

RICH simulation for Upgrade 2

LHCb-UK meeting

Introduction

- For the RICH system in Upgrade 2, many options are being considered
 - These are categorized in the scoping document
 - These may evolve as more information regarding photon detectors and other components, comes to light.
- In principle, the programs can be tailored for simulating each of these options in detail. However, it may not be practical to proliferate the number of options to pursue.
- The RUN5 simulations are based on the software developed for RUN3 in recent years.
- This presentation:
 - Description of the simulation framework to study the various options
 - Results in terms of resolutions and yields, from some of the options
 - Caveats: Issues that beset the simulation studies
 - Plans

Overview of software used

- For simulating the RICH system in Upgrade 2 :

- 'Detector' package for creating detector descriptions
- 'Gaussino + Gauss' for detector simulations
- Developing digitization software
- Starting to set up the reconstruction sequence to process the simulated data

All done within the DD4HEP framework.

All the software developed for RICH in RUN5 so far, are available in various MR.

- In parallel to these :

- Different optical configurations for the RICH system are starting to be explored
- The usage GPUs is being planned for RUN5
 - *Example: usage of Opticks + OptiX for simulations*
- Software for RICH in RUN4 is being developed. Some of these would be useful for RUN5 also

Not covered today

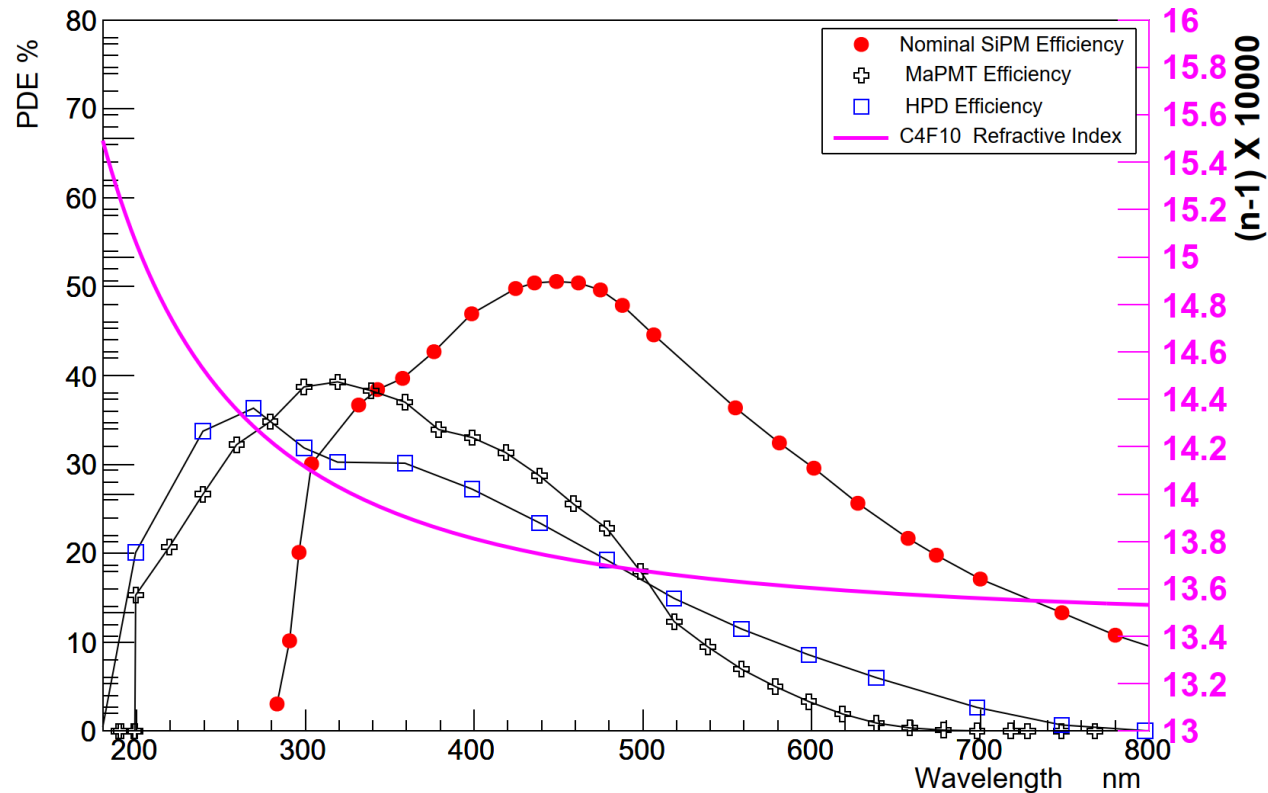
Detector configurations

- The 'Detector' package enables to maintain multiple geometry versions in the same branch.
For the RICH, for now, three labels are created as the versions for RUN5, along with the corresponding folders. (This is in addition to the three that is created for RUN3).
 - (a) **Rich_Run5_v3**: SiPM + geometry update , for now.
This presentation: Optics update for RICH1 as described in the FTDR.
 - (b) **Rich_Run5_v4**: SiPM and nominal Run3 geometry as indicated in the FTDR, for now.
 - (c) **Rich_Run5_v5** : Facilitate RICH + TORCH studies.
TORCH envelope and master volumes created inside RICH2
- Known 'unknowns':
 - Hardware structure to install photon detector assemblies in the RICH for Upgrade 2
 - *For now, using the same structure as that in RUN3: with PDM , ECR and ECH etc.*
 - *For now, each 'MaPMT' volume is repurposed to use as SiPM*
 - *For configuring 1 mm pixel size :*
Use 25 X 25 pixels in 'R-type MaPMT' and 50X50 pixels in 'H-type MaPMT'.

Detector configurations

- Large magnetic shielding structure in RICH1 :
 - *For now, removed in 'Rich_Run5_v3', to study potential increases in Mirror ROC*
- Properties of detector components :
 - *Minor changes in the inputs in recent years for RICH1, after the FTDR studies.*
In mirror reflectivities, properties of quartz, optics etc.
- Photon detectors:
 - *Started with SiPM, as this was used for the FTDR studies.*
 - *Usage of MCPs : [Presentation today, from Lais](#)*
- PDE for SiPM:
 - *Many tables were received (from Rok. et.al.) based on developments at FBK*
 - *For now, plan to use a 'nominal table'*

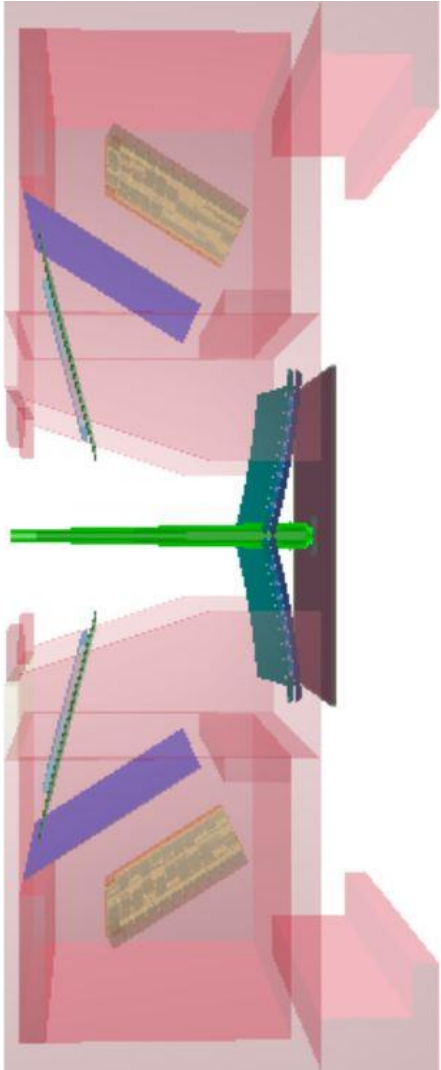
Photon detector : SiPM



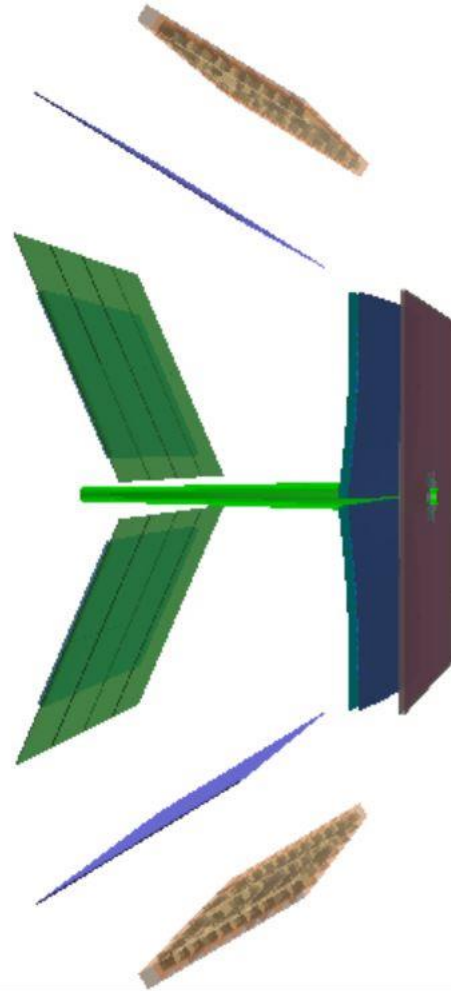
- SiPM configurations:
 - For now, using 1 mm pixel size everywhere
 - ❖ micro-lensing planned for the future
 - ❖ Other pixel sizes are planned to be configured
 - Wavelength cuts, used so far :
 - ❖ 400 nm, 300 nm and 180 nm
 - ❖ The 180 nm cut, corresponds to having 'no cut'
- No cut applied for MaPMT configurations.

■ **Red Curve** : 'Nominal SiPM' : This is used as a 'baseline', for now.

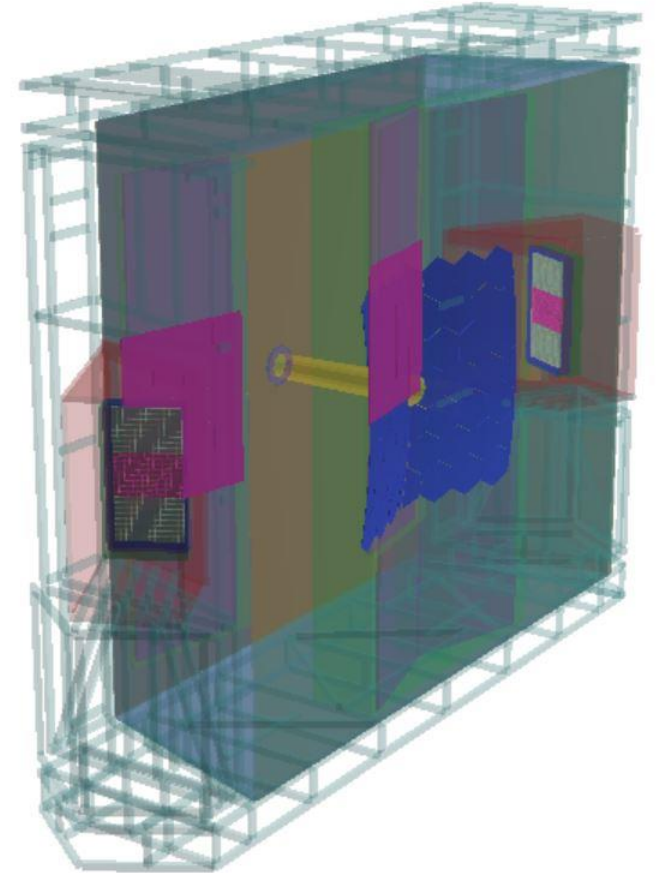
RICH pictures : DD4HEP



RICH1 : Nominal RUN3 optics
used for RUN5 studies ([Rich_Run5_v4](#))



RICH1: Upgraded RICH1 optics as in the FTDR
([Rich_Run5_v3](#))

