

RICH Reconstruction

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RICH Software Release

RICH Package 1.0

Test release beginning of May, CCDB and misalignment still incomplete

preliminary: ✓ stable running
✓ no issue with CPU time $\sim 10 \mu\text{s}$ per event

RICH Package 2.0

Released end of May, complete misalignment and basic CCDB

still missing: ✓ mirror optical properties, MaPMT efficiencies

RICH Package 2.1

On probation, Hipo4 ready

RICH Engine:

reconstruction/rich/src/main/java/org/jlab/rec/rich/*

CSG Geometry:

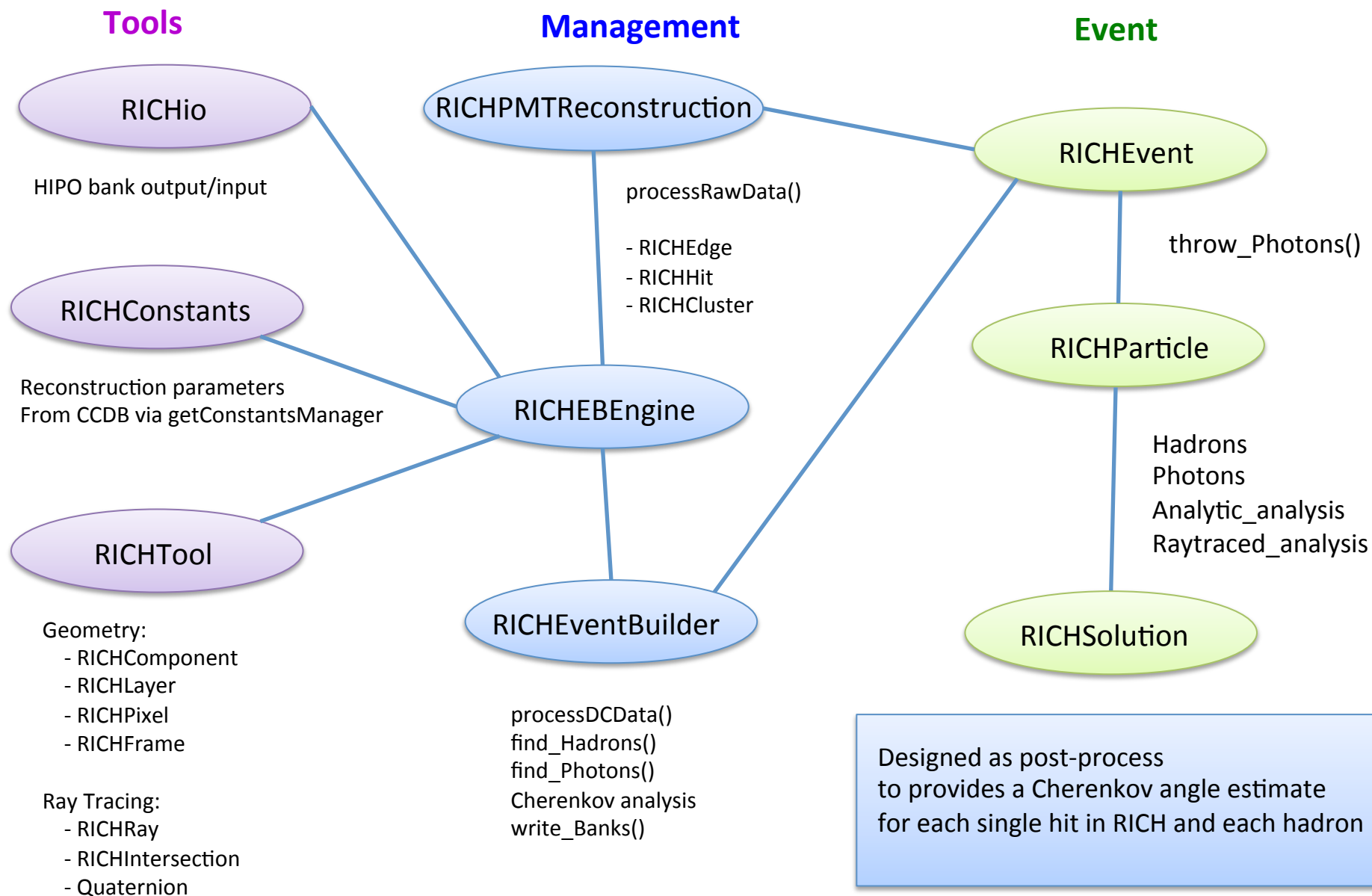
common-tools/clas-jcsg/src/main/java/org/jlab/detector/geant4/v2/RICHGeant4Factory.java

common-tools/clas-jcsg/src/main/resources/rich/cad/*

Banks:

coatjava/etc/bankdefs/hipo/RICH.json

Software Architecture



CCDB Database

✓ calibration/rich/parameter [ok]

sector	layer	component	flag1	flag2	flag3	flag4	flag5	flag6	flag7	flag8	flag9	flag10	flag11	flag12	flag13	flag14	flag15	par1	par2	par3	par4	par5	par6	par7	par8	par9	par10
4	0	0	1	0	0	1	0	1	1	0	0	0	50	1	1	1	0	80	15	0.6	4.2	10.0	10.0	0.0	1.5	1.0	1.0

Showing 1 to 1 of 1 entries

First Previous 1 Next Last

✓ Calibration/rich/misalignments [ok, values to be defined]

sector	layer	component	dx	dy	dz	dthx	dthy	dthz
4	0	0	0	0	0	0	0	1
4	201	0	0	0	0	0	0	0
4	202	0	0	0	0	0	0	0
4	203	0	0	0	0	0	0	0
4	204	0	0	0	0	0	0	0
4	301	1	0	0	0	0	0	0
4	301	2	0	0	0	0	0	0
4	301	3	0	4	0	0	0	0
4	301	4	0	0	0	0	0	0
4	301	5	0	0	0	0	0	0

Showing 1 to 10 of 24 entries

First Previous 1 2 3 Next Last

✓ calibration/rich/aerogel [ok, radius and center values to be defined]

sector	layer	component	thickness	n400	n_p1	n_p2	A0	L400	clarity	planarity	radius	xc	yc	zc
4	201	1	20	1.05054	0.09683	84.13	0.9772	44.92	0.0056990205	0.42	0.00000	0.00000	0.00000	0.00000
4	201	2	20	1.05164	0.09683	84.13	0.9842	53.00	0.0048301887	2.71	0.00000	0.00000	0.00000	0.00000
4	201	3	20	1.05227	0.09683	84.13	0.9717	48.45	0.0052837977	1.63	0.00000	0.00000	0.00000	0.00000
4	201	4	20	1.05175	0.09683	84.13	0.9863	54.13	0.0047293553	3.64	0.00000	0.00000	0.00000	0.00000
4	201	5	20	1.05214	0.09683	84.13	0.9863	53.71	0.0047663377	3.25	0.00000	0.00000	0.00000	0.00000
4	201	6	20	1.05208	0.09683	84.13	0.9812	44.89	0.0057028291	2.07	0.00000	0.00000	0.00000	0.00000
4	201	7	20	1.05096	0.09683	84.13	0.9737	49.99	0.0051210242	1.71	0.00000	0.00000	0.00000	0.00000
4	201	8	20	1.05110	0.09683	84.13	0.9540	57.20	0.0044755245	1.34	0.00000	0.00000	0.00000	0.00000
4	201	9	20	1.05158	0.09683	84.13	0.9866	54.65	0.0046843550	1.72	0.00000	0.00000	0.00000	0.00000
4	201	10	20	1.05189	0.09683	84.13	0.9832	48.36	0.0052936311	1.11	0.00000	0.00000	0.00000	0.00000

Showing 1 to 10 of 102 entries

First Previous 1 2 3 4 5 Next Last

CCDB Database

✓ calibration/rich/time_offset [ok, values to be defined]

sector	layer	component	offset
4	1	1	-9.27
4	1	2	-8.81
4	1	3	-8.78
4	1	4	-8.85
4	1	5	-8.64
4	1	6	-8.95
4	1	7	-9
4	1	8	-8.73
4	1	9	-8.83
4	1	10	-8.81

Showing 1 to 10 of 25,024 entries

First Previous 1 2 3 4 5 Next Last

✓ calibration/rich/time_walk [ok, values to be defined]

sector	layer	component	D0	m1	m2	T0
4	1	0	61.28	36.85	0.600	-0.155
4	2	0	59.52	34.44	0.575	-0.195
4	3	0	59.51	33.21	0.555	-0.143
4	4	0	60.38	33.42	0.550	-0.169
4	5	0	58.74	30.91	0.523	-0.165
4	6	0	59.56	33.07	0.554	-0.170
4	7	0	59.44	32.39	0.543	-0.155
4	8	0	57.84	29.83	0.506	-0.177
4	9	0	59.45	31.43	0.526	-0.161
4	10	0	57.47	29.57	0.511	-0.162

Showing 1 to 10 of 391 entries

First Previous 1 2 3 4 5 Next Last

Geometry

Read CSG volumes from CAD stl files

Convert volumes into tracking surfaces (Shape3D) and spheres (Sphere3D) with given orientation

Each Sphere3D has an associated Shape3D to define its solid angle of acceptance

Misalign the tracking surfaces (as per mounting points)

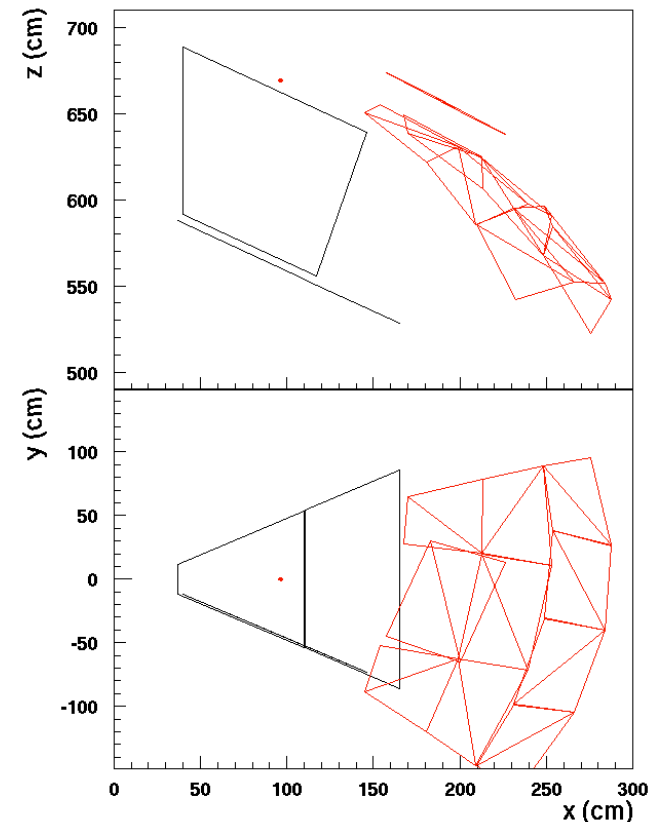
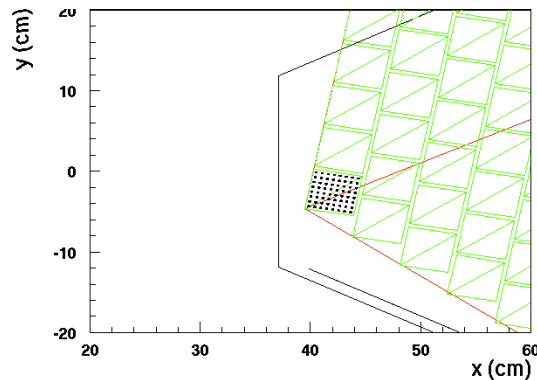
Survey

