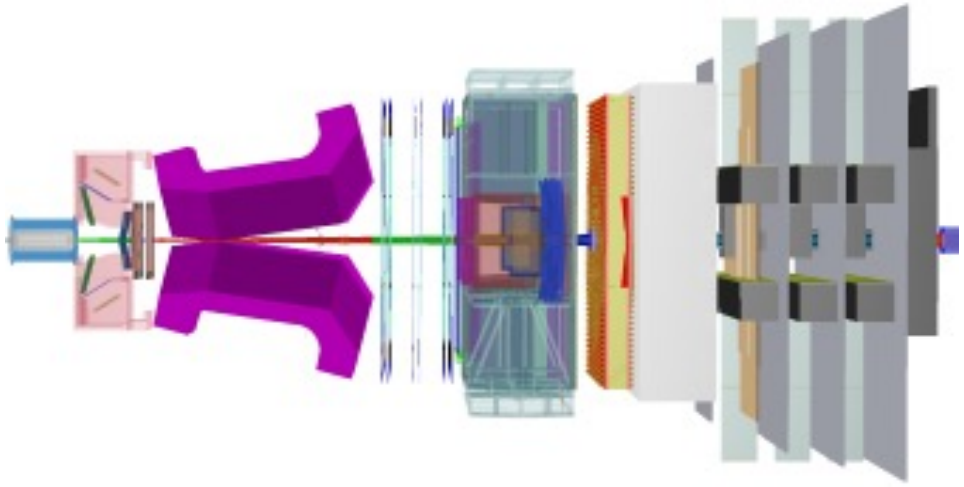
Upgrade II studies: RICH simulation using MCPs



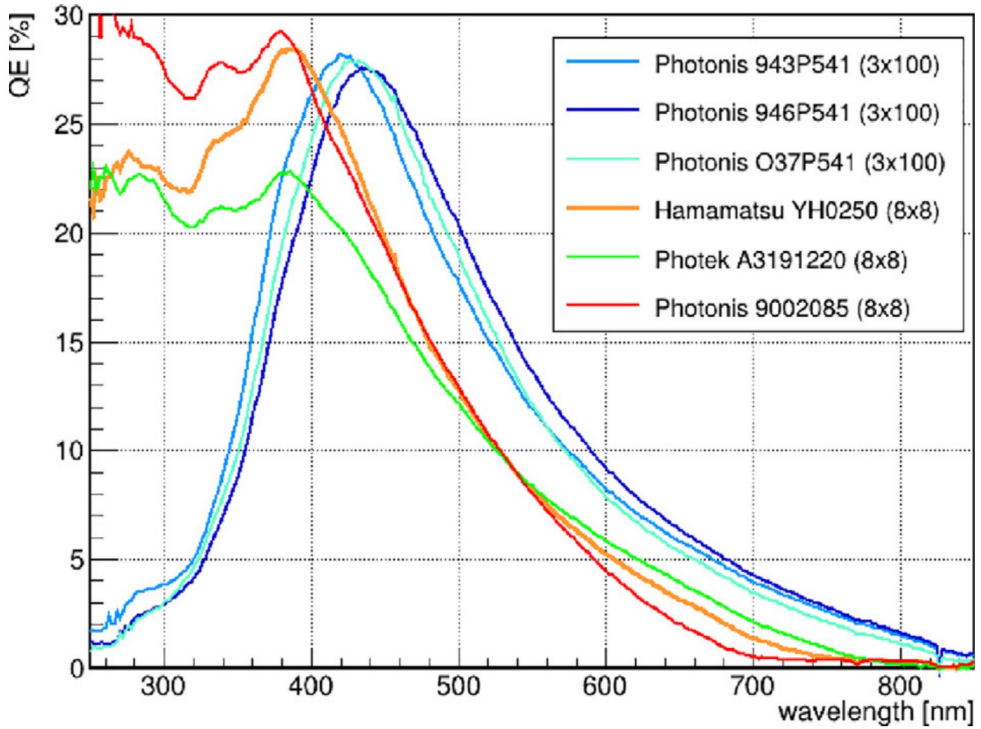
Sajan Easo[1] and Lais Lavra[2]