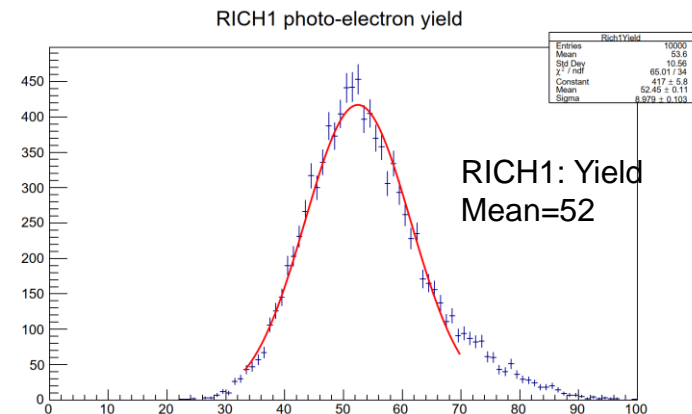
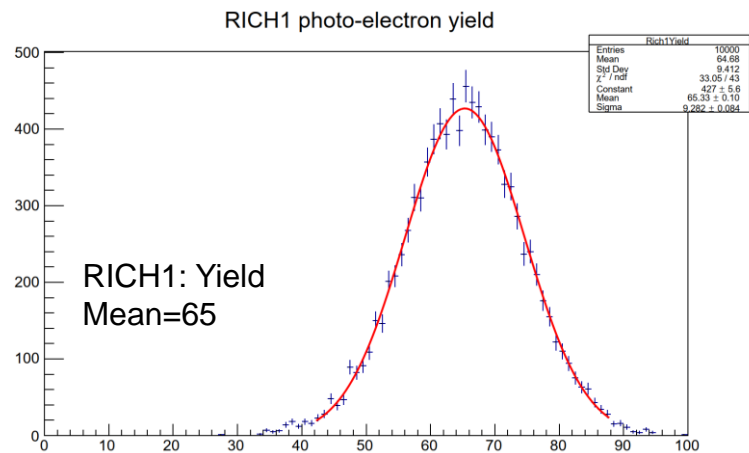
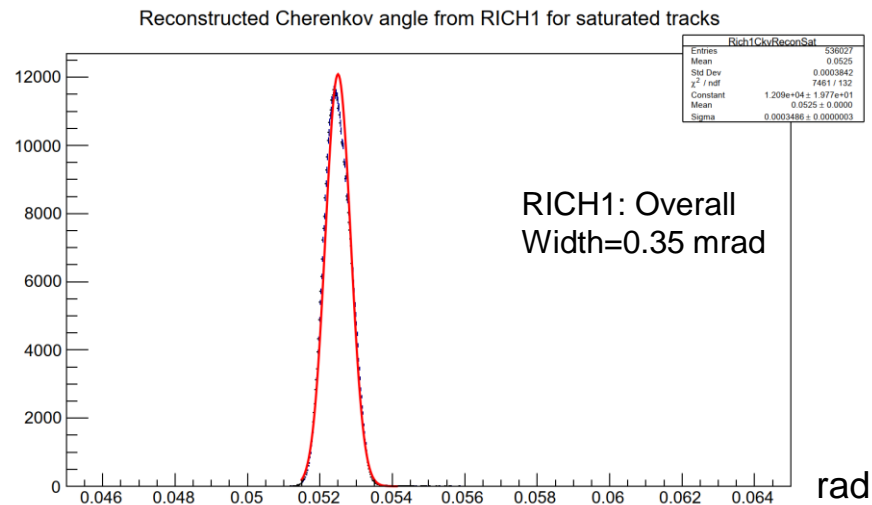
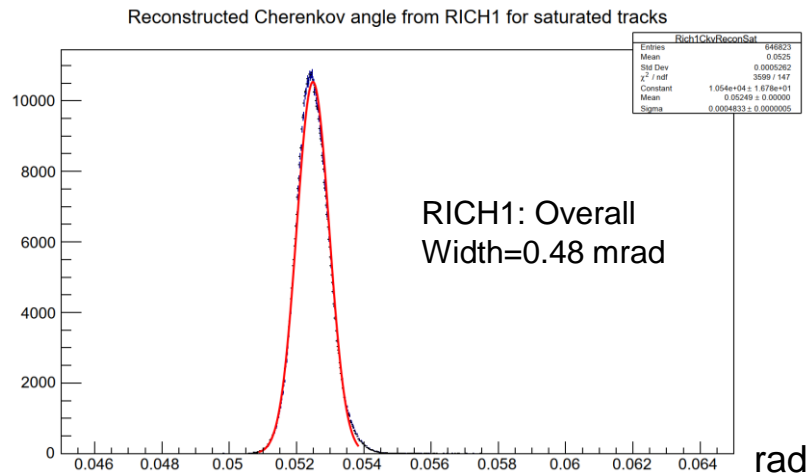


RICH2: Nominal RUN3 optics
used for RUN5 studies

Simulation configuration

- For the RICH system, using the detector configurations listed in the previous pages.
*For all other LHCb detectors, the 'full RUN5-setup' was not available in master branches.
Hence using the 'default RUN3' configuration.*
- Gauss and Gaussino:
 - RICH system is used with the latest available versions of : VP, UT, FT, Ecal and Hcal
 - Using default values for gas pressure, temperature etc. (Gauss was not using the full 'conditions database' features).
 - Usage of SiPM with large number of channels and the introduction of TDC for RICH, requires a 64-bit channel ID
This new feature is planned to be implemented.
 - The full simulation of the readout in Boole requires simulated data with spill-over. This is not yet supported in Gaussino.
 - RICH in RUN3 vs RUN5 :
 - ❖ RUN3 simulations based on DD4HEP, kept 'stable' in a package named *GaussPhotonics*
 - ❖ New features needed for RUN5 introduced in a package named *GaussOptix*
 - Today: Resolutions and yields using particle gun events in the best regions of the RICH system.
Hit distributions from running PYTHIA minimum bias events in nominal RUN3 beam setup.

RICH1 : resolutions and yields with SiPM



Nominal SiPM, 300 nm wavelength cut-off,
Nominal Run3 geometry

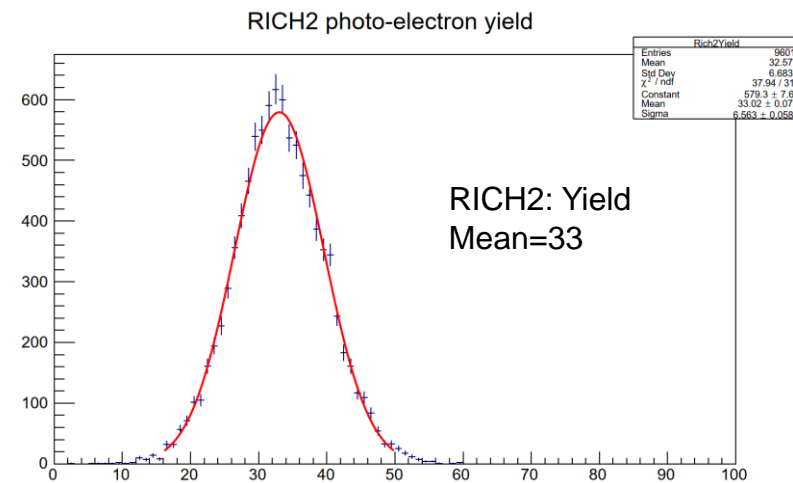
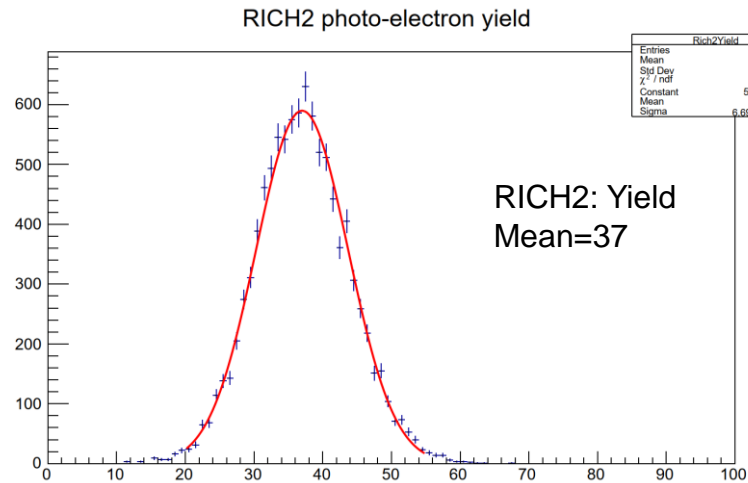
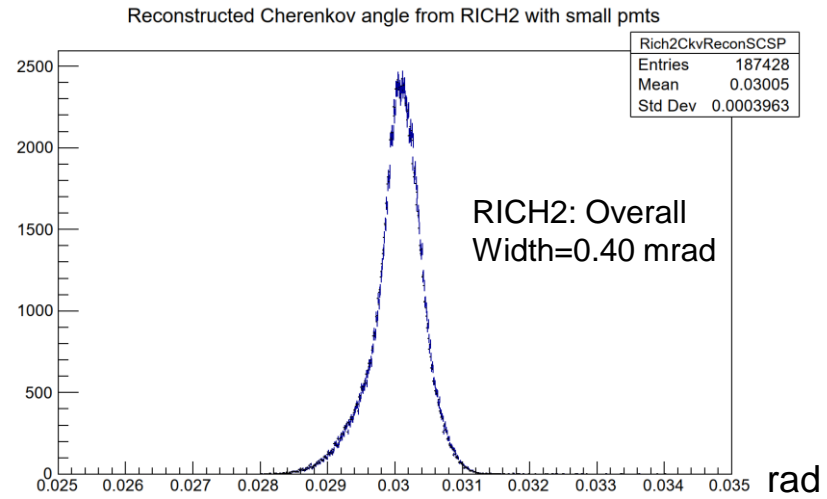
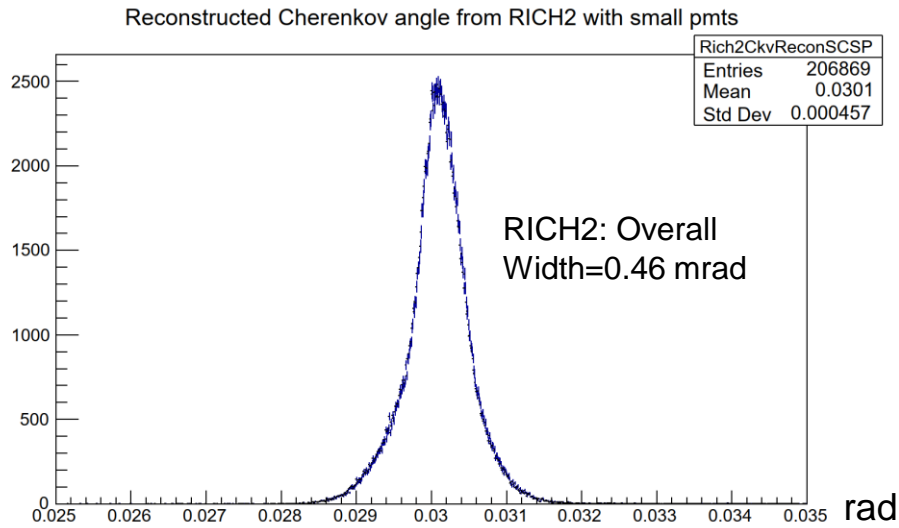
Nominal SiPM, 300 nm wavelength cut-off,
Upgraded RICH1 geometry as in FTDR

- Simulated data reconstructed at the end of Gauss

RICH1 Resolutions : Summary

RICH1 SiPM Nominal PDE 400 nm cut in photon wavelength	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.39	0.11	0.37	0.16	33
Upgraded Optics (FTDR)	0.24	0.11	0.13	0.16	27
RICH1 SiPM Nominal PDE 300 nm cut in photon wavelength	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.48	0.28	0.37	0.17	65
Upgraded Optics (FTDR)	0.35	0.28	0.13	0.16	52
RICH1 SiPM Nominal PDE No cut in photon wavelength	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.50	0.36	0.37	0.17	70
Upgraded Optics (FTDR)	0.41	0.38	0.13	0.16	57