Global RICH

Layer (aerogel, MaPMTs, spherical mirror assembling)

Components (each single mirror)

Detail MaPMT pixel geometry (on the misaligned plane)

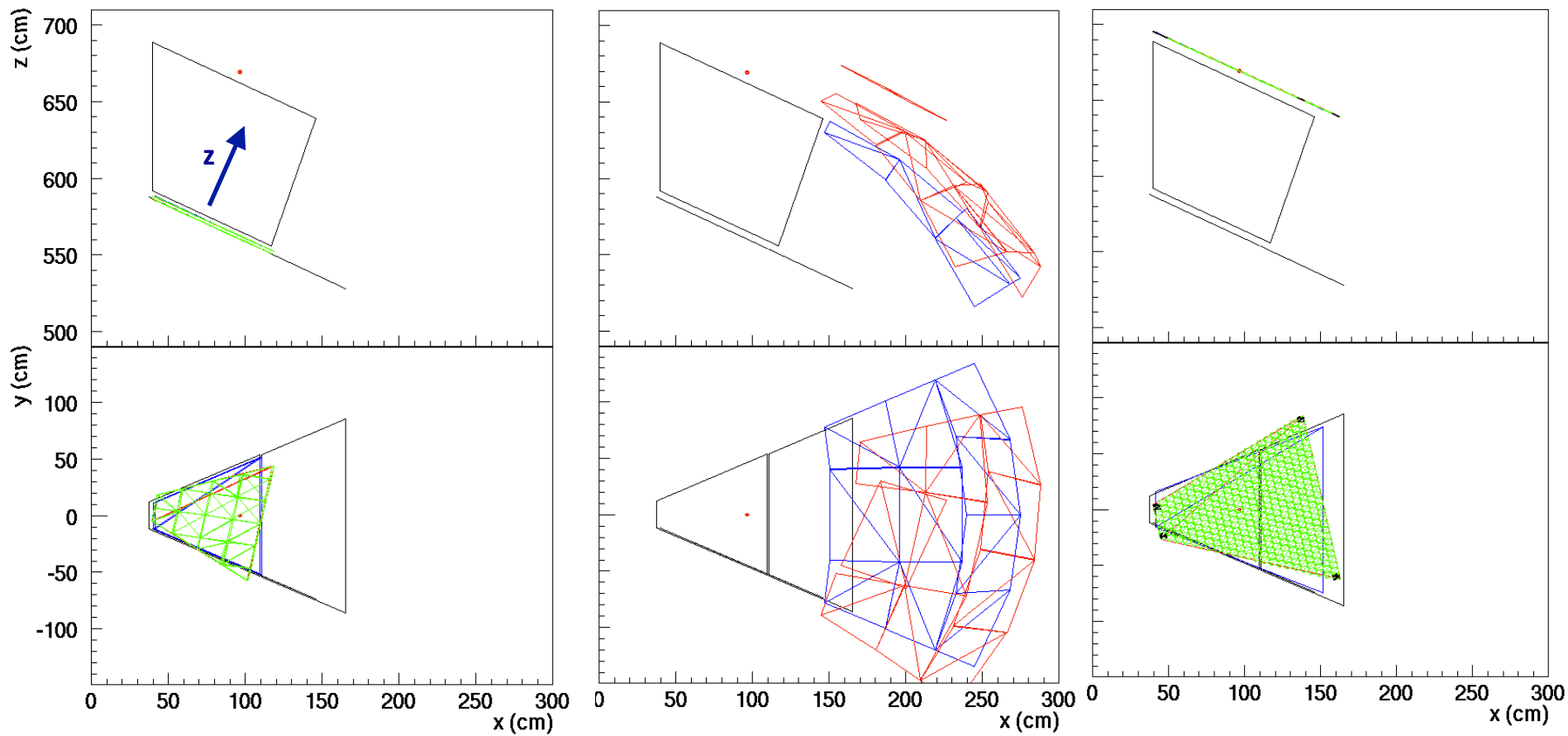


Misalignment

4 201 0 0.0 0.0 0.0 0.0 0.0 0.0 90.0

4 00 0.0 0.0 0.0 0.0 0.0 0.0 90.0
4 302 0 0.0 0.0 0.0 90.0 0.0 0.0 0.0
4 302 5 0.0 0.0 0.0 90.0 0.0 0.0 90.0

4 401 0 0.0 0.0 0.0 0.0 0.0 0.0 90.0



Cherenkov Analysis

Analytic solution for direct photons

“Exact” solution for the Cherenkov Angle

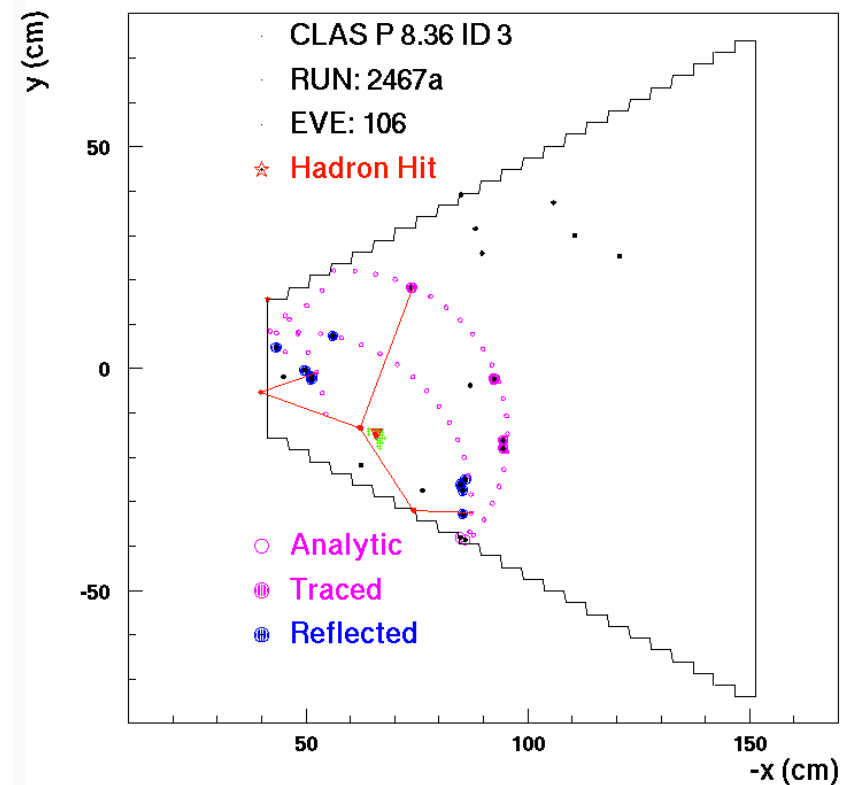
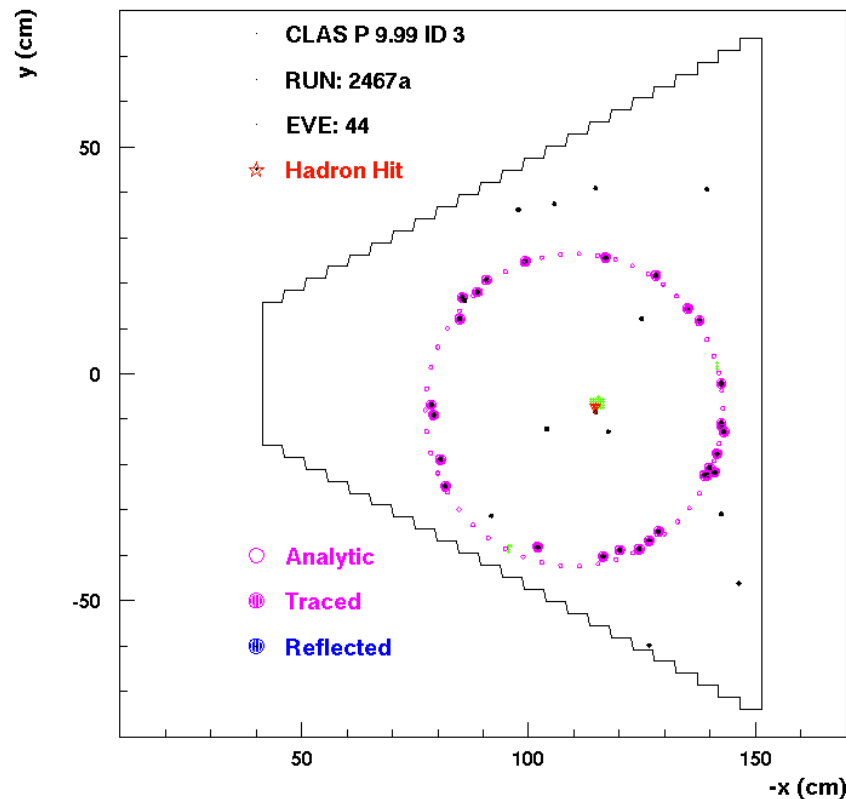
Only direct photons

Ray traced solution for direct photons

Assume knowledge of aerogel ref index

Any photon

GOAL: get a Cherenkov angle estimate for each photon for detailed PID optimization



