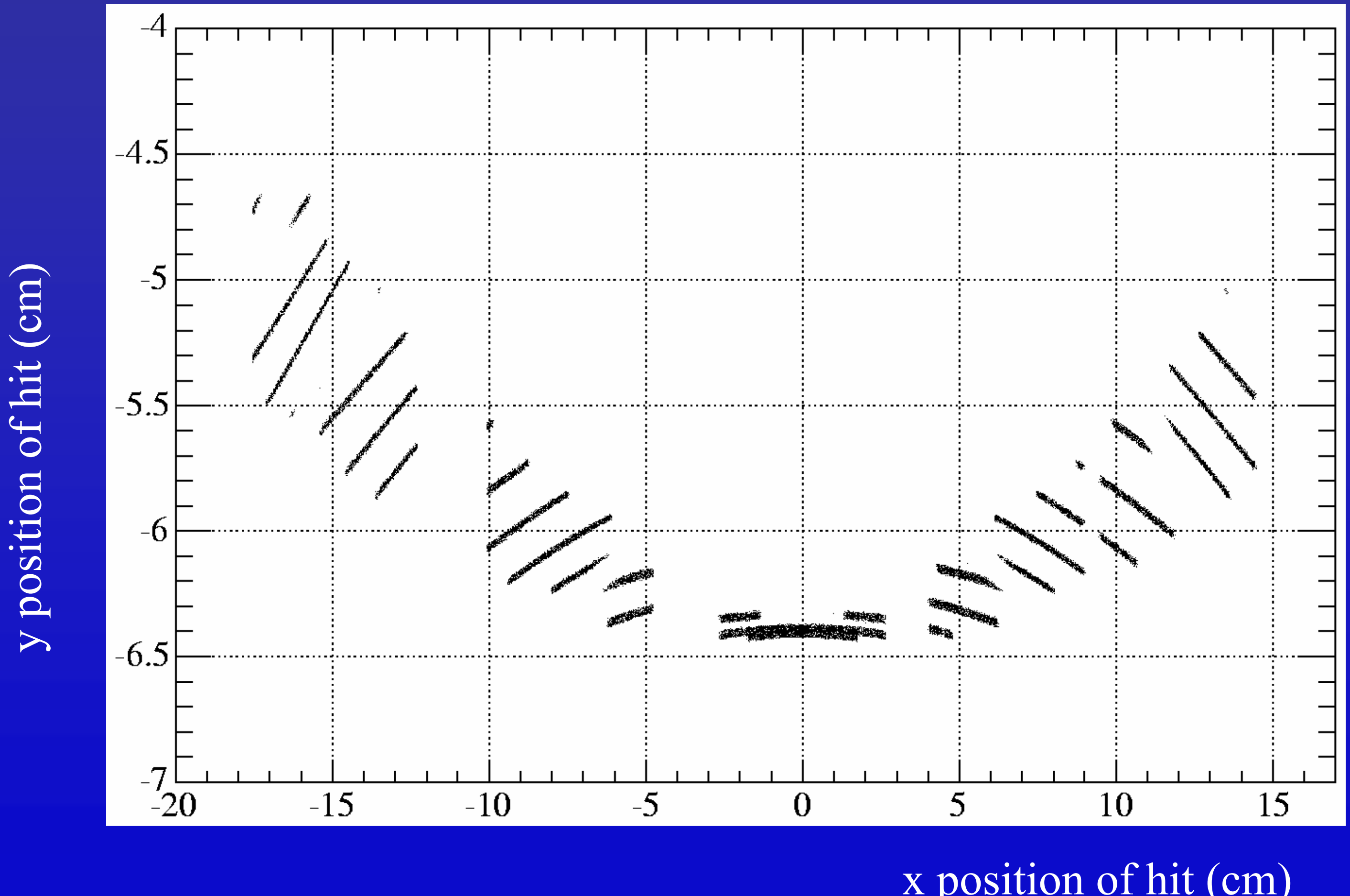
Example for a single photon production polar angle (822mrad)

varying azimuth angle over whole detectable range

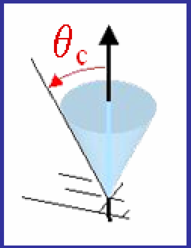
(fringes first seen several months ago by Jose's ray tracing)