RICH2 : resolutions and yields with SiPM



Nominal SiPM, No wavelength cut-off
RICH2: RUN3 nominal geometry

Nominal SiPM, 300 nm wavelength cut-off
RICH2: RUN3 nominal geometry

All plots with 1 mm pixel size

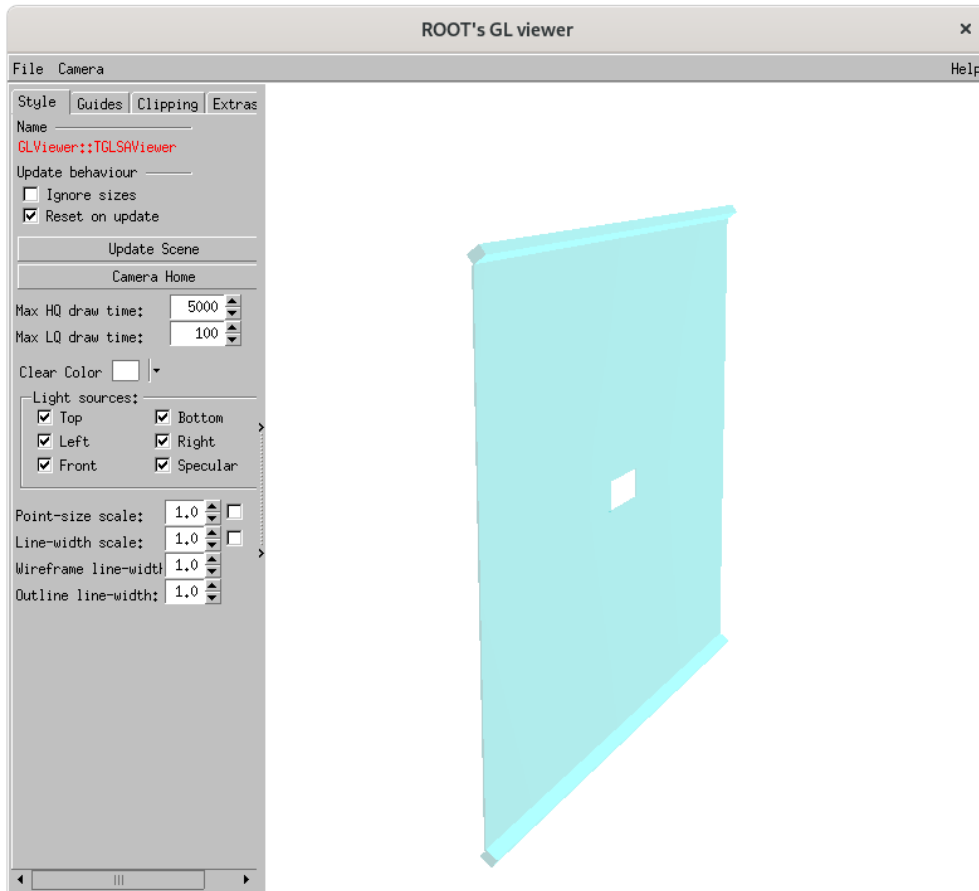
RICH2 Resolutions : Summary

RICH2 Nominal RUN3 geometry SiPM : Nominal PDE	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
400 nm cut in photon wavelength	0.38	0.09	0.35	0.07	16
300 nm cut in photon wavelength	0.40	0.19	0.36	0.07	33
No cut in photon wavelength	0.46	0.29	0.36	0.07	37

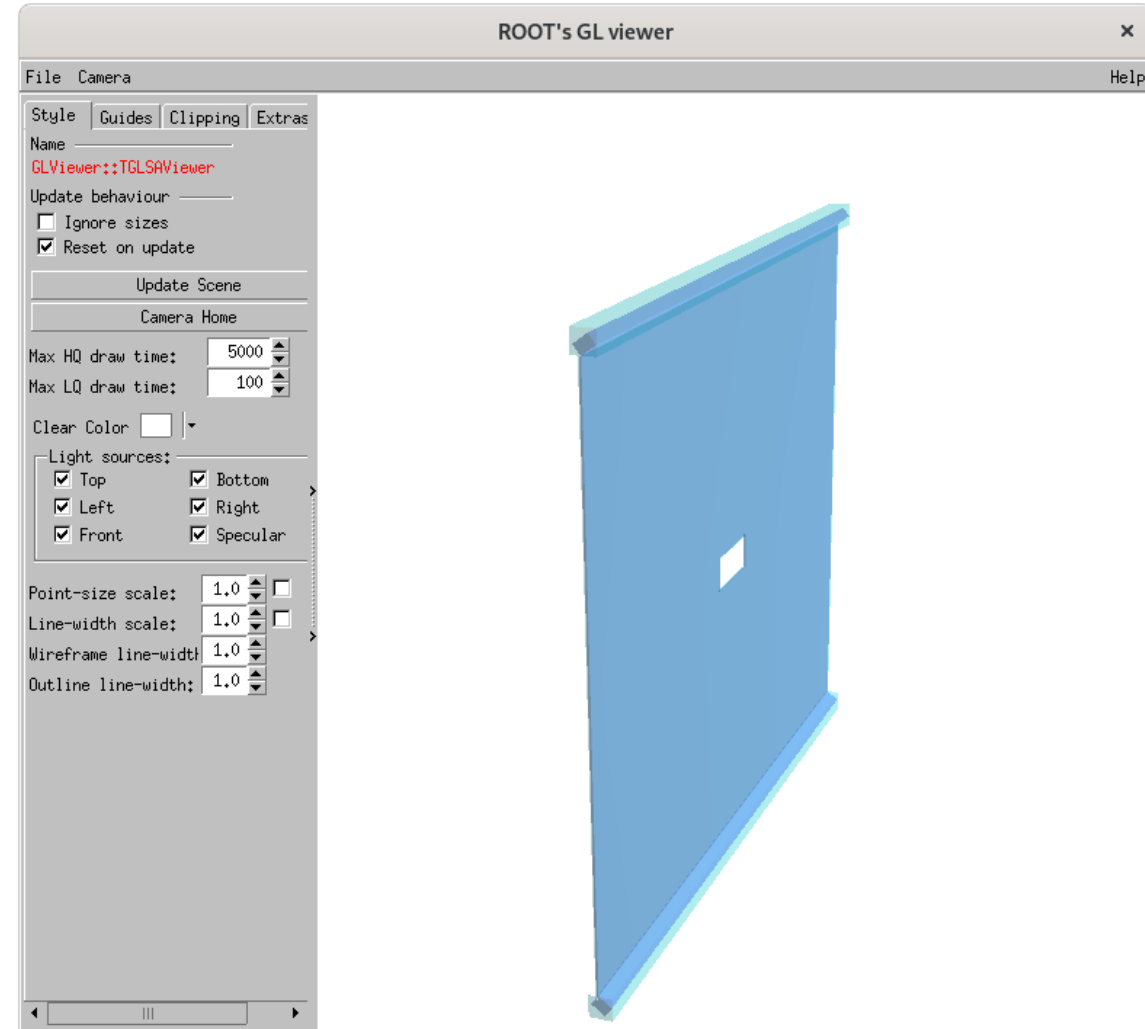
- Similar results for RICH1 and RICH2 in the RUN3 configuration, are listed in backup pages

TORCH Support

- The dimensions and shape of the TORCH master volume, were provided by Michal Kreps.
- This contains the quartz plate region and the focusing blocks.
- The TORCH envelope was created based on this information



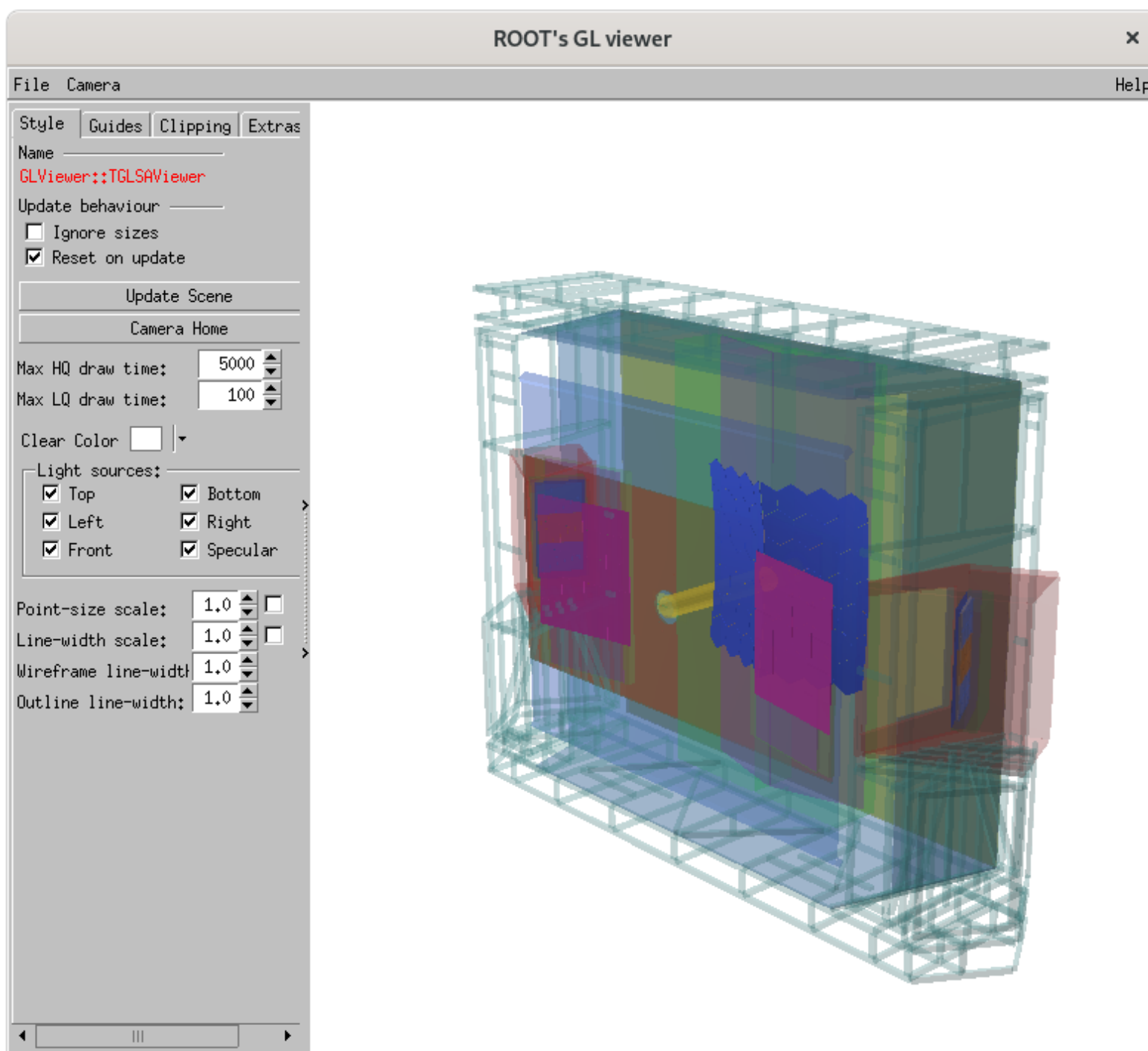
'TORCH master' volume



'TORCH master' inside the 'TORCH envelope'