Ray Tracing

Use Line3D intersections with Shape3D and Sphere3D

Use global surface for a layer, to avoid gaps between components

Register anyway the component to get optical parameters

Apply reflection and transmission

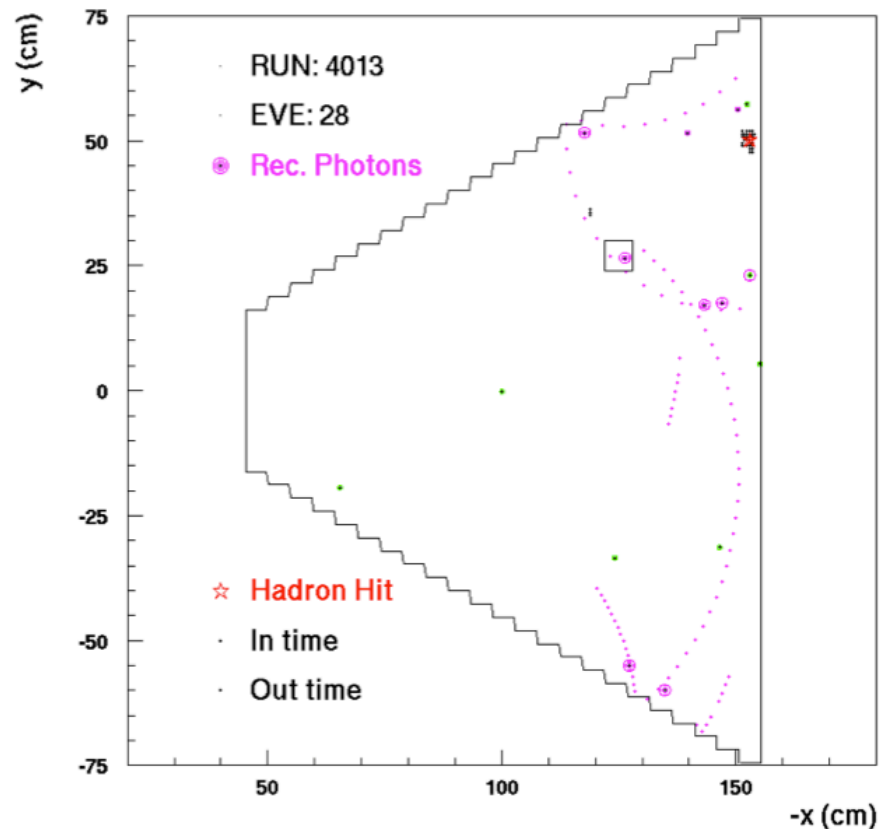
Missing: mirror reflectivity
MAPMT pixel efficiency

.....

Option: non spherical aerogel surface

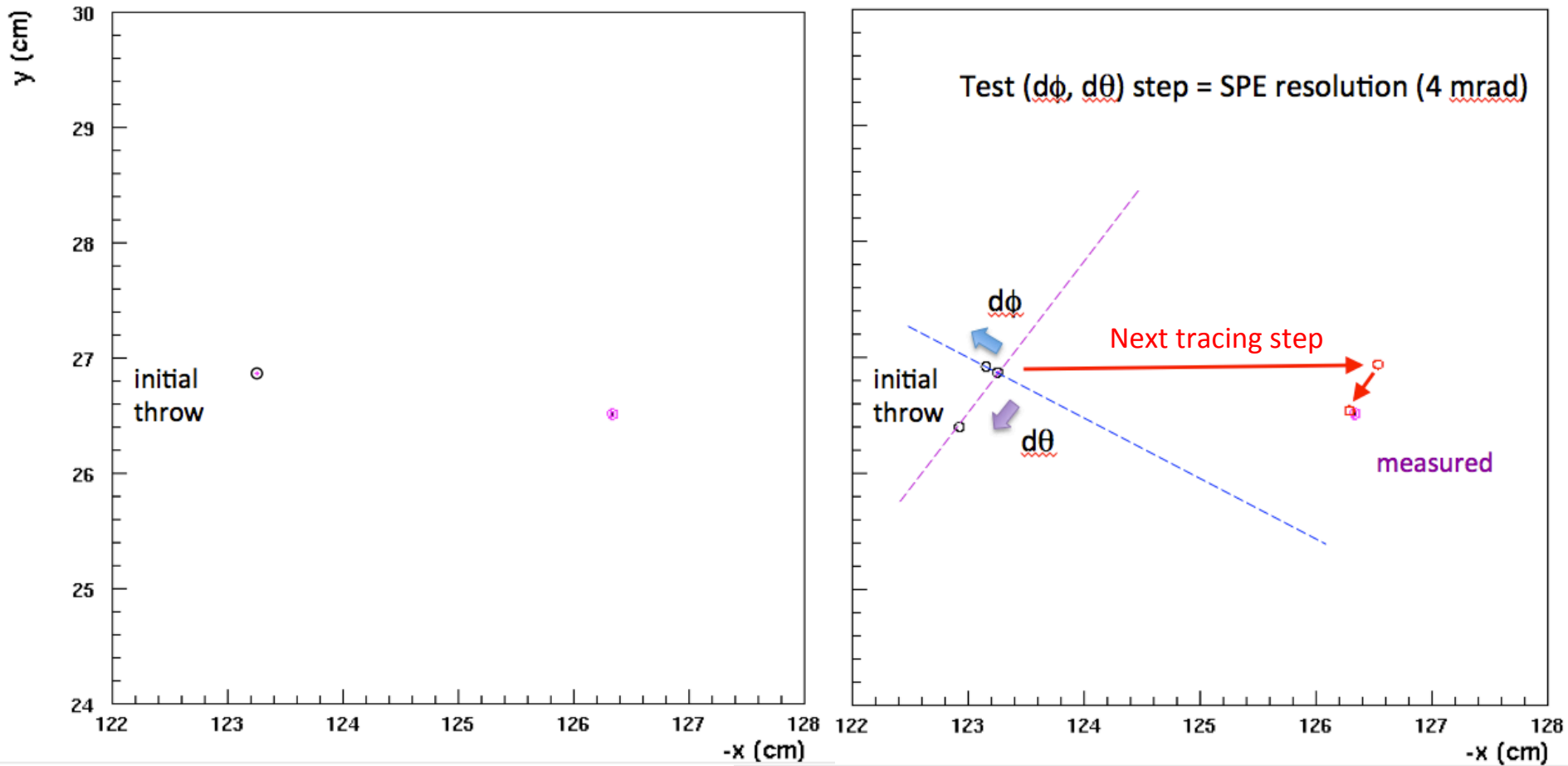
Start by throwing photons for
a given PID hypothesis

Refine the ray-tracing using the most close throw



Ray Tracing

Stop when closer than half expected (angular) resolution



RICH Hipo Banks

Raw data:

"bank": "RICH::tdc", "group": 21812, "info": "digitized bank Ring Imaging Cherenkov"

[FULL, CALIB, DST]

RICH alone information

"bank": "RICH::hits", "group": 22021, "info": "Reconstructed Hits in RICH"

[FULL, MONITOR, CALIB]

"bank": "RICH::clusters", "group": 22022, "info": "Reconstructed Clusters in RICH"

[FULL]

RICH – CLAS12 Particle Matching

"bank": "REC::RICH", "group": 341, "info": "RICH Responses for Particles bank"

[FULL]

RICH Cherenkov Analysis:

"bank": "RICH::hadrons", "group": 22023, "info": "Reconstructed Hadrons in RICH"

[FULL, MONITOR, CALIB]

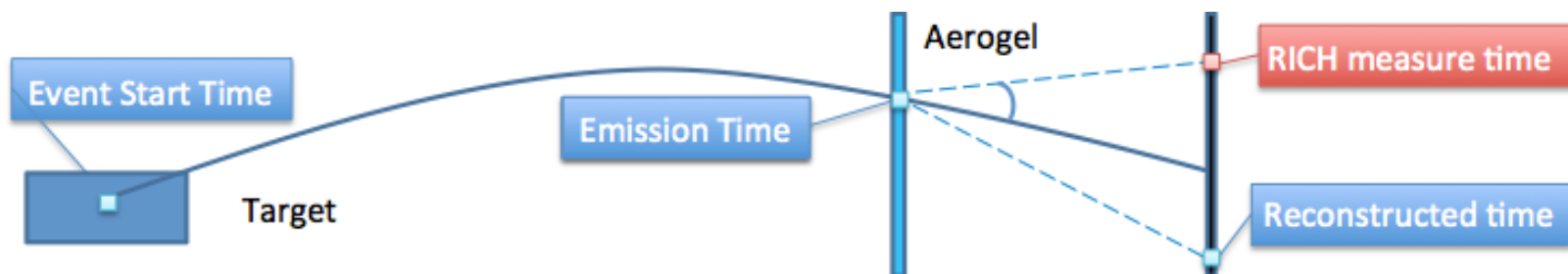
"bank": "RICH::photons", "group": 22024, "info": "Reconstructed Photons in RICH"

[FULL, MONITOR, CALIB]

"bank": "REC::RingCher", "group": 22025, "info": "Reconstructed Cherenov nformation in RICH"

[DST]

RICH: Single Photon Time Analysis



CLAS12 Reconstructed Time and Position:

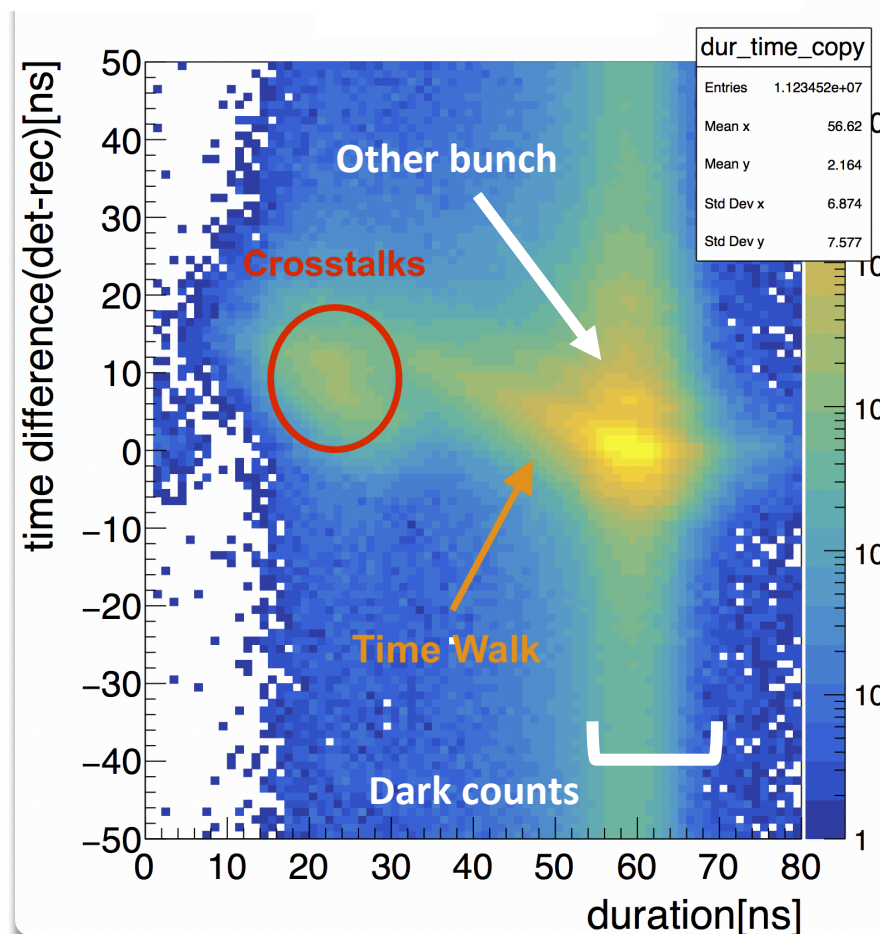
Photons are traced using information from other CLAS12 detectors