1 Science and Technology Facilities Council STFC
2 The University of Edinburgh

Introduction

- Implementation of MCPs features in the current simulation framework for Upgrade II studies
  - Geometry description based on DD4HEP framework
  - Simulation software: Gauss + Gaussino
- Events generated with Particle Gun (10k events)
- Geometry versions for Run5
  - (a) RICH_Run5_v3: upgraded geometry for Run 5 (only RICH1 optics) as in FTDR, SiPMs as photon detector (Sajan) + MCPs as photon detector
  - (b) RICH_Run5_v4: nominal Run 3 geometry, SiPMs as photon detector (Sajan) + MCPs as photon detector
  - (c) RICH_Run5_v5: RICH+ TORCH studies
- Resolution and yields estimates

QE of different MCP-PMTs



Thierry's presentation
NIMA 1049 (2023) 168047

Comparison of Photon detectors

3 PDE evaluated

- MCP Photonis 943P541 (blue curve)
- MCP Photonis 9002085 (green curve)
- LAPPD126 (yellow curve)

Geometry

- Run 3 geometry
- Upgraded geometry for Run 5 (FTDR)

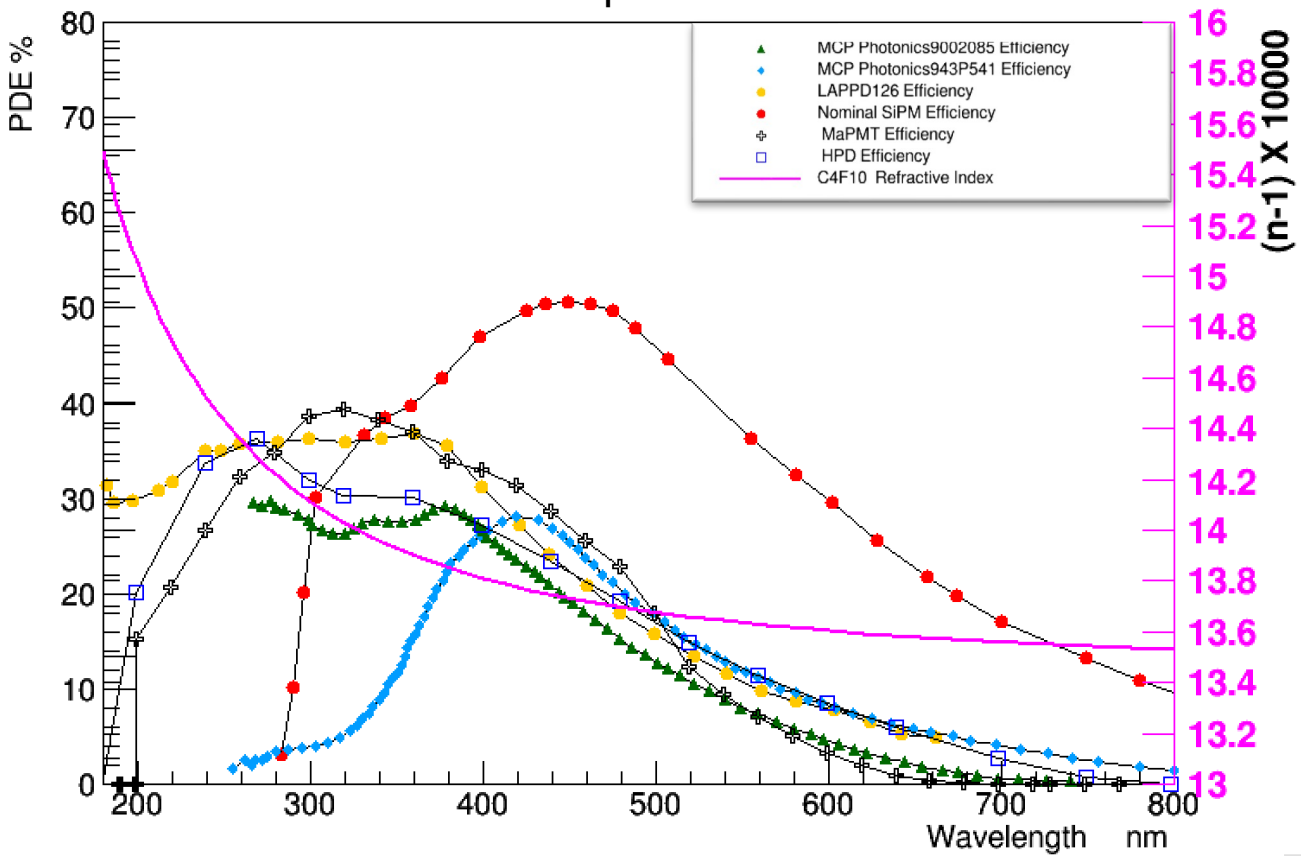
MCPs as photon detector

- Each MaPMT volume is repurposed to use as MCP
- 1 mm pixel size (plan to change the pixel sizes)

Wavelength cuts :

- 180 nm (no wavelength cut)
- 300 nm
- 400 nm (for **MCP Photonis 9002085** only)

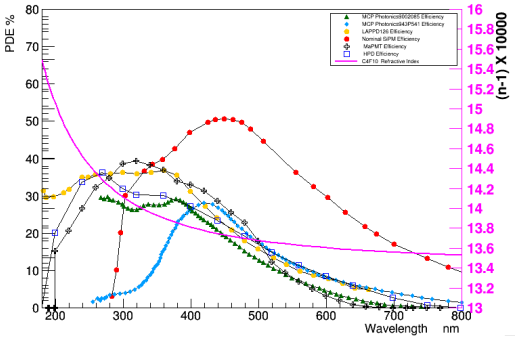
PDE for photon detectors



Run 3 Geometry
RICH1

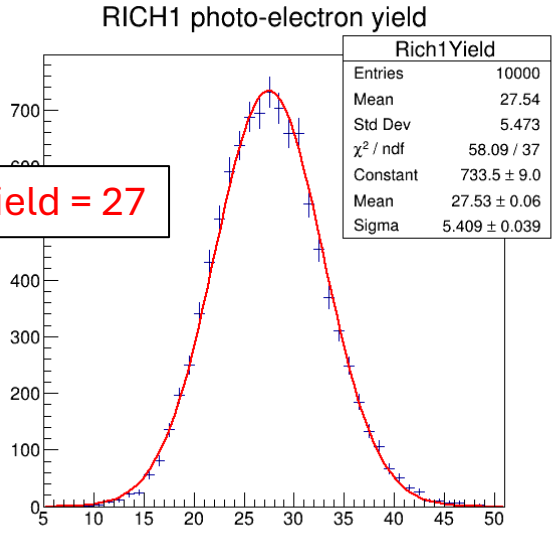
Run3 Geo - NO wavelength cut-off

RICH 1 with Photonis 943P541 (blue curve)