TORCH inside RICH2

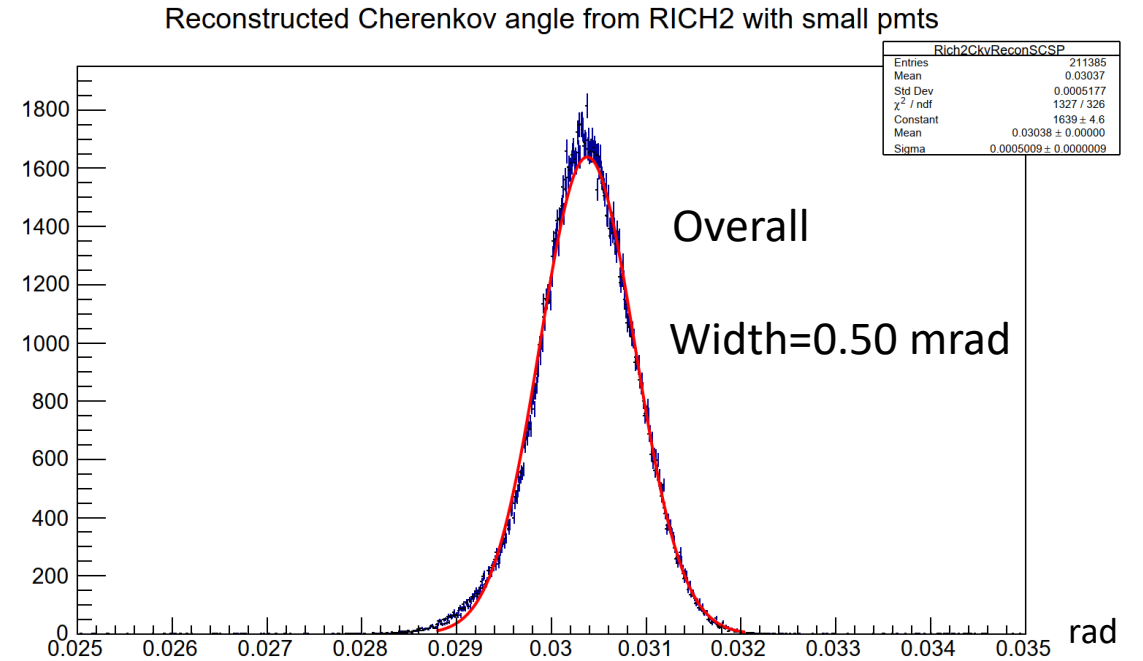
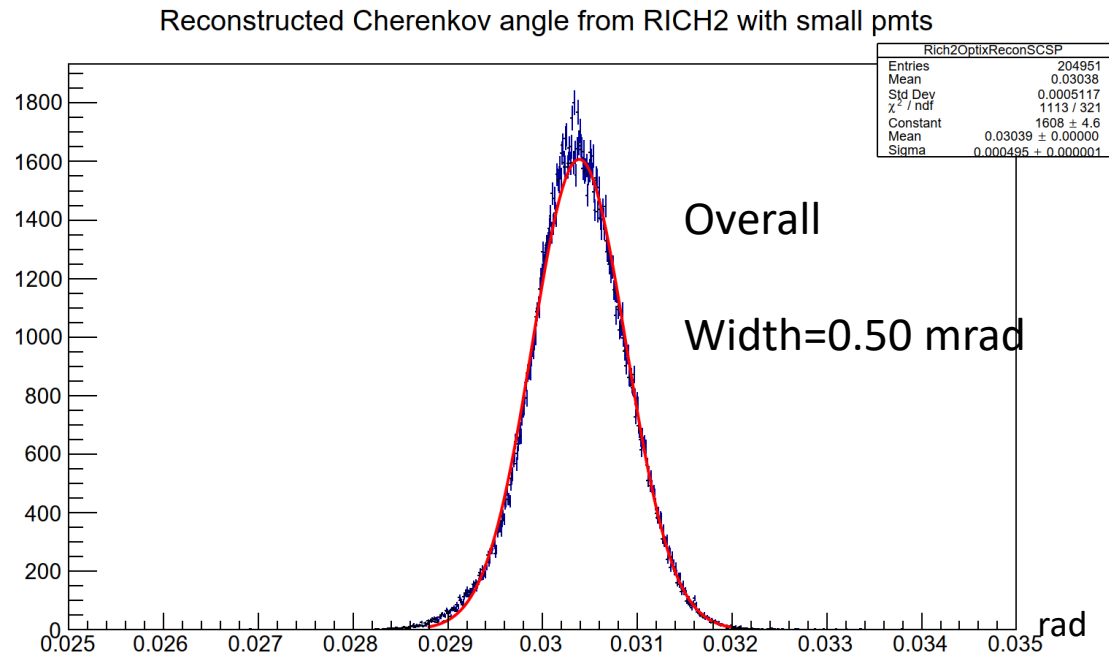
- In order to get the space for the TORCH, many structures inside the RICH2 were sliced off.
 - Upstream end of the RICH2 gas volume
 - The envelopes of the gas enclosure at the two lateral sides.
 - The 'beam tube lock' at the upstream end was removed.
 - The RICH2 entrance window was cut the top and bottom to get space for the TORCH focusing block.
 - The upstream edge of the 'flat mirror support' was also sliced off.
- The RICH2 optics was kept unchanged.
 - ❖ *More pictures in backup pages*
- For now, TORCH envelope and master volumes are made of 'air'.
Hence very little effect from material budget, for now.



RICH2 with
TORCH envelope

Rich_Run5_v5 version

RICH2 resolutions : TORCH envelope

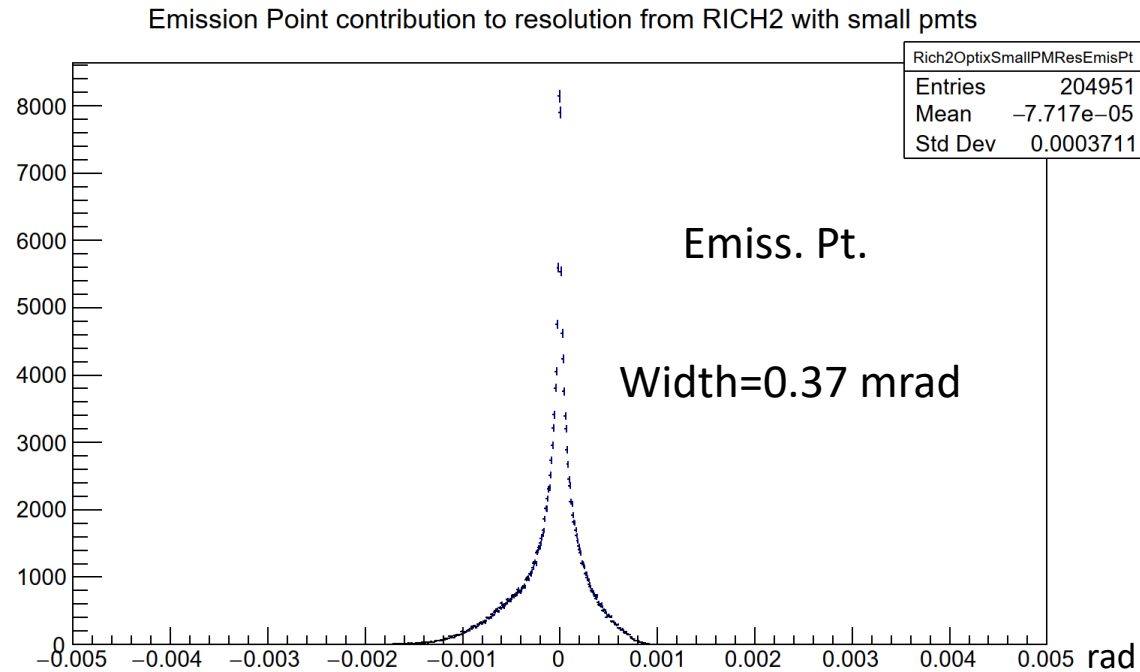


RICH: **Rich_Run5_v5** : RICH2 with TORCH envelope

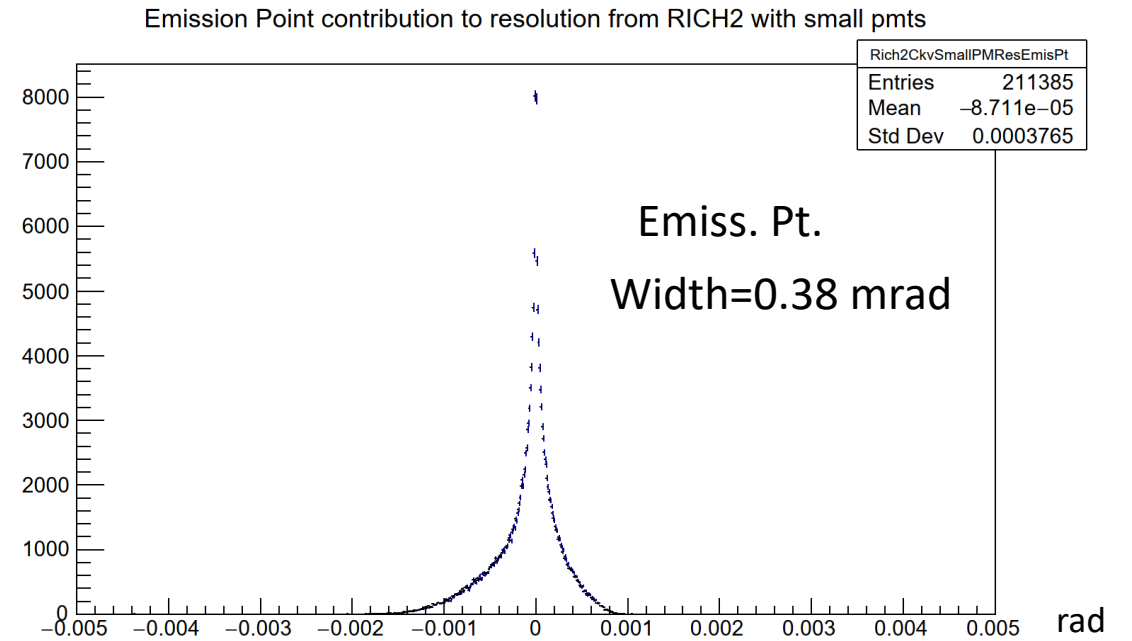
RICH: **trunk** : RICH2 in RUN3 configuration

- *Negligible effect on RICH2 overall resolution, from inserting the TORCH envelope.*
- *All plots created using particle Gun with 80 GeV/c muons in the good acceptance region.*

RICH2 resolutions : TORCH envelope



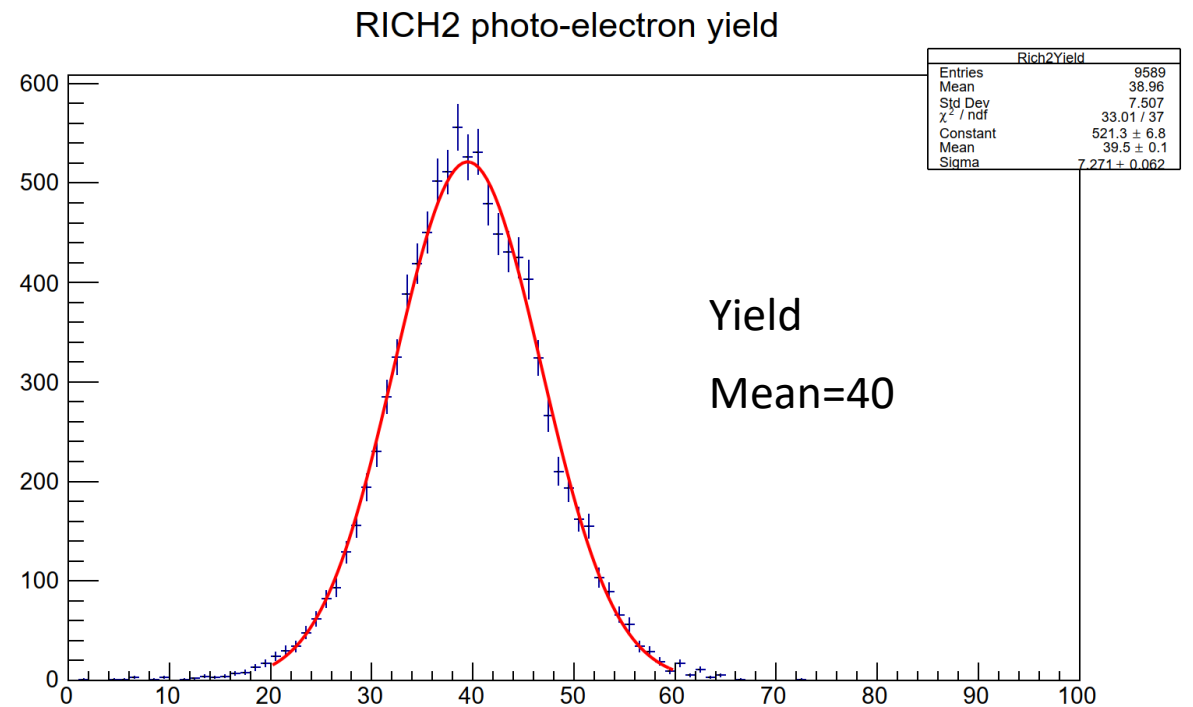
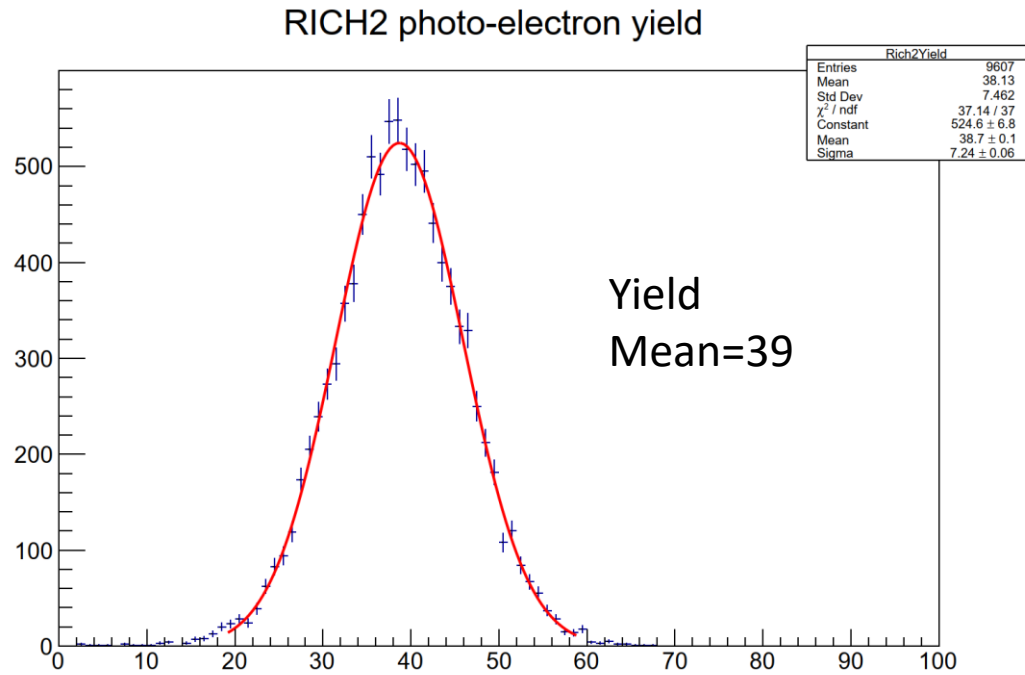
RICH: Rich_Run5_v5 : RICH2 with TORCH envelope