RICH Measured Time and Position:

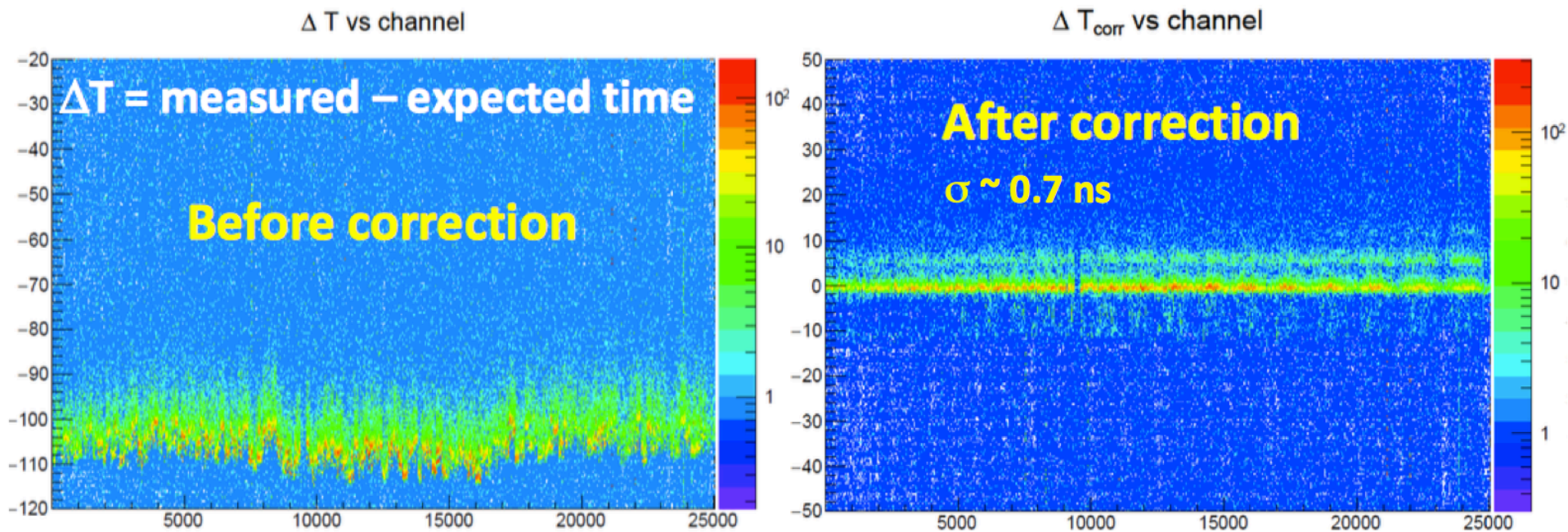
Defined by the RICH DAQ

Good photons should match in time and space

Time analysis allows to separate spurious signals



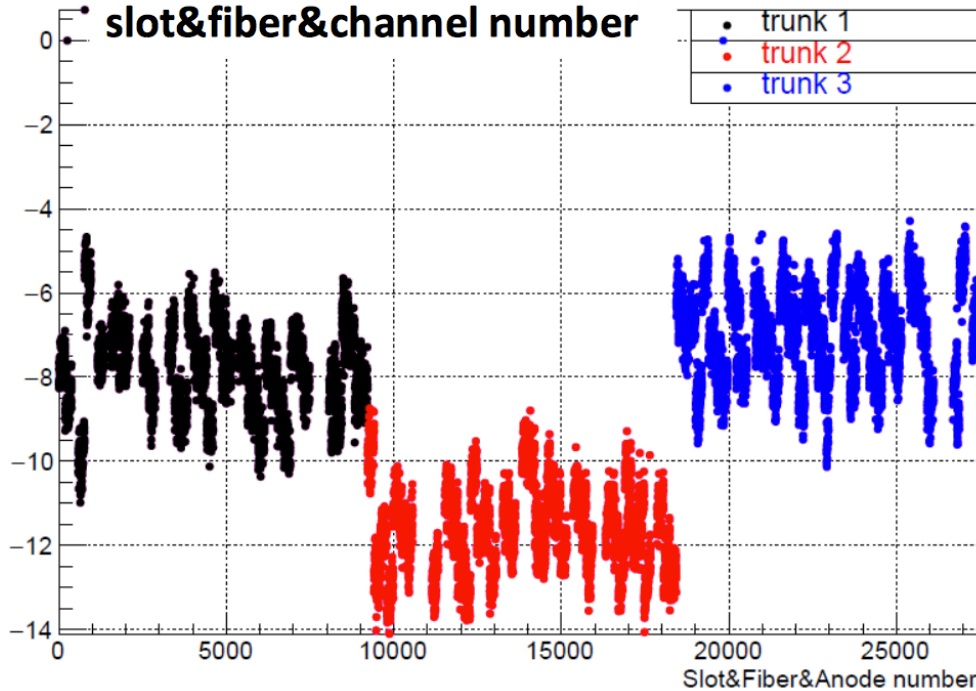
Time Calibration



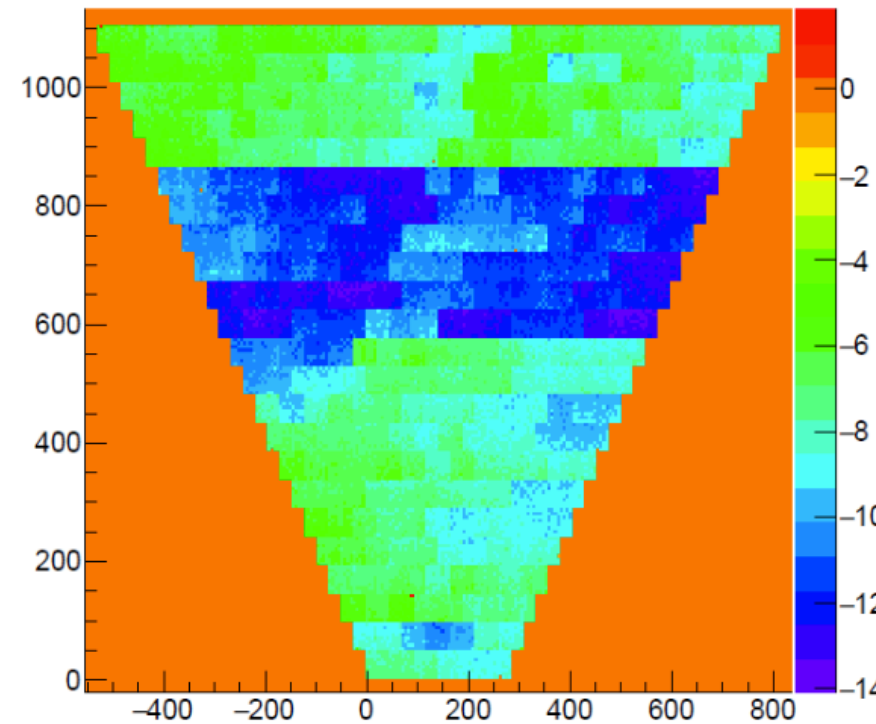
Offsets sv Hardware

Major features could be explained, but no fine tuning achieved

Offsets ordered according to
slot&fiber&channel number



Time offset map



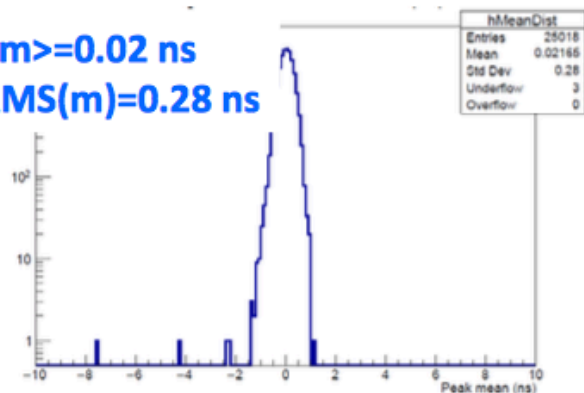
Are time offsets universal?