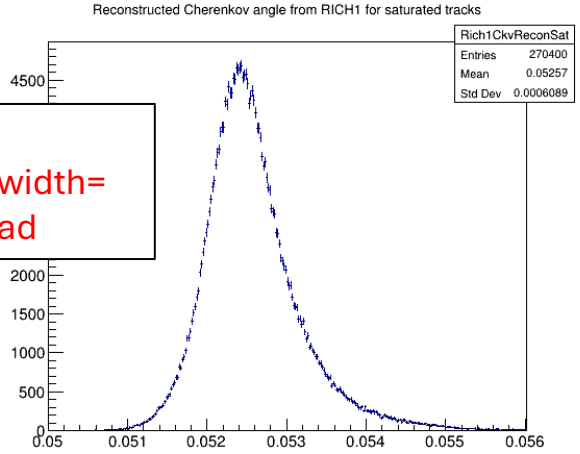
Yields

RICH1 Yield = 27

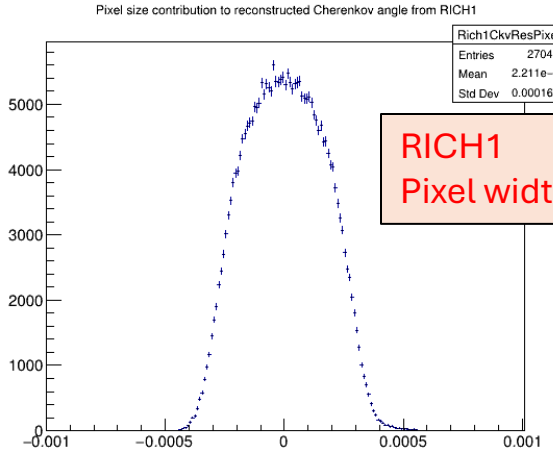


Resolutions

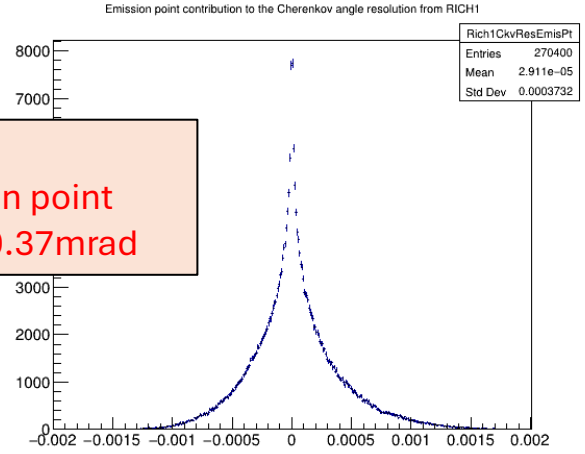
RICH1
Overall width=
0.60 mrad



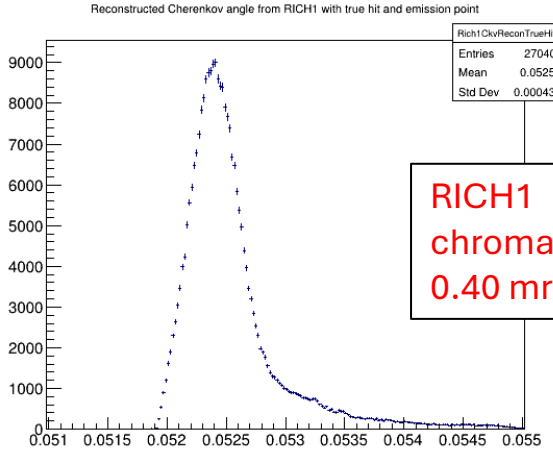
RICH1
Pixel width=0.17 mrad



RICH1
Emission point