Rich: trunk : RICH2 in RUN3 configuration

- *Negligible effect on RICH2 emission point error, from inserting TORCH envelope.*
- *All plots created using particle Gun with 80 GeV/c muons in the good acceptance region.*

RICH2 yield : TORCH envelope



RICH: Rich_Run5_v5 : RICH2 with TORCH envelope

Rich: trunk : RICH2 in RUN3 configuration

- *Negligible effect on RICH2 yield, from inserting the TORCH envelope.*

Summary of TORCH support

RICH2 Nominal RUN3 geometry with MaPMTs	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Rich_Run5_v5: With TORCH envelope	0.50	0.34	0.37	0.20	39
Nominal RUN3	0.50	0.33	0.38	0.20	40

Resolutions quoted are with small MaPMTs

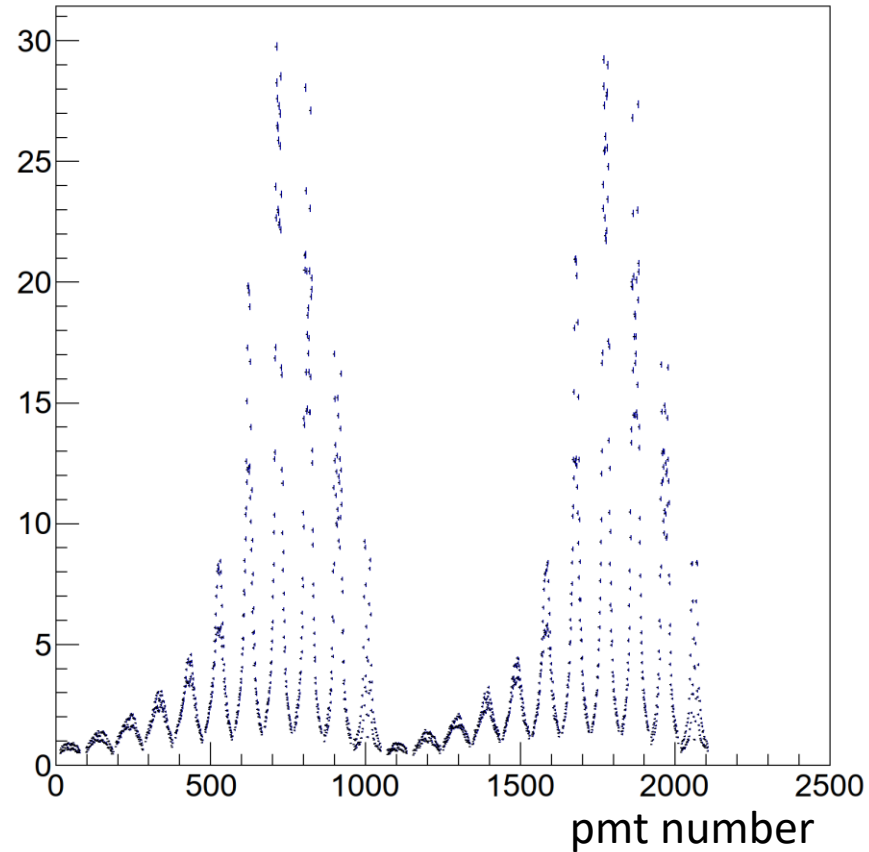
- All these are implemented in the **Rich_Run5_v5** version of the geometry.
- All the necessary information to use this program is provided to the TORCH colleagues.
- We wait for them to implement the internal structures of TORCH and to run the simulation program with TORCH. Once the corresponding simulated data are created by them, the subsequent step would be to try to run the reconstruction program using RICH+TORCH

RICH simulation using minimum bias events

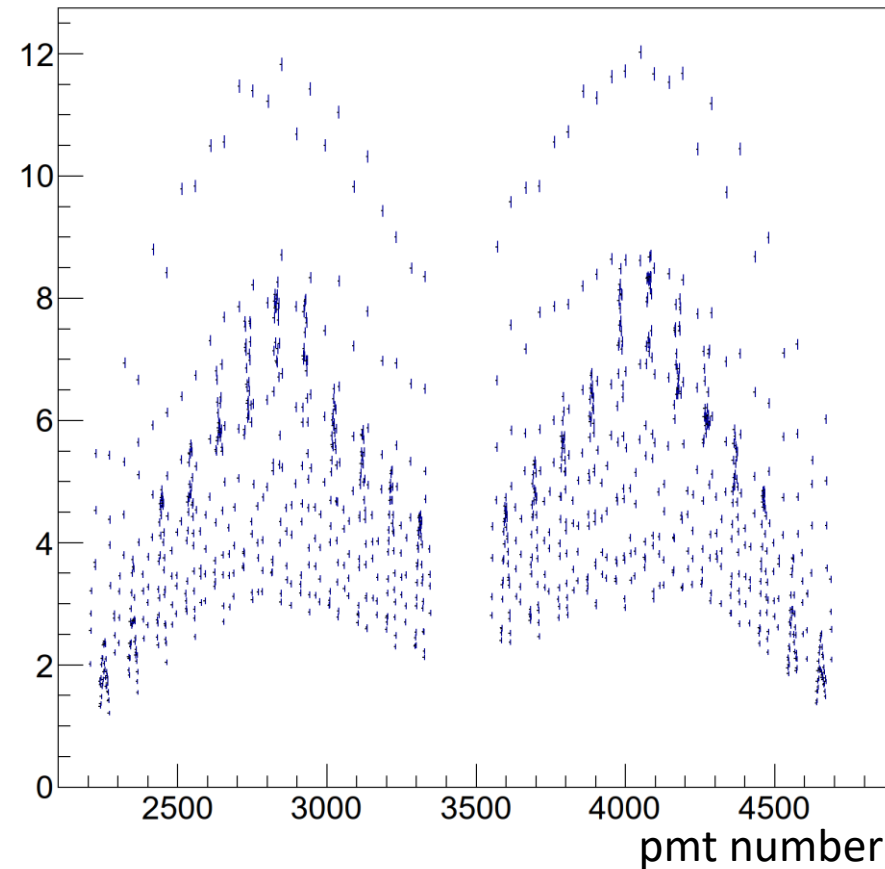
- This was done in Gauss for :
 - RUN3 configuration
 - RUN5 configuration with SiPMs
- Data from the RUN3 configuration was used in the development of Boole
- Boole:
 - RICH system is used with latest available versions of : VP, UT, FT and the Calorimeters
 - For now, using RICH software developed for RUN3 digitization (CLARO chip, SIN effects etc.)
 - In the future, we would like to simulate the features of the FastRICH chip,
that will be used for RUN4 and RUN5
 - For quick studies , the current framework also has the option to effectively bypass Boole simulations
- Reconstruction for PID using Boole output : Work in progress