Run 6288

Calibration from run 6233

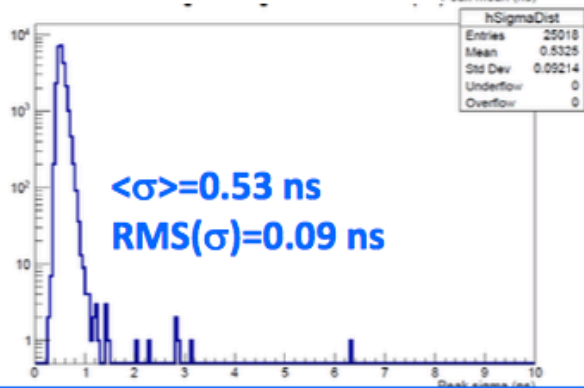
$\langle m \rangle = 0.02$ ns

$\text{RMS}(m) = 0.28$ ns



$\langle \sigma \rangle = 0.53$ ns

$\text{RMS}(\sigma) = 0.09$ ns

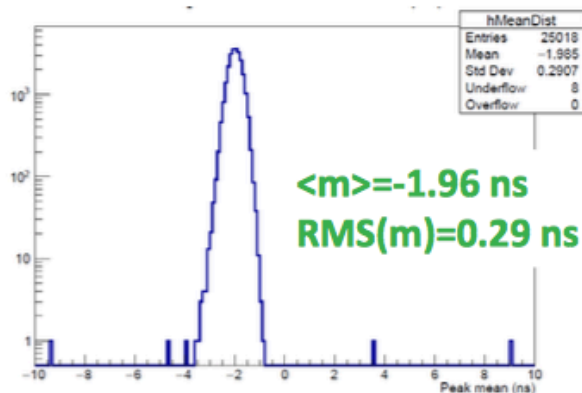


Run 6489

Calibration from run 6233

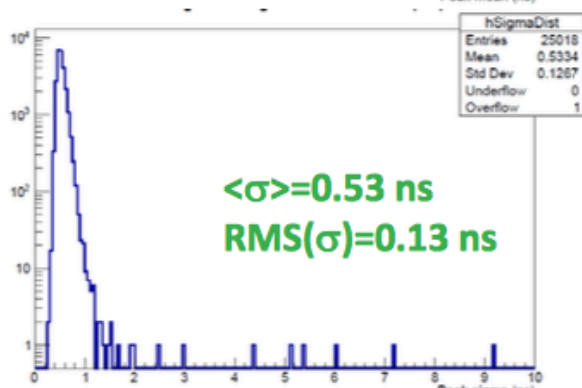
$\langle m \rangle = -1.96$ ns

$\text{RMS}(m) = 0.29$ ns



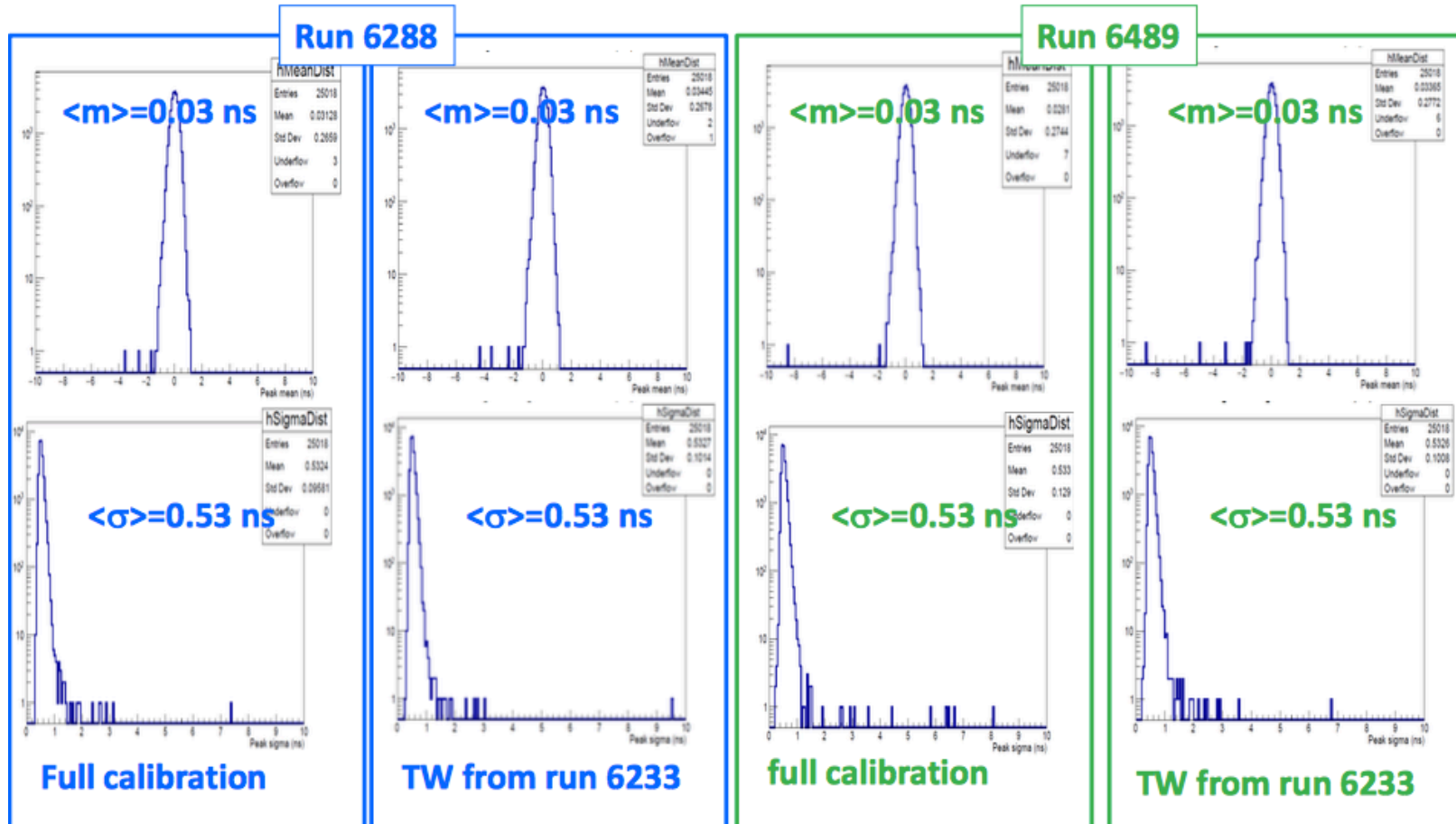
$\langle \sigma \rangle = 0.53$ ns

$\text{RMS}(\sigma) = 0.13$ ns



- 2 ns shift in the timing
- marginal variations in the resolution

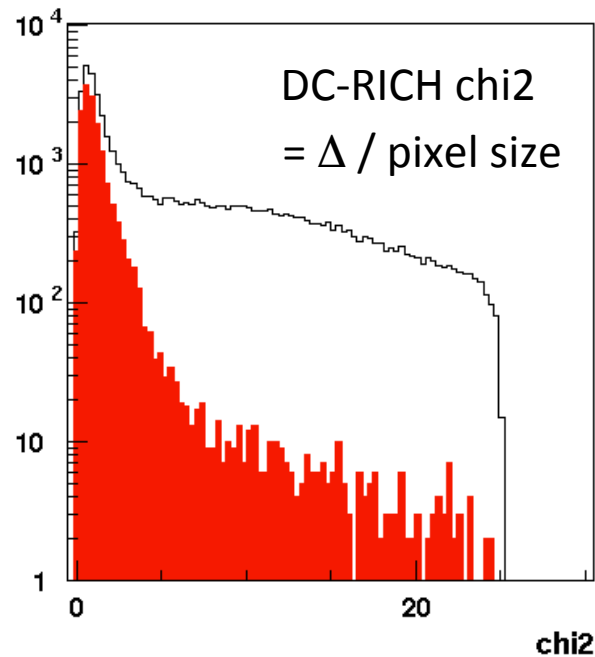
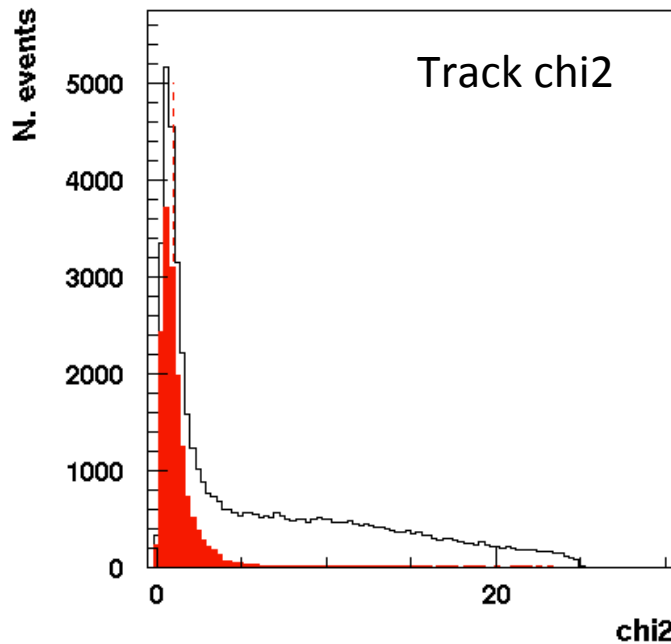
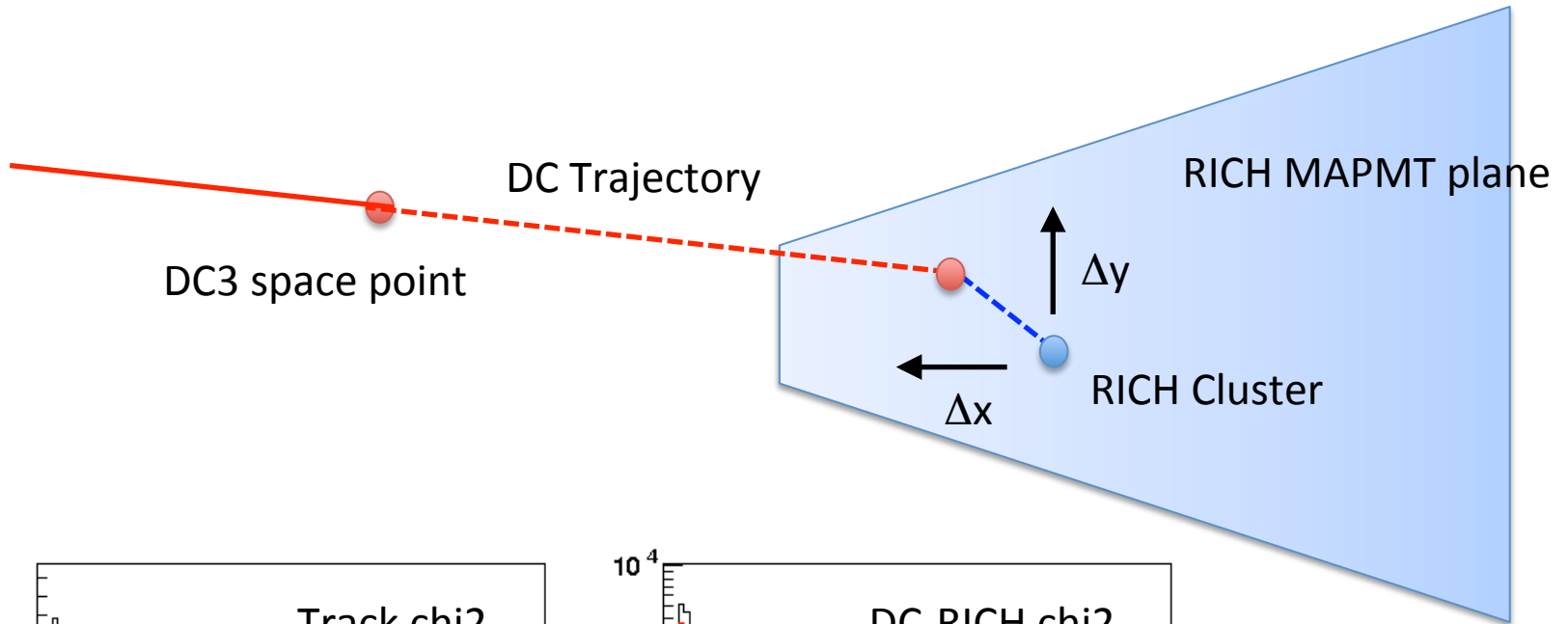
Are time walks universal?