Not quite the ring image I naïvely expected…

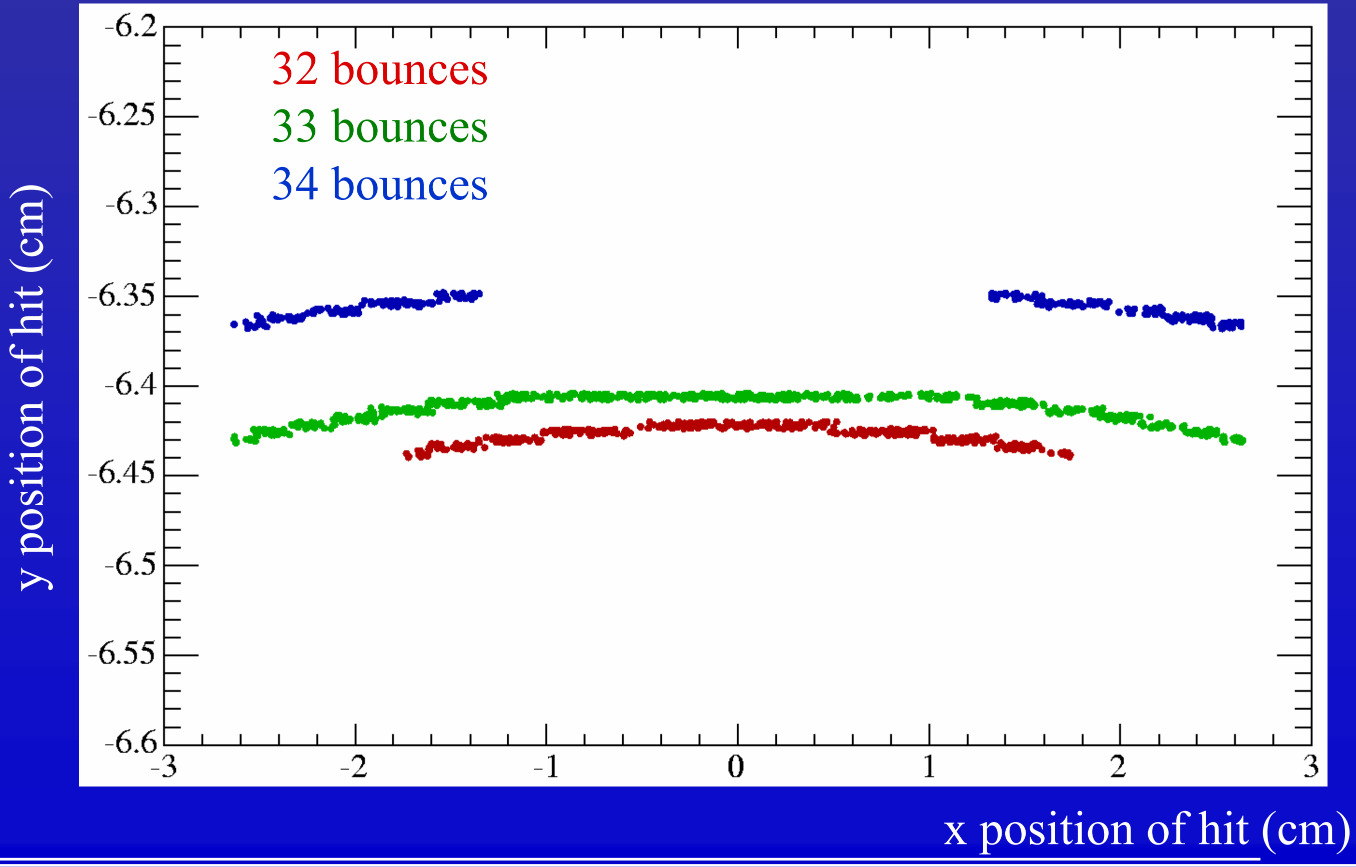


A closer look: zoom into slot 4 for fixed polar angle (~θ_c)