RICH occupancy : RUN3

RICH1 PMT Occupancy in Percent



RICH2 PMT Occupancy in Percent

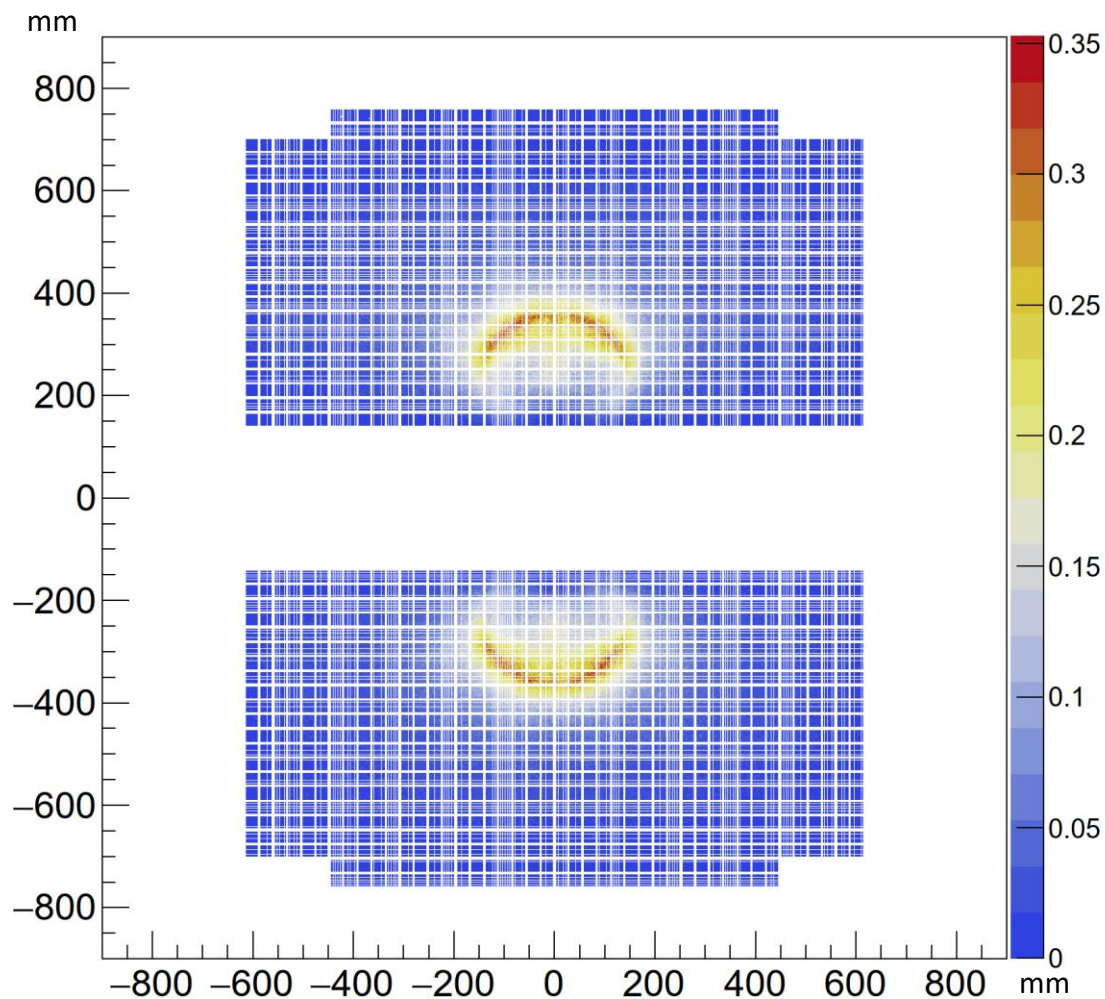


RICH in Run3 configuration

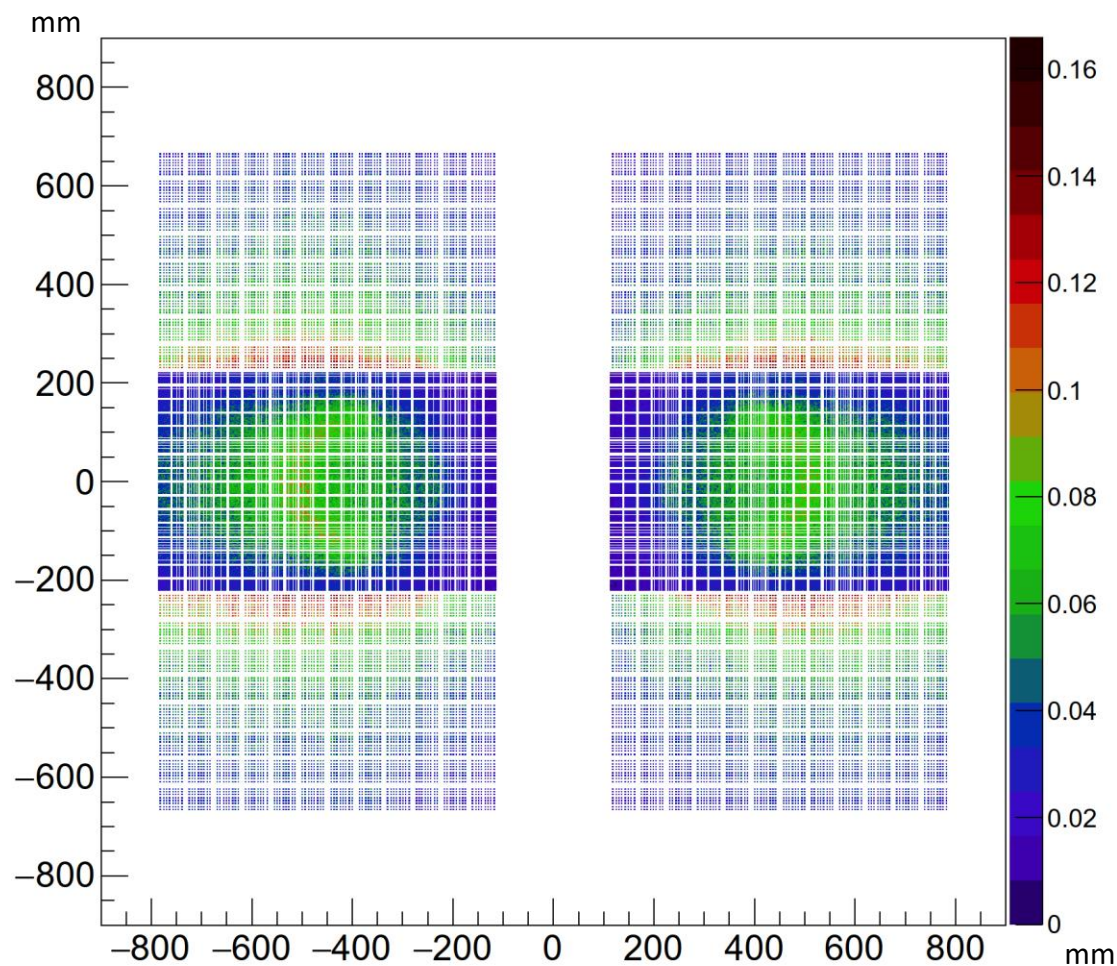
Occupancy = number of hits in a Mapmt * 100 / 64

Distribution of hits in RICH for RUN3 from Gauss

RICH1 Panels : Y vs X of Hits



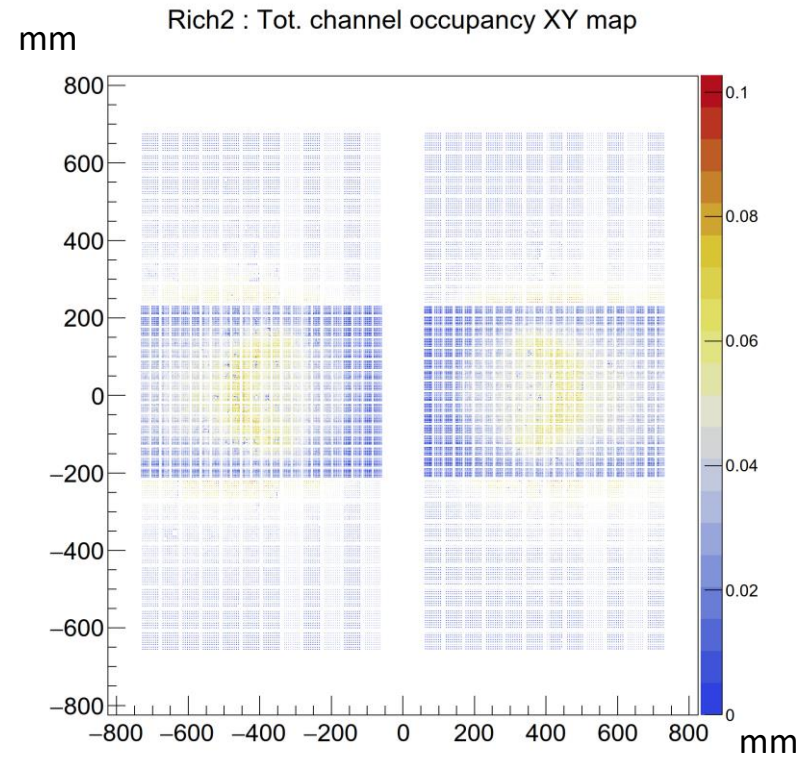
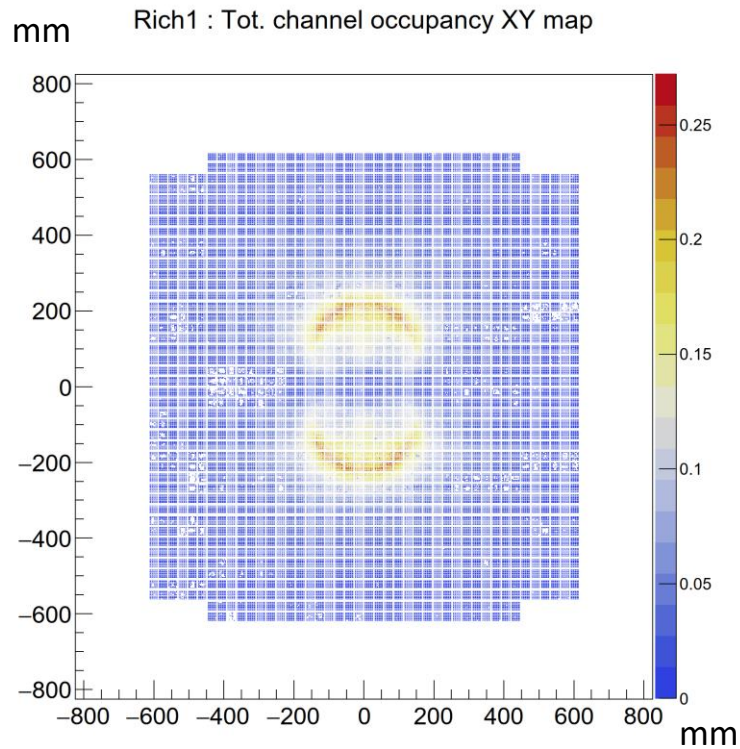
RICH2 Panels : Y vs X of Hits



- All plots from minimum bias MC events and nominal RUN3 luminosity
- The information obtained from the 1d occupancy plots can also be inferred from here

Example of the distribution of hits from Boole : RUN3

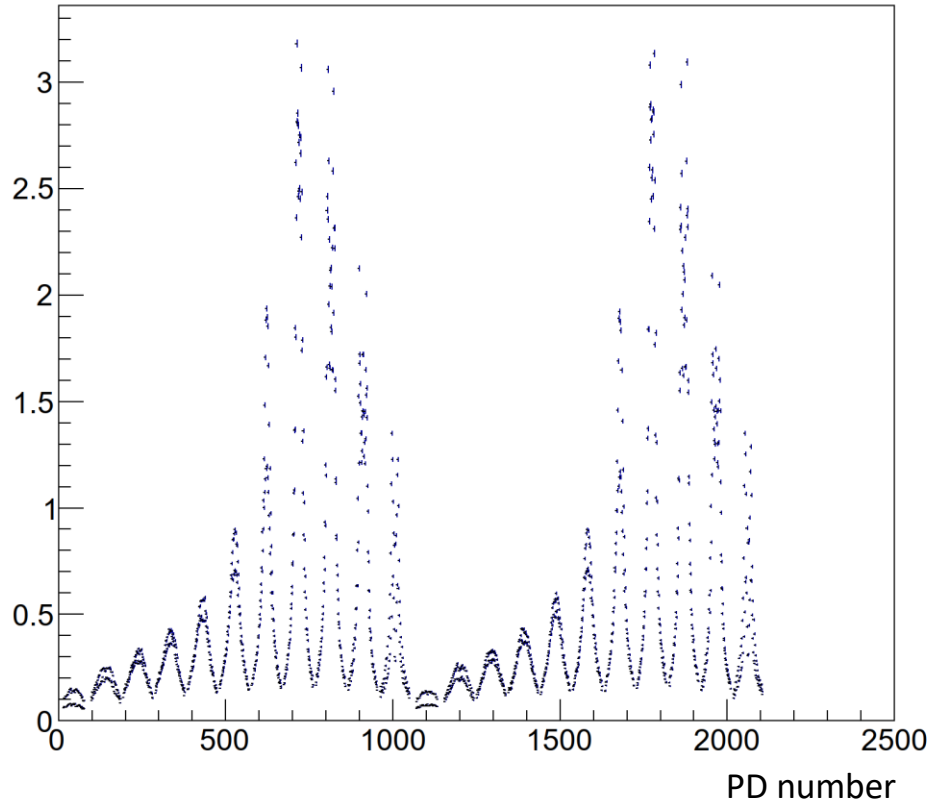
*DB updates of PD properties
from Edoardo, Giovanni.
Boole studies from Ollie.*



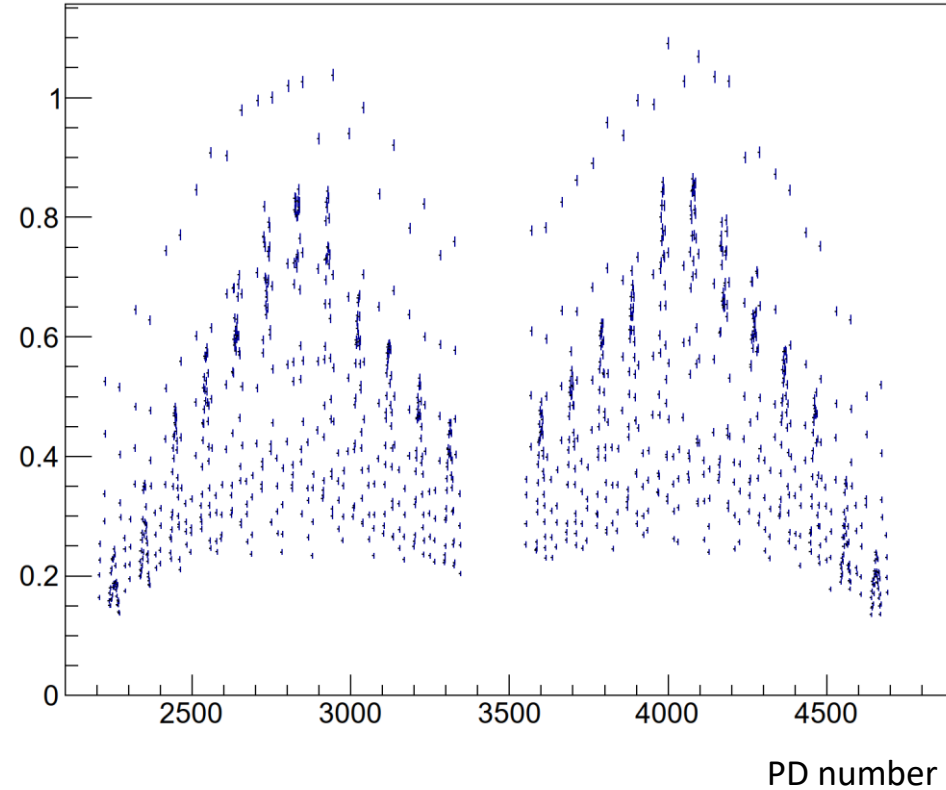
- The PMT occupancy at a time-window cut of 9 ns is shown here for illustration
- Boole creates data in terms of xdigi files that are ready to be used in Reconstruction.