Answer could be YES (as expected)

- need more runs to check

RICH-DC Matching

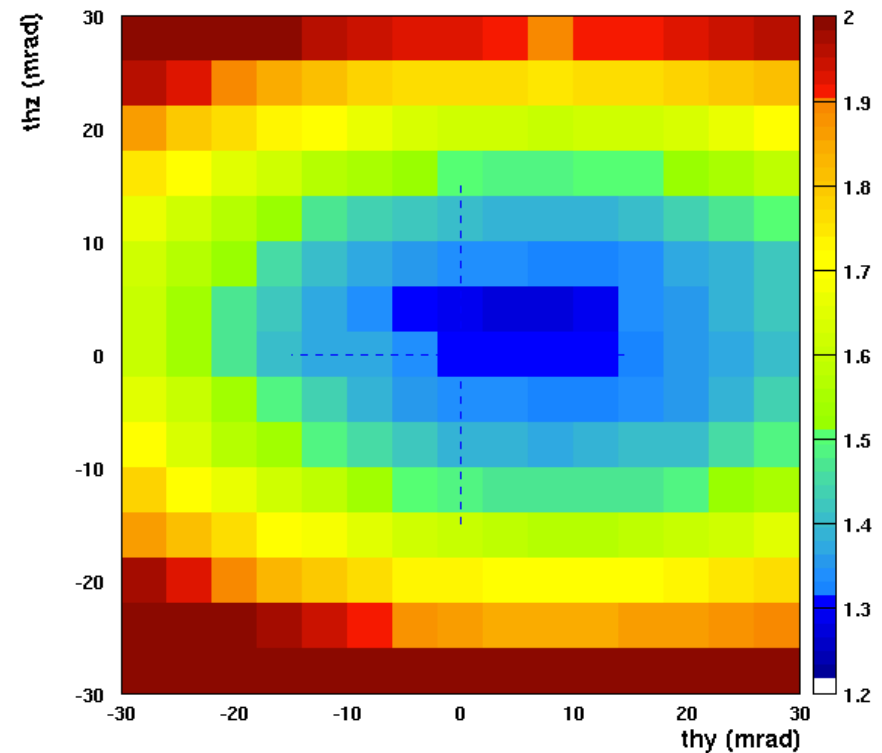
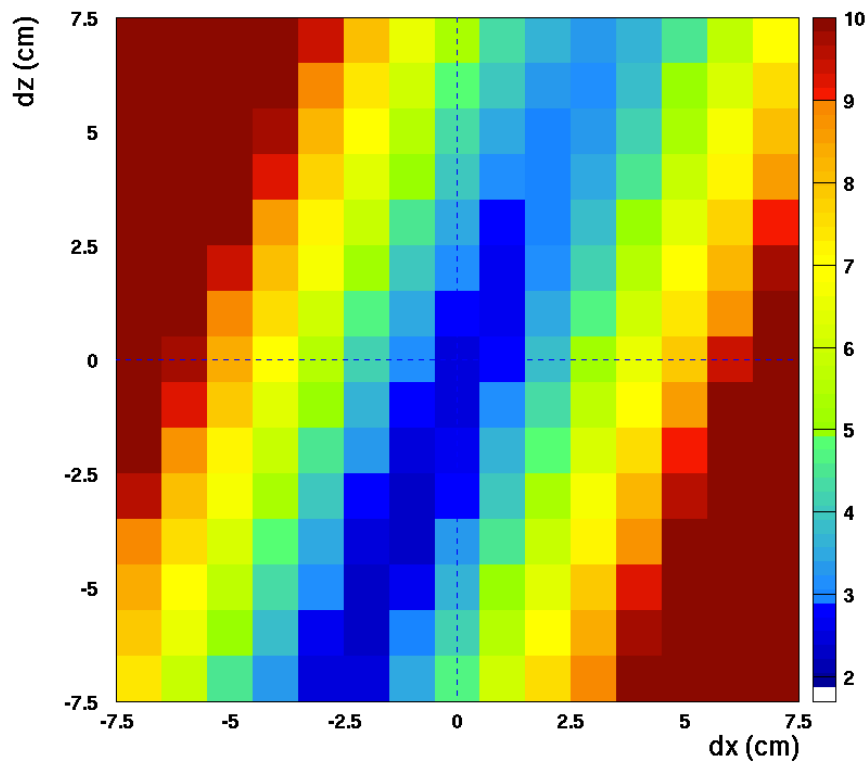


RICH-DC Matching

Run 2467

Average χ^2 in RICH cluster - DC track matching distance

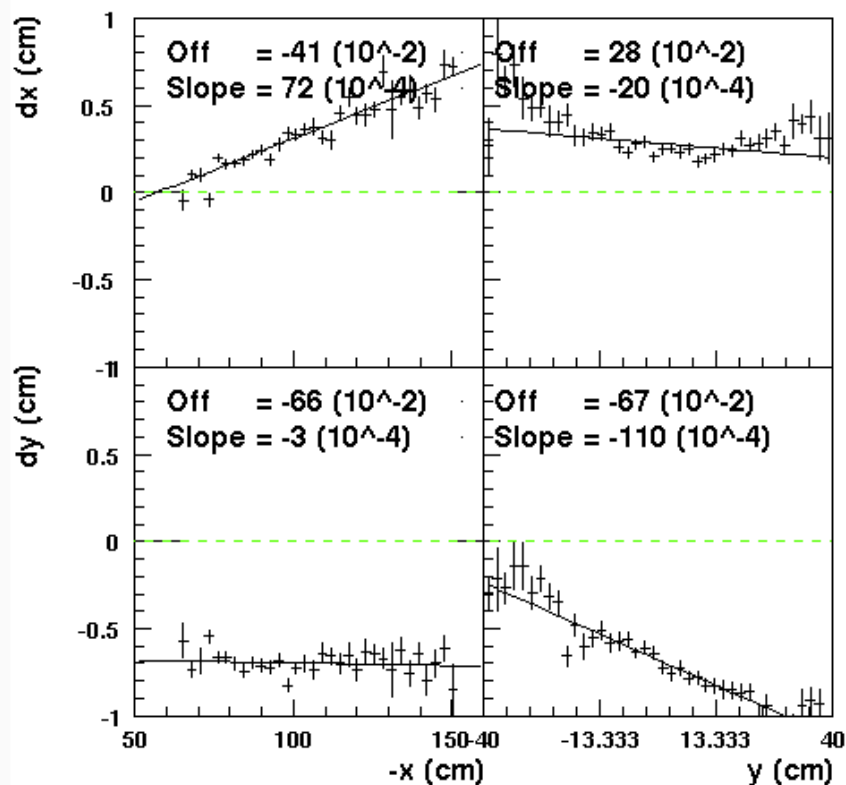
Indication of a preferred PMT plane (RICH) position and orientation in space