different colors for different numbers of internal reflections

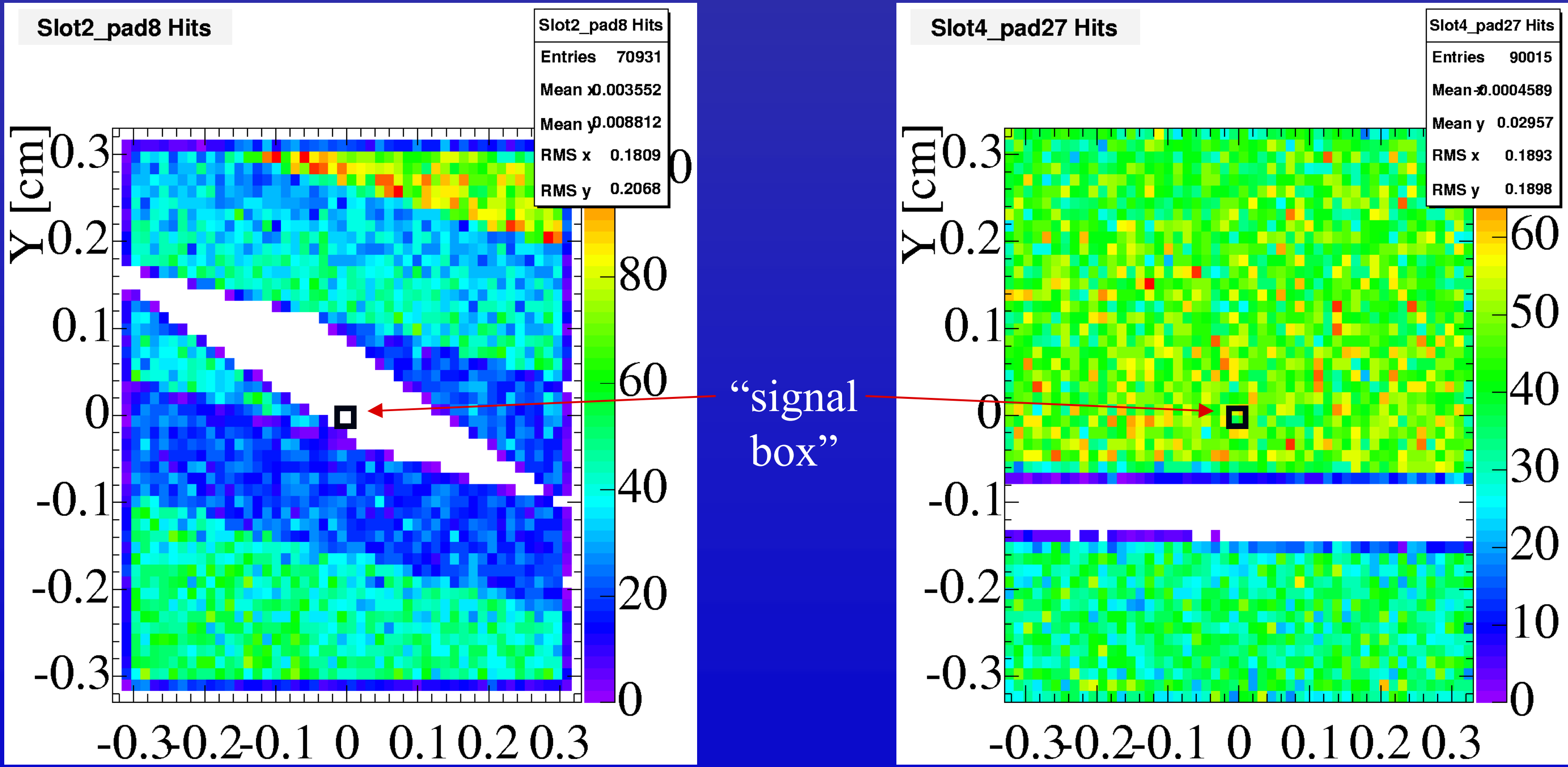
As the photon azimuth angle varies along the cone the number of bounces changes and the last bounce of the photon in the bar will determine the exit angle (up/down/left/right) resulting in significant differences in the hit locations



What happens on specific pads?

Examples: slot 2, pad 8 – has no associated angles if only the central 0.2mm are considered
slot 4, pad 27 – clearly the average over the whole pad will be different from average over the central 0.2mm

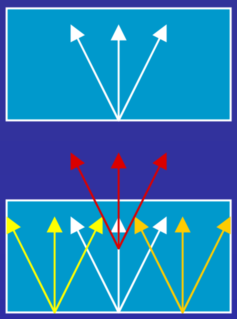
Need to use larger area for average, maybe whole pad?