RICH occupancy : Example for RUN5

RICH1 PD Occupancy in Percent

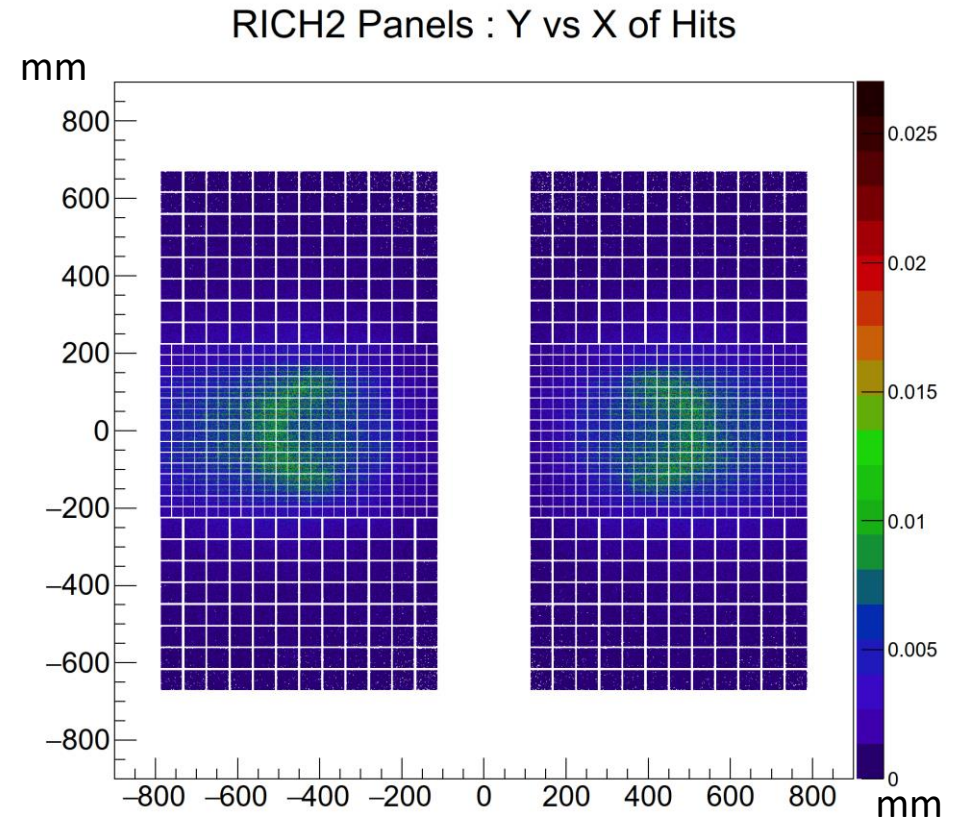
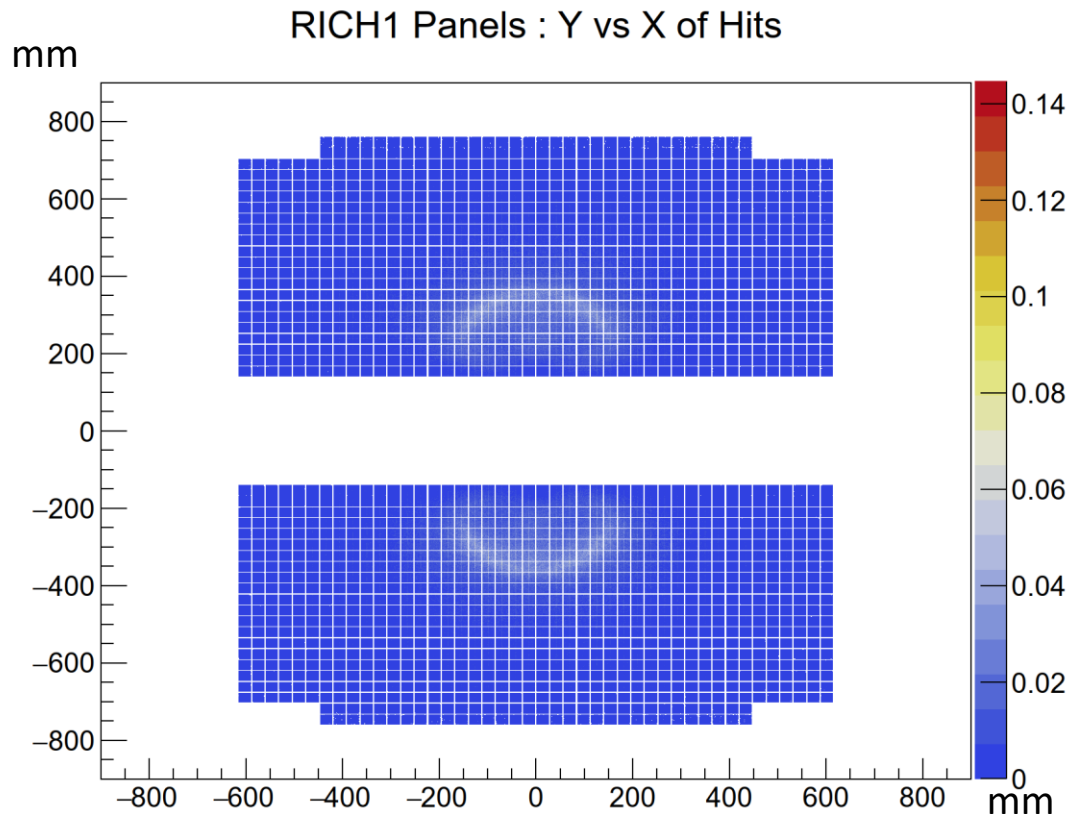


RICH2 PD Occupancy in Percent



Rich-Run5-v3 configuration
No wavelength cut
Distributions from Gauss

Example of distribution of hits in RICH for RUN5



Rich-Run5-v3 configuration

No wavelength cut

Distributions from Gauss

Summary

- Several options envisaged for the RICH system in Upgrade2
- Simulation of some of these options started using the new software framework
- Results in terms of resolutions and yields obtained for some of these options. They were used for the scoping document.
- Support for TORCH is provided.
- A first version of the readout simulation is developed for the RUN3 configuration. It can form the basis for simulating the RUN5 readout.
- Plans :
 - Reconstruct the data for determining the PID performance
 - Implement the options that are being discussed in recent months

BACKUP PAGES

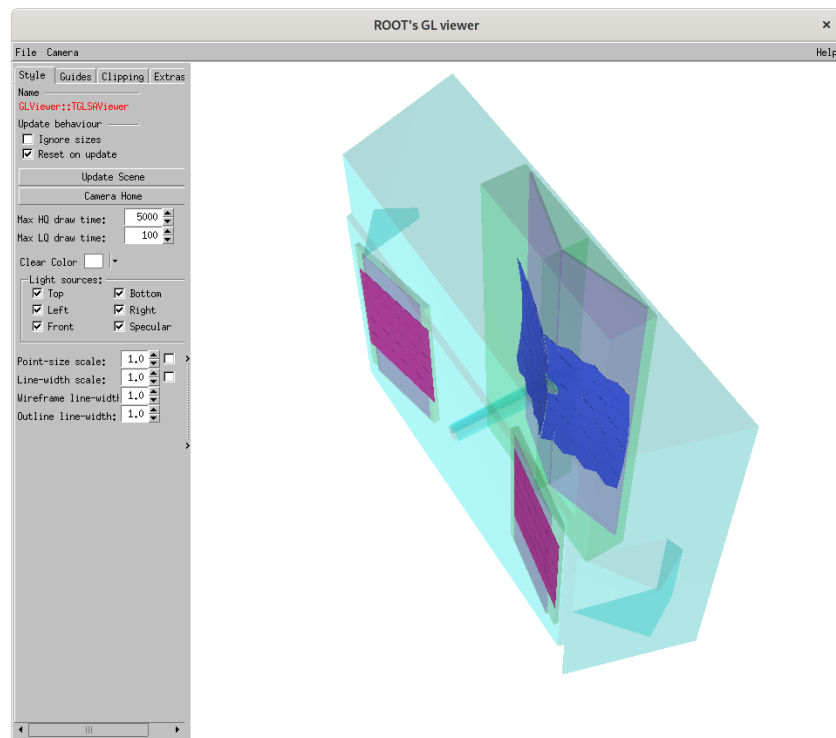
RICH: Summary of Run3 resolutions and yields

RICH1 MaPMT for RUN3	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.82	0.59	0.38	0.46	62
RICH2 Small MaPMT for RUN3	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.50	0.33	0.37	0.20	39
RICH2 Large MaPMT for RUN3	Overall mrad	Chromatic mrad	Emis.Pt mrad	Pixel mrad	Yield
Nominal RUN3 geometry	0.66	0.33	0.44	0.41	39

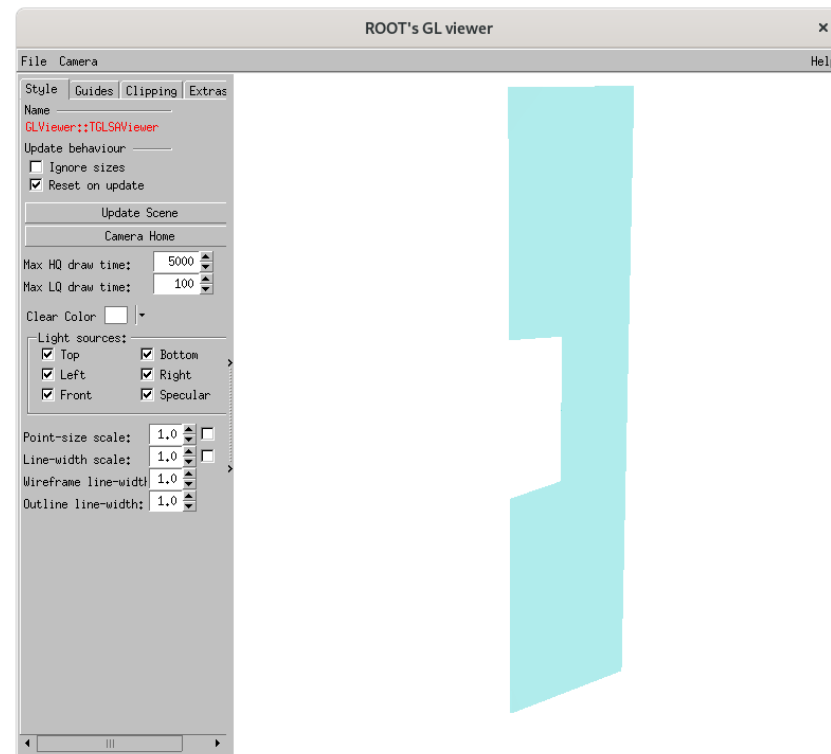
*RICH2 resolutions close to those in real data
Work in progress for RICH1 alignment*

- RICH2 yields are combined yields for small and large PMTs
- These resolutions do not include contributions from the tracking system