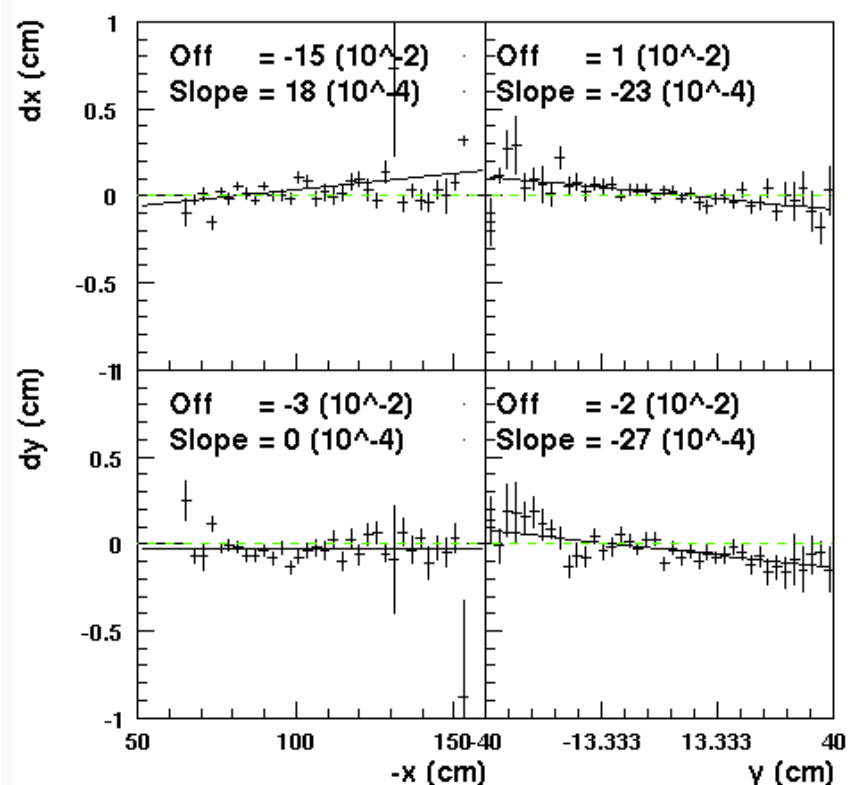
RICH-DC Matching

Run 2467

No misalignment



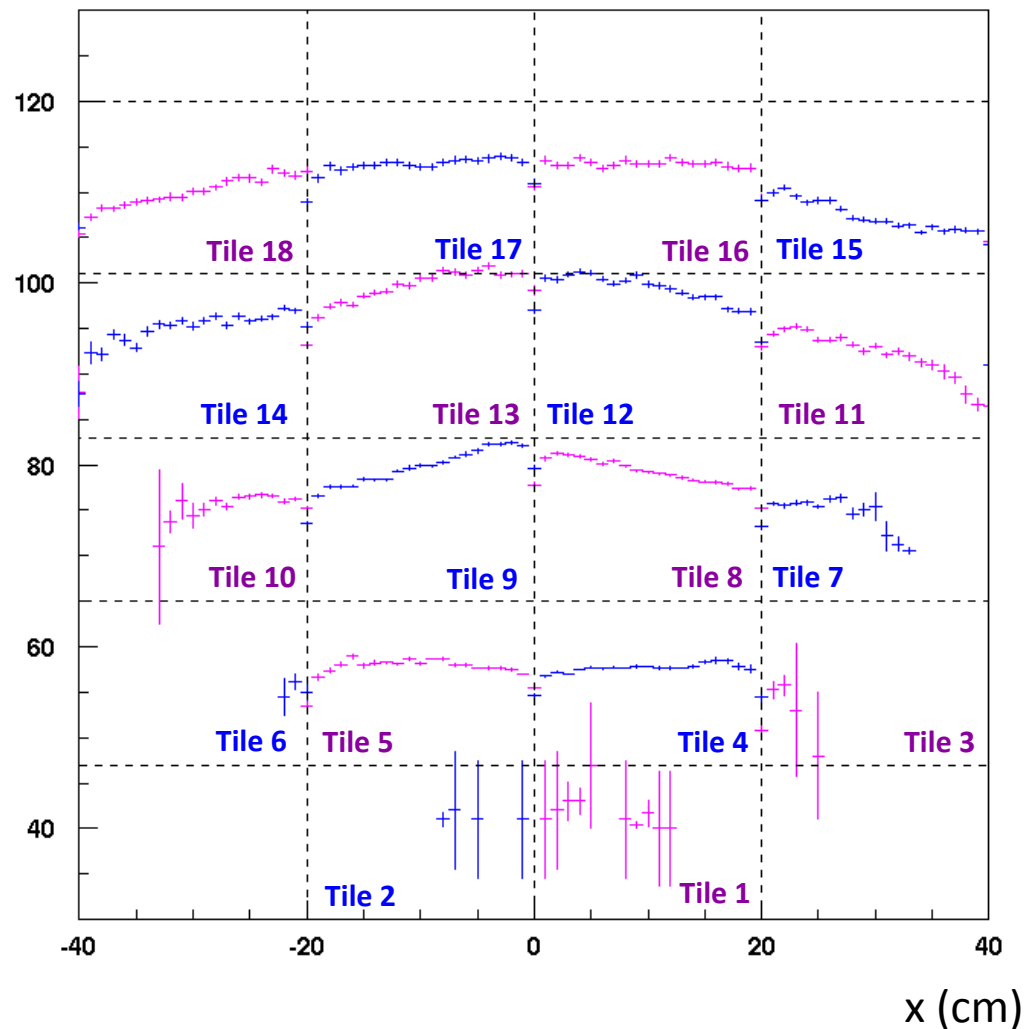
After alignment



Number of Photons

Run 2467, partial alignment

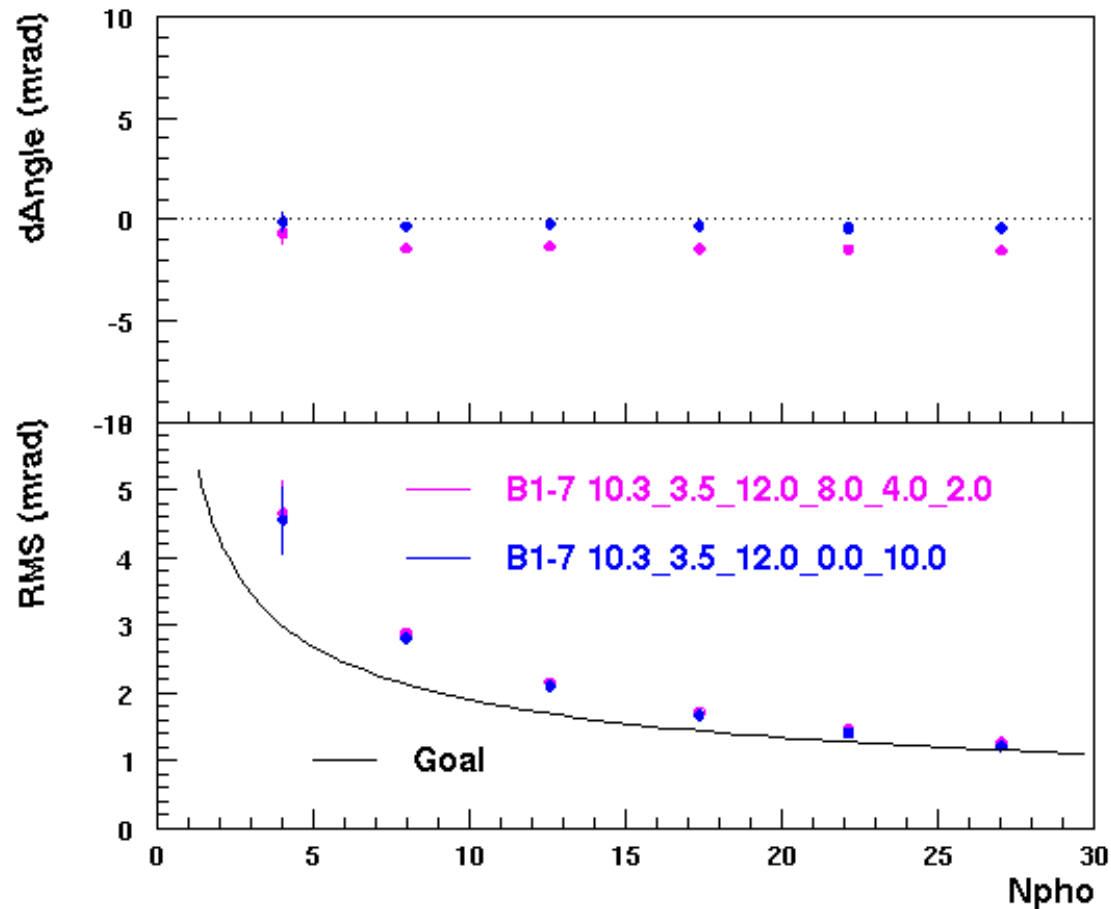
N. Photons – 18
+ aerogel max x



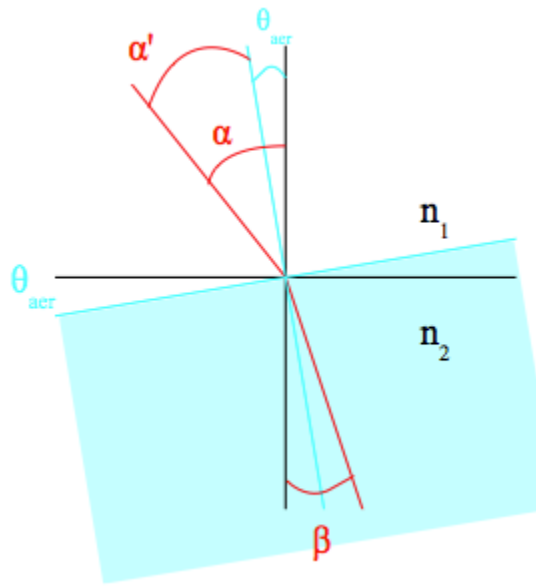
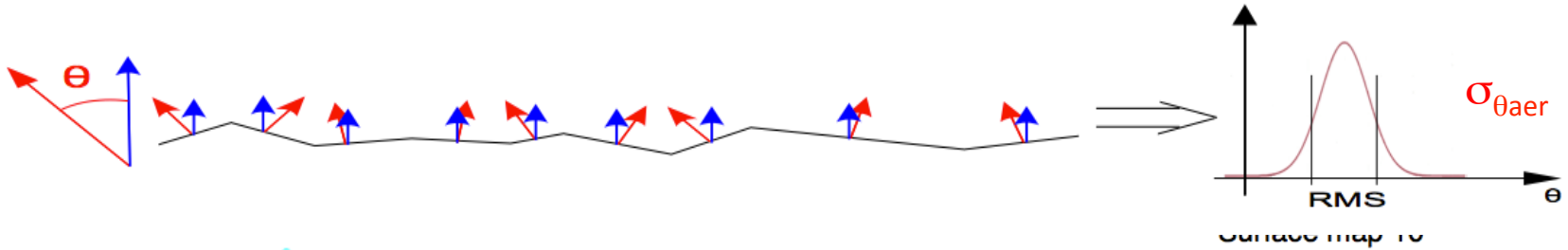
Cherenkov Angle Reconstruction

Run 2467, partial alignment

Direct light not too sensitive on rotations

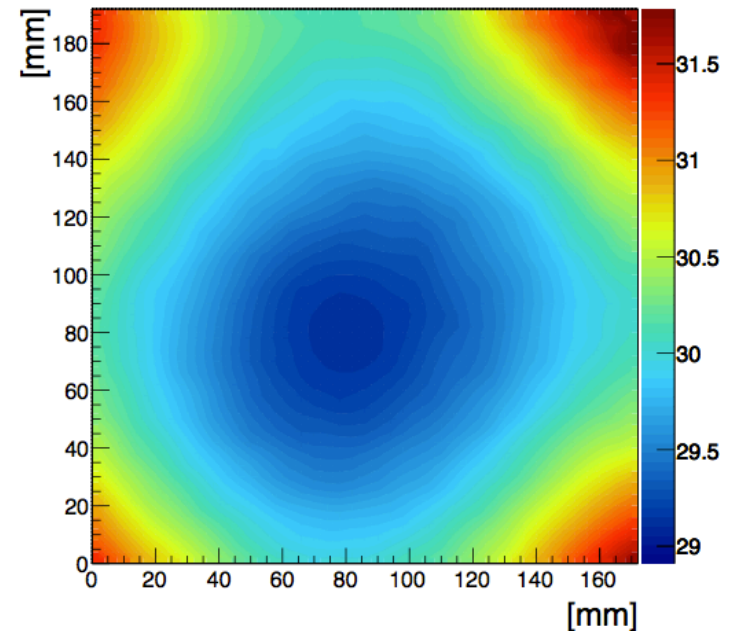


Aerogel Surface Quality



Refraction from a surface
with local normal deviation θ

$$\beta = \vartheta_{aer} + \arcsin\left(\frac{1}{n} \sin(\alpha - \vartheta_{aer})\right)$$



Contribution on light dispersion
at small incident angles

$$\sigma_{\vartheta_{light}} = \left(1 - \frac{1}{n}\right) \cdot \sigma_{\vartheta_{aer}} \approx 0.05 \cdot \sigma_{\vartheta_{aer}}$$

Aerogel Specifications

OPTICAL:

Density	$0.223 < \rho < 0.245$	gr/cm ³
Refractive index	$(n^2 = 1 + 0.438 \rho)$	$1.0477 < n < 1.0523$
Scattering length	$L_{sc} > 43$	mm
Absorption coefficient	$A > 0.95$	

MECHANICAL:

No bubbles, cracks; chips limited to less than 1 % area

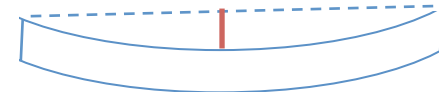
Side to side length variation $\Delta L_{side} < 0.25$ mm