Second problem with the current method:

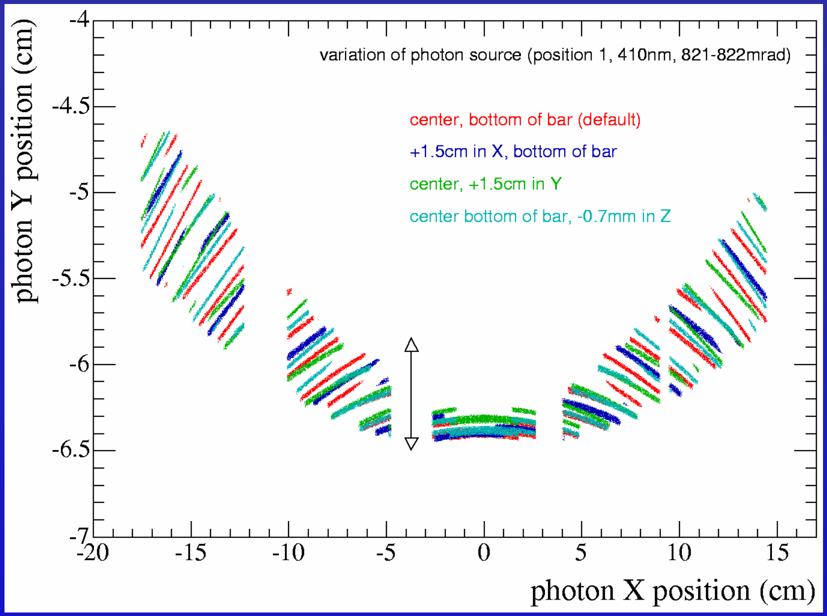
only one location is used for generating photons,

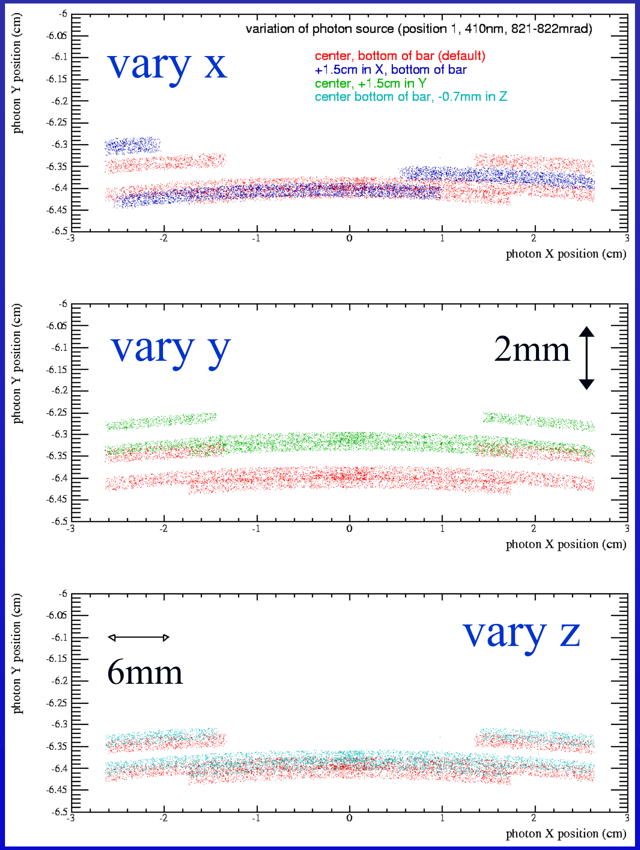
no variation in (x,y,z)



in real data the photons will come from a range of locations

what is the effect of different x, y, and z positions?