width=0.37mrad

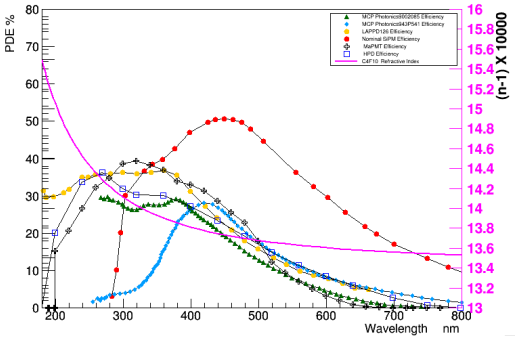


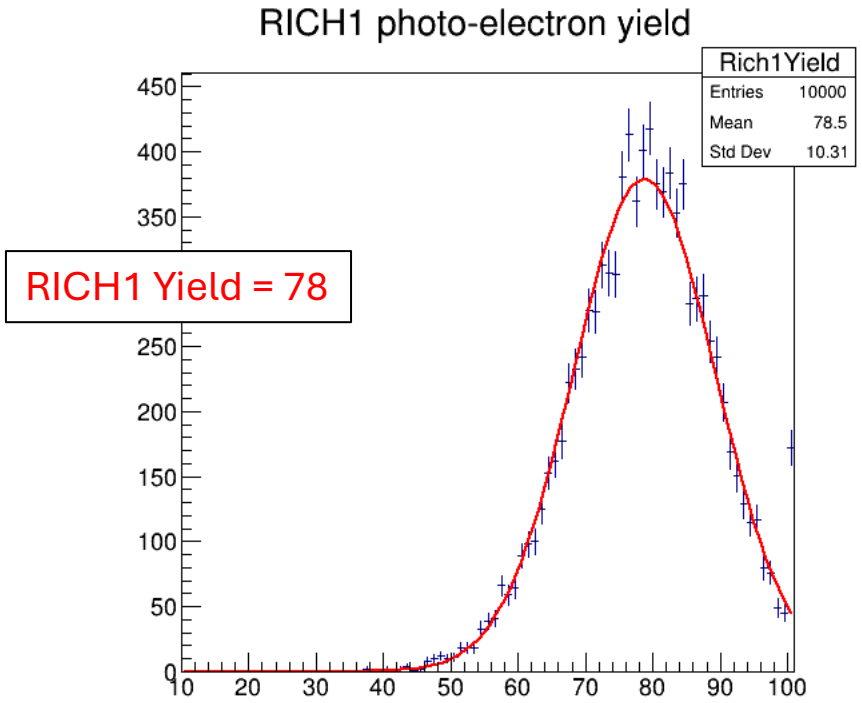
RICH1
chromatic width=
0.40 mrad



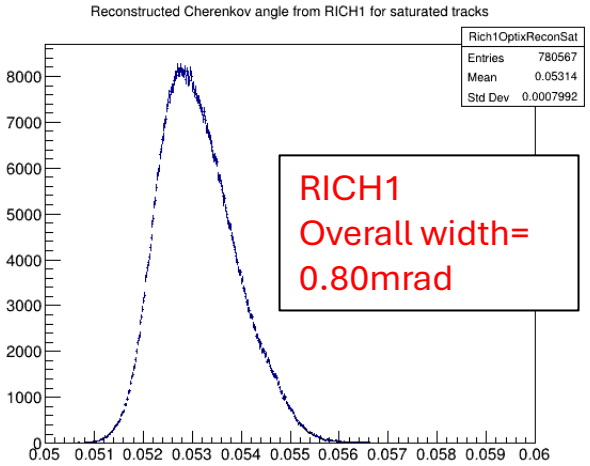
Run3 Geo - NO wavelength cut-off

RICH 1 with LAPPD126(yellow curve)

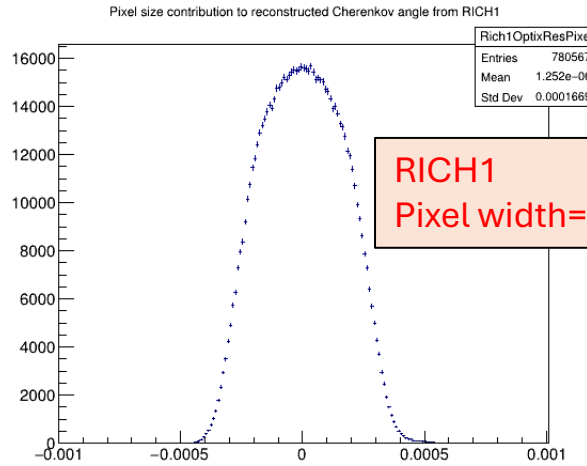