Tile to tile thickness variation $\Delta H_{tile} < 1.5$ mm

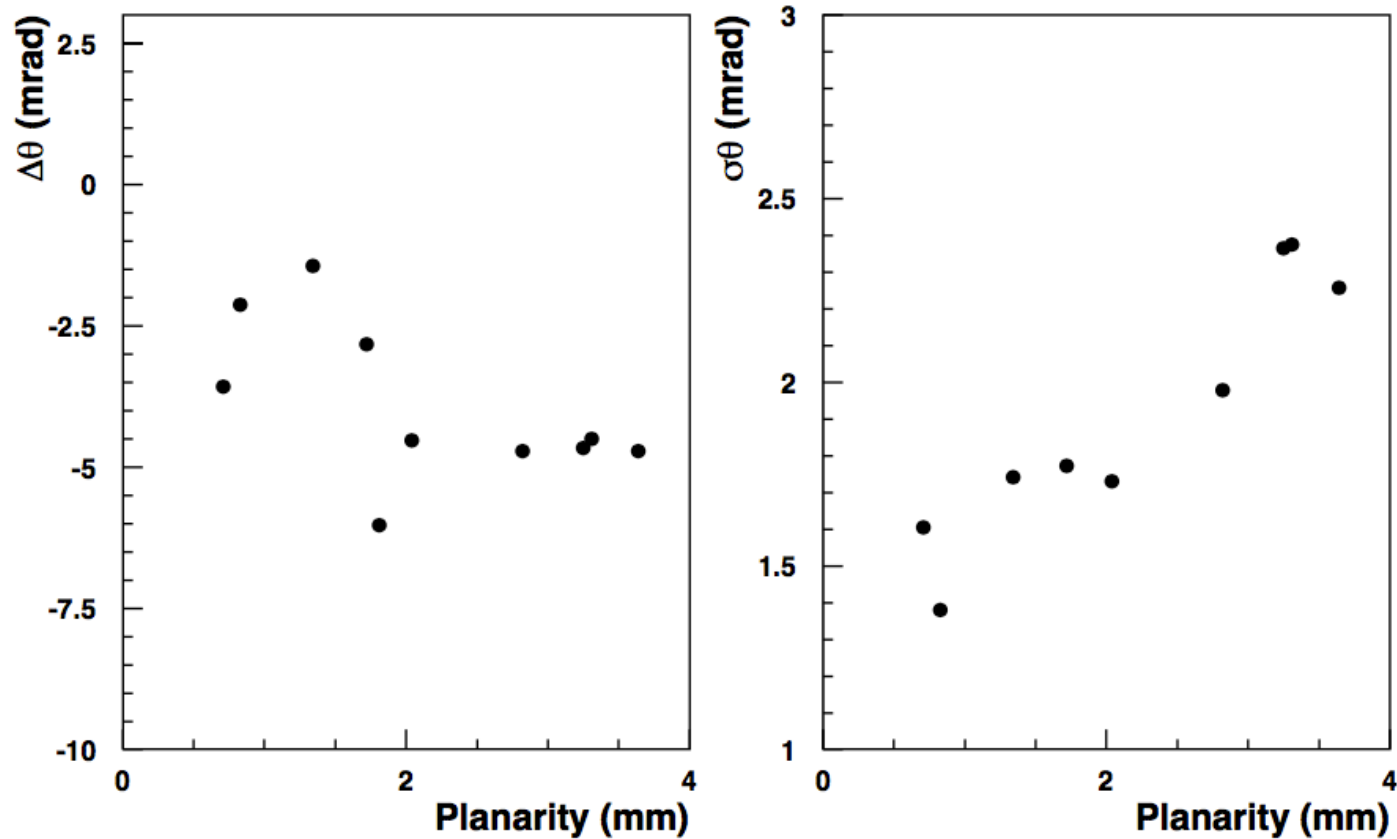


Surface planarity $\Delta S_{surf} < 1$ % of lateral side



Resolution vs Planarity

Run 2467, partial alignment



Response to Electrons

Run 5038 with
Un-calibrate time and partial alignment
(Aerogel Layer 0 , Tile 12)

Electron as identified by EB

Can not be distinguished from pions

Average Cherenkov angle in the event

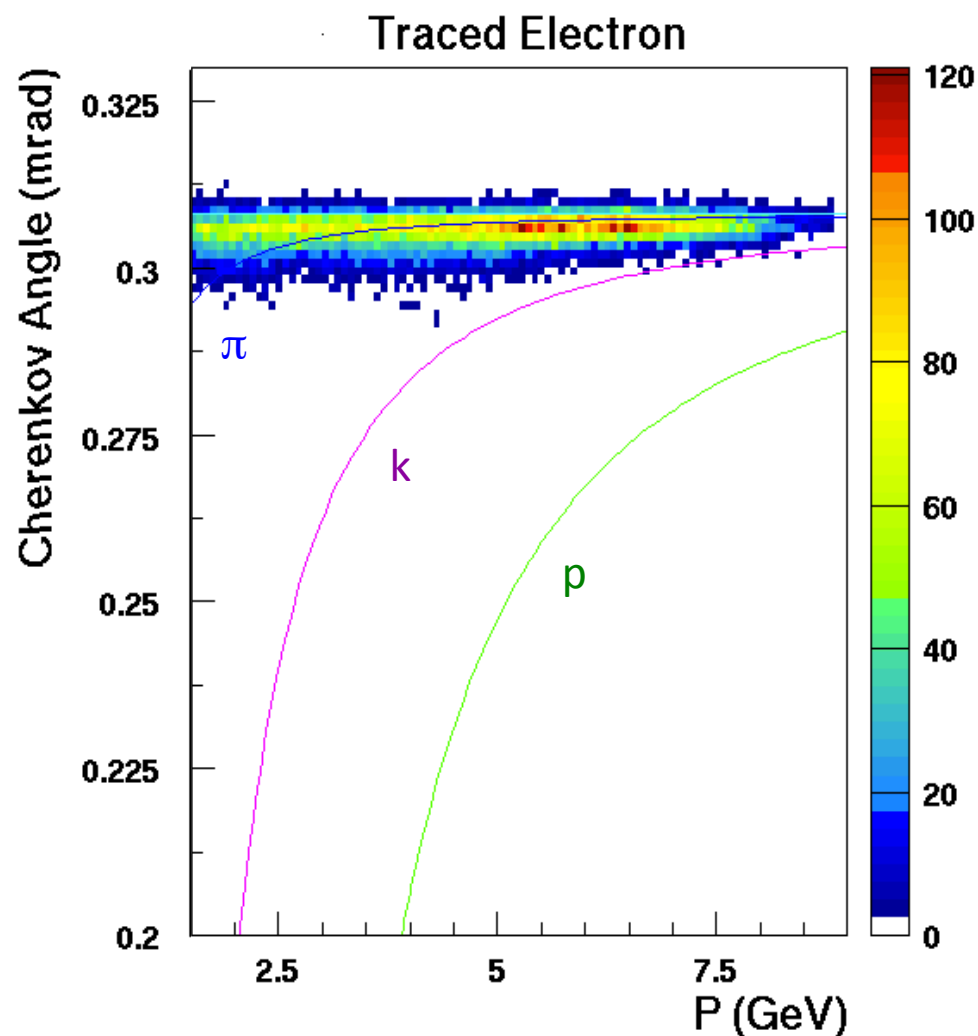
for each photon-hit:

RICH-CLAS12 time matching
(measured in RICH vs tracked in CLAS12)

single-photon angles within physics boundaries
(from particle momentum)

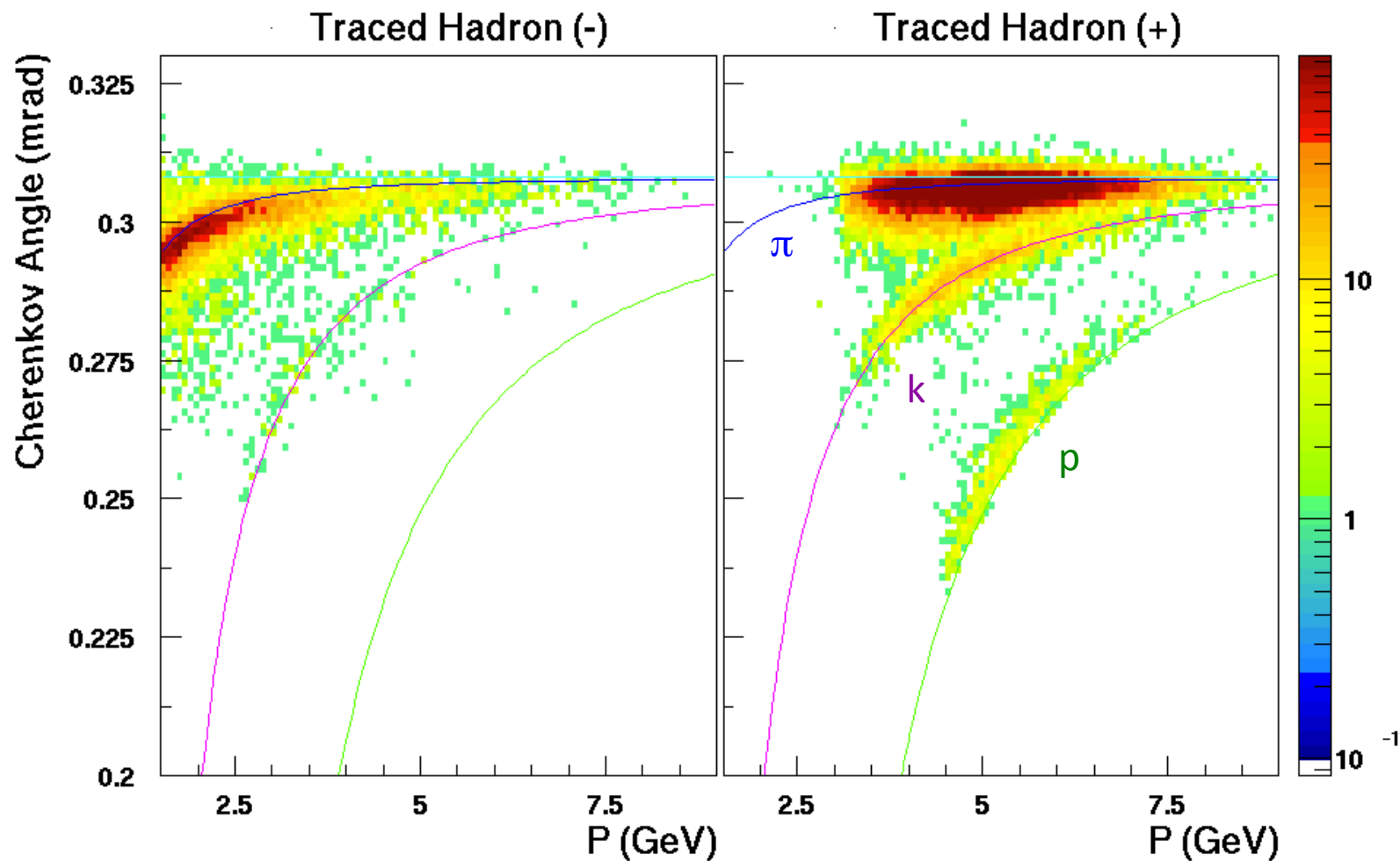
pion guess for starting throws
(only initial values, secondary bias on solution)

no other hypotheses



Response to Hadrons

Run 5038 with un-calibrated time and partial alignment (Aerogel Layer 0, Tile 12)



Conclusions & Outlook

RICH reconstruction software is ready for mass production

Stress tests

Reconstruction and calibration of a large data set

Study misalignment:

A preliminary study has been done, need to be refined and extended to the spherical mirror

Refine optical surfaces

Aerogel non-planarity

Mirror efficiency / MaPMT efficiency

Refine code structure

`eu.mihosoft.vrl.v3d` → `org.jlab.geom.prim`

Perform PID

Basic calculations are already available, no outputs (on purpose)