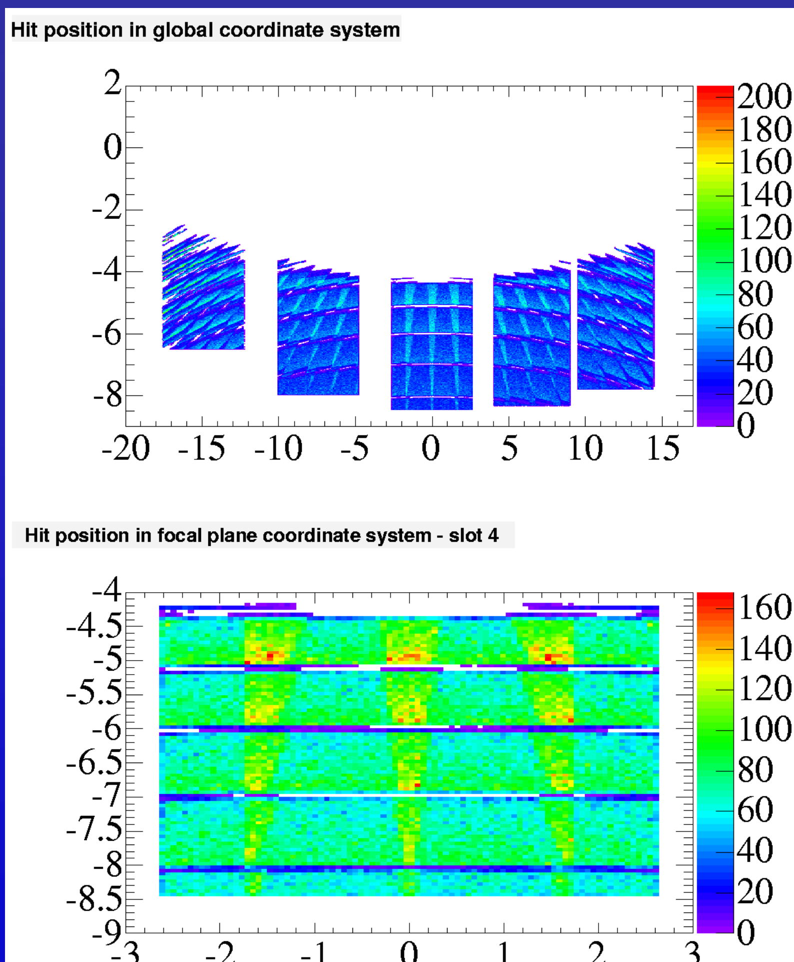
Should take this variation into consideration.

→ smear production point using hodoscope info and track length in bar

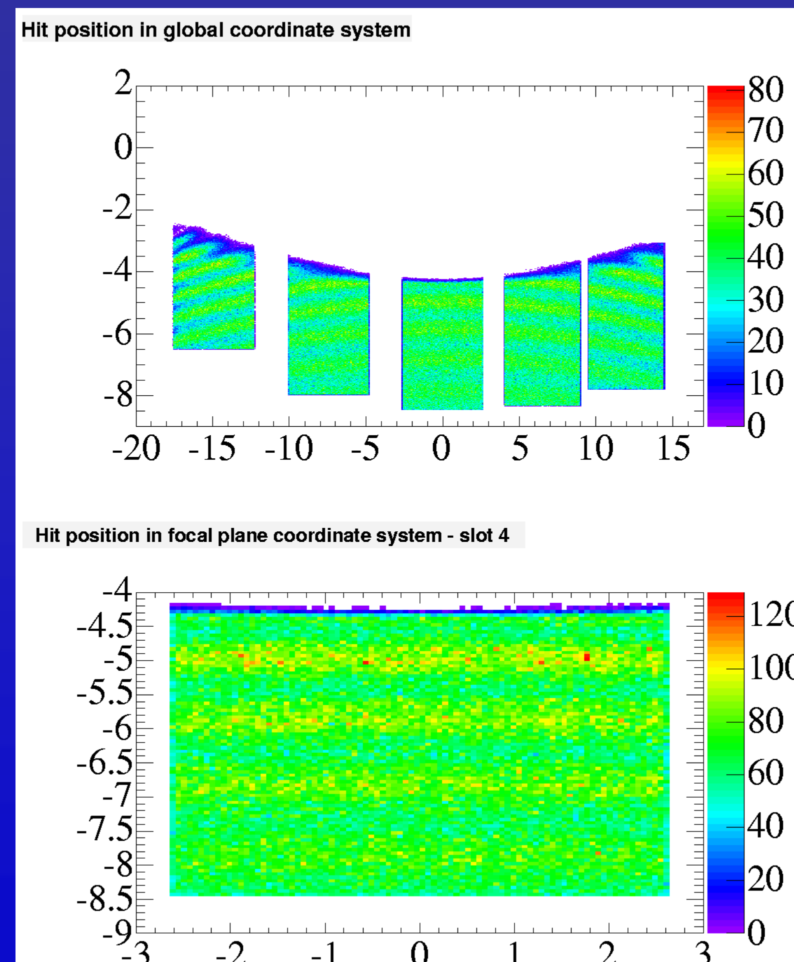
Comparison of old fixed lambda method (left) and new method (right)

→ effect of fringes reduced, occupancy much more uniform, no dead spaces

old

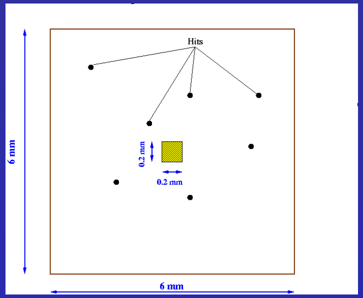


new



Even with the new method the fringes remain visible.