TORCH Support

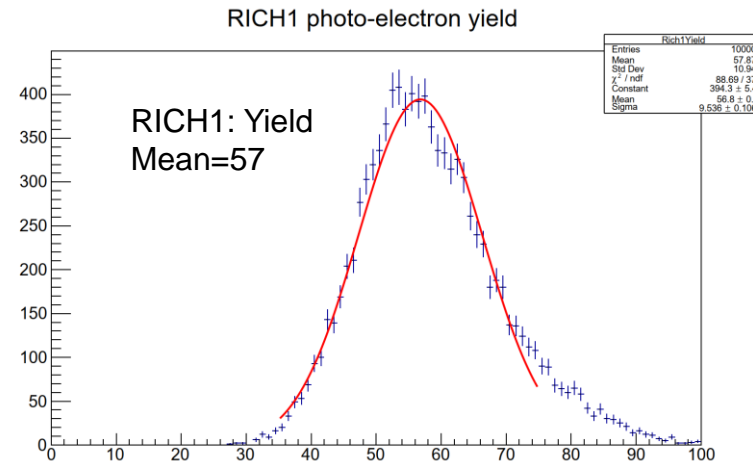
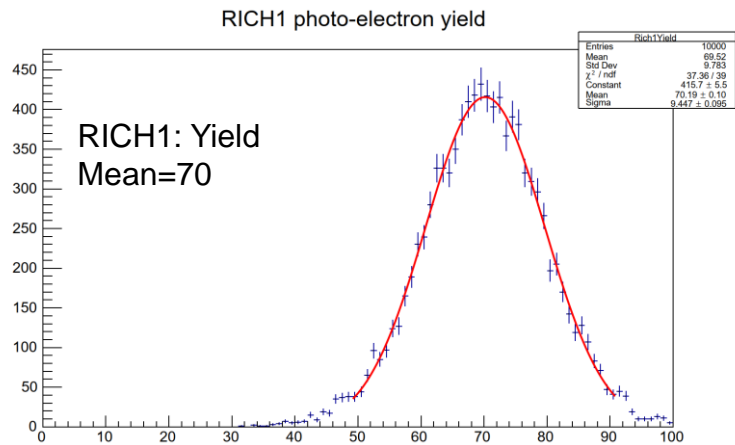
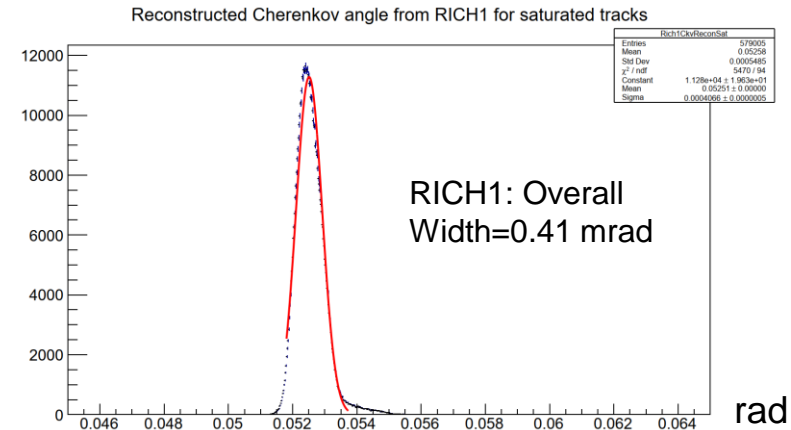
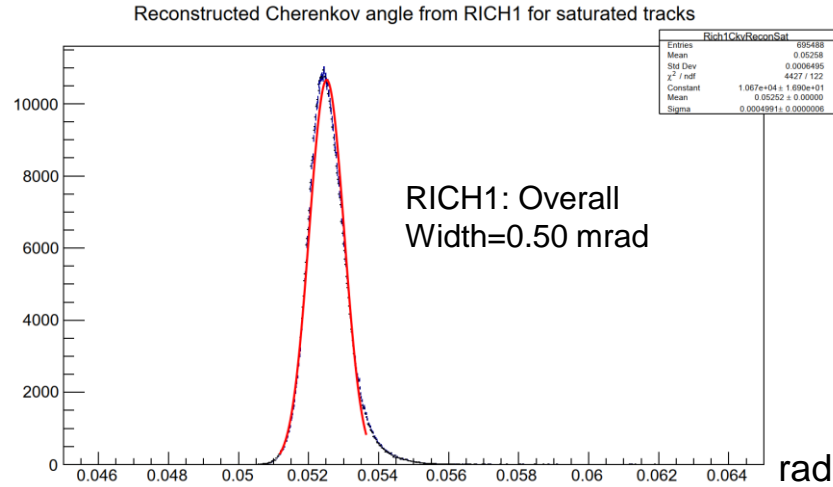


RICH2 gas enclosure with TORCH



Side wall of gas enclosure with TORCH

RICH1 : resolutions and yields with SiPM



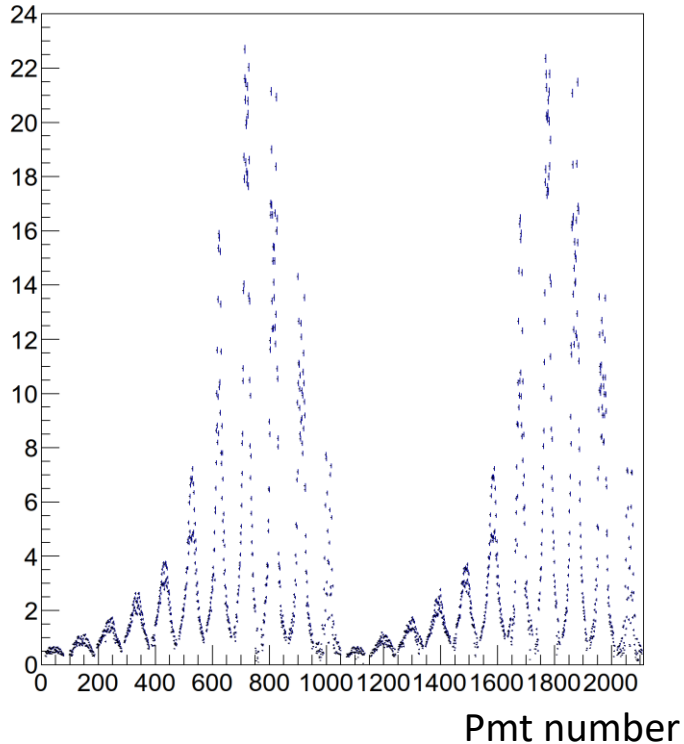
Nominal SiPM, No wavelength cut-off
RICH1 RUN3 nominal geometry

Nominal SiPM, No wavelength cut-off,
Upgraded RICH1 geometry as in FTDR

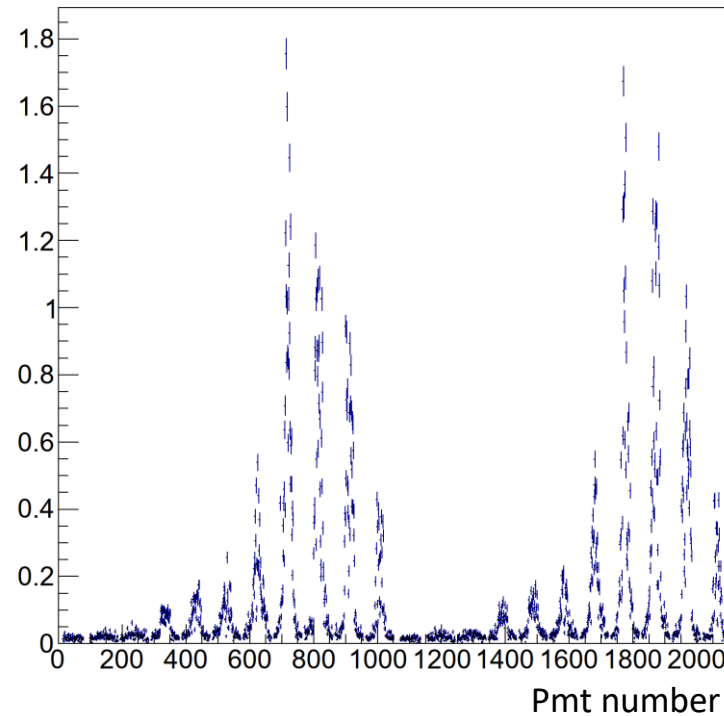
Example of distribution of hits from Boole :RUN3

*DB update from Edoardo, Giovanni
Boole studies from Ollie*

RICH1-Boole PMT Occupancy in Percent : All hits



RICH1-Boole PMT Occupancy in Percent : SIN Hits



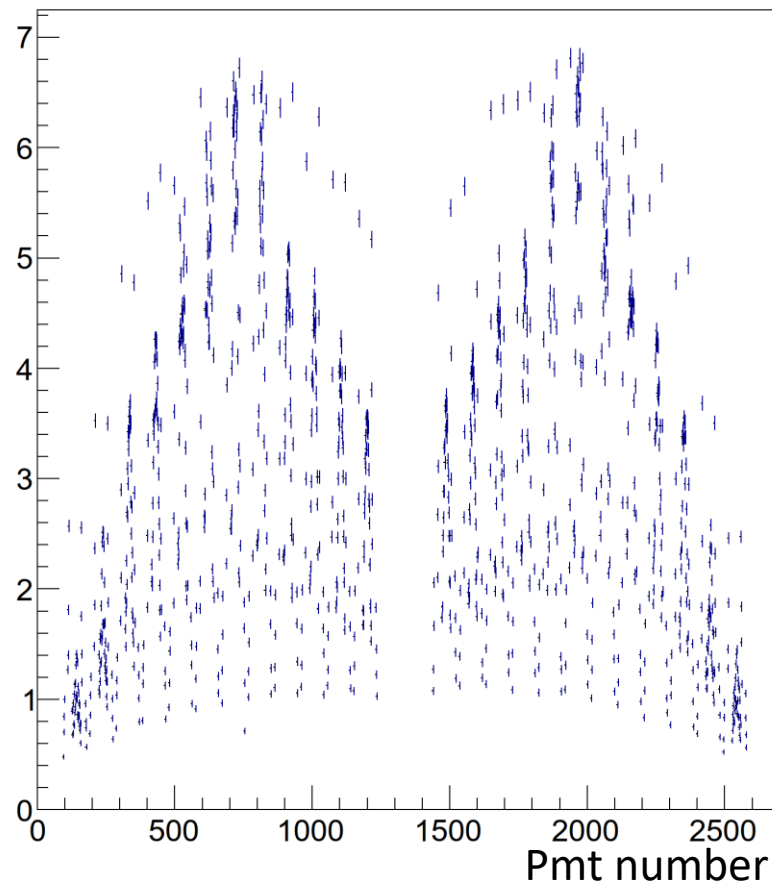
- The PMT occupancy at a time-window cut of 9 ns is shown here for illustration
- Study planned to optimize the time-window cut.

- Boole simulates the readout of MaPMTs and CLARO chip
- The tuning of SIN and other features of the readout will need simulated data with spill-over
- It is also planned to resurrect and use the simulation of PV-time for this.

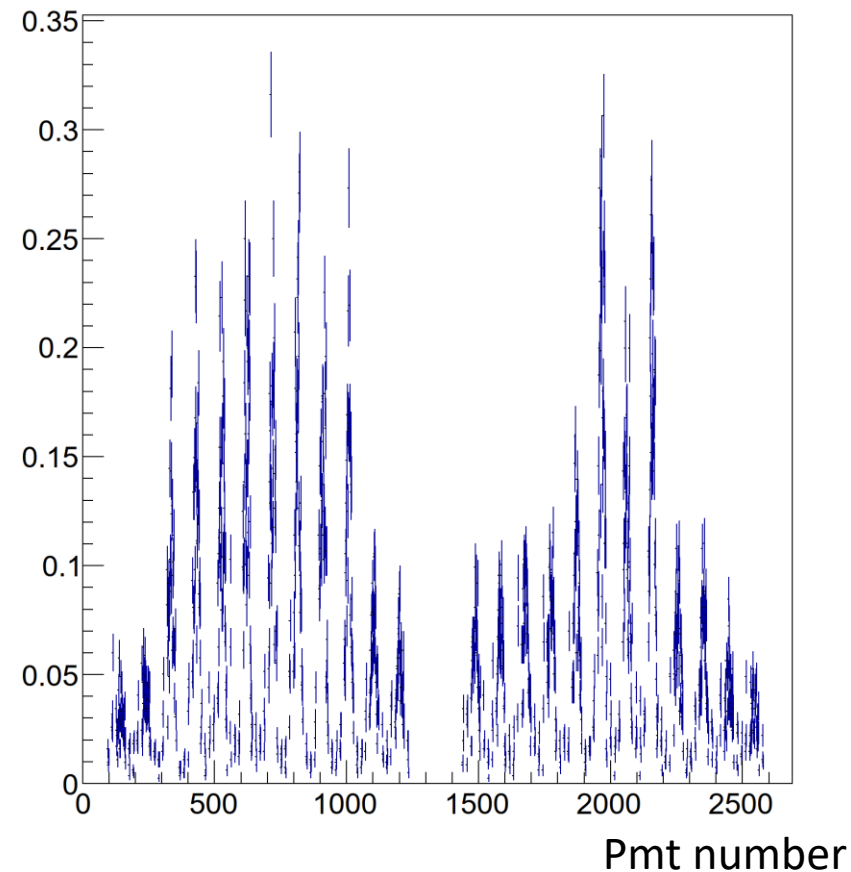
Example of distribution of hits from Boole :RUN3

*DB update from Edoardo, Giovanni
Boole studies from Ollie*

RICH2-Boole PMT Occupancy in Percent : All hits



RICH2-Boole PMT Occupancy in Percent : SIN Hits



- The PMT occupancy at a time-window cut of 9 ns is shown here for illustration
- Study planned to optimize the time-window cut.