The pad center is not necessarily a good representation of the whole pad.



Use hits on whole pad to determine average angles and paths
instead of 0.2mm around center.

Significant effect on angles – example for slot 4, pad 27:

Ivan's latest thetaC for 0.2mm:	838.9mrad
new thetaC for whole pad:	836.8mrad

Last issue:

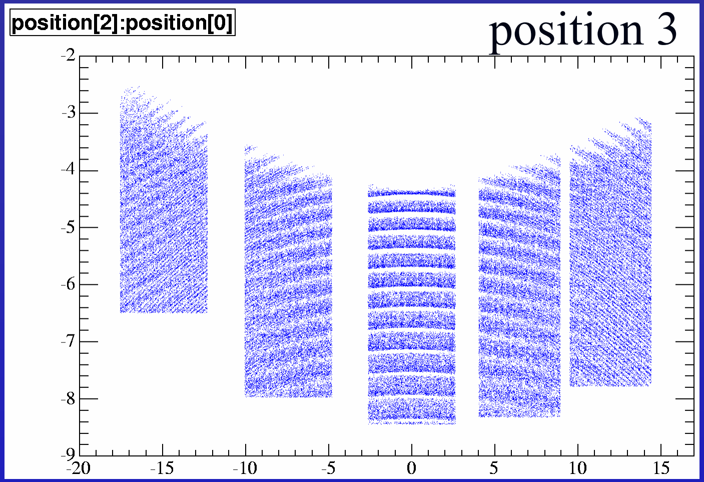
Ivan used only position 1 (closest to SOB)

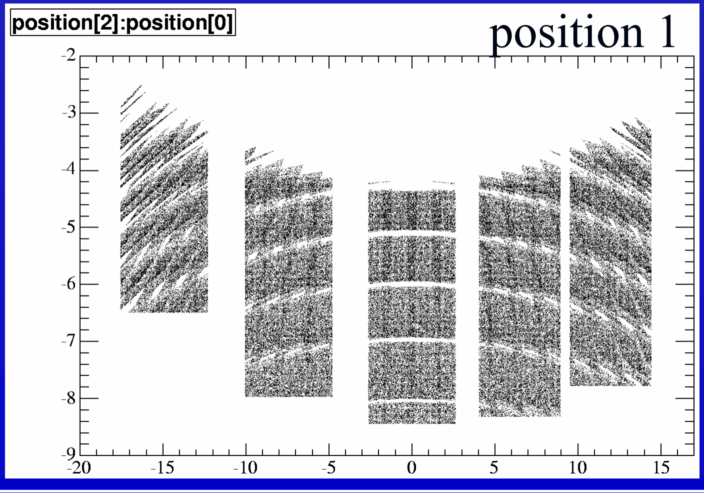
However, fringes look different as function of beam position (shown without smearing)

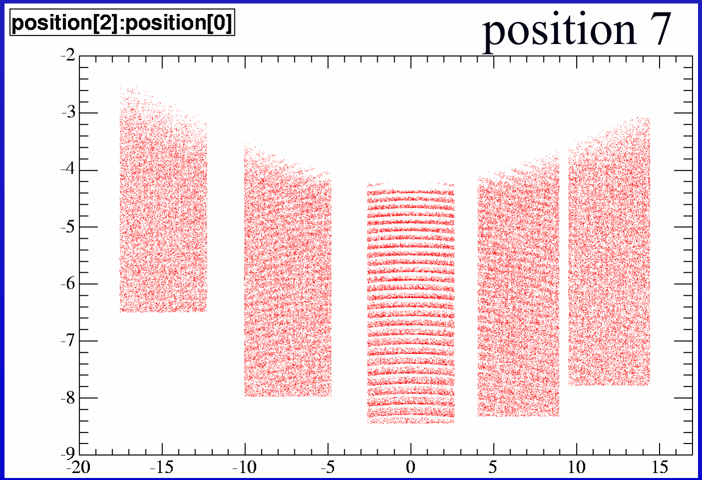
I now generate angles for each beam position.

Example for thetaC for slot 4, pad 27:

position 1:	836.8mrad
position 2:	837.9mrad
position 3:	837.1mrad

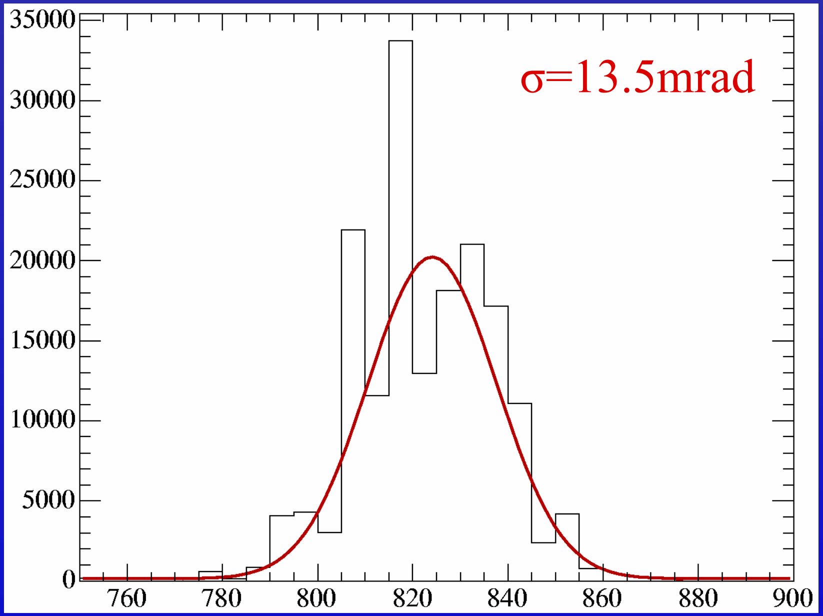




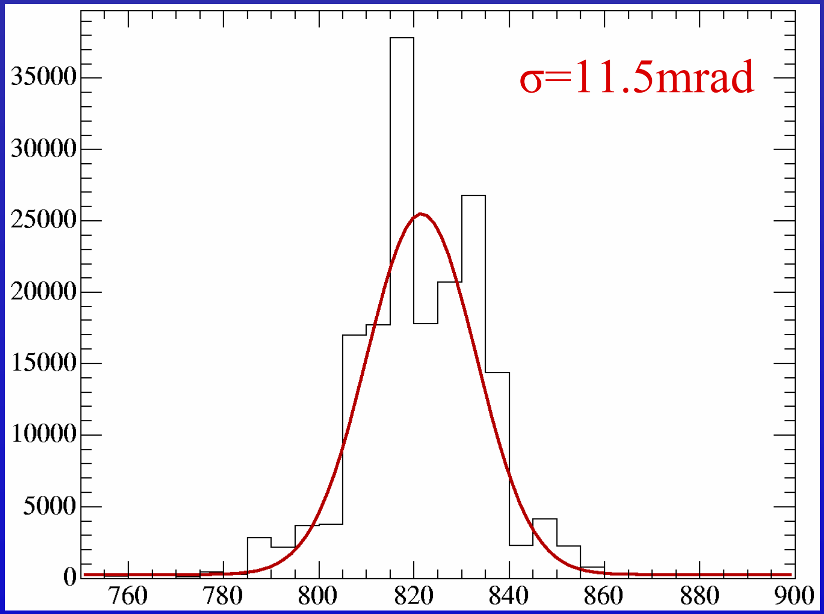


Reanalyze data with new angles from the fixed lambda analysis

run 12b, peak 1, old angles



run 12b, peak 1, new angles



Net effect of these changes does not look like much – but it makes a significant difference – approx. 2mrad improvement

Resolution now matches results obtained with Jose's ray tracing angles.

Maybe 50% of the difference between measured and expected resolution from pixels has been removed by the changes to the fixed lambda method.

I am still in the process of creating all relevant angles and paths for all beam positions using both variable lambda and the new method for fixed lambda.
New, massive C++ classes (30k lines each…)
Should have new results within a week or so.

(Jerry will show more detailed results with first version of new angles for position1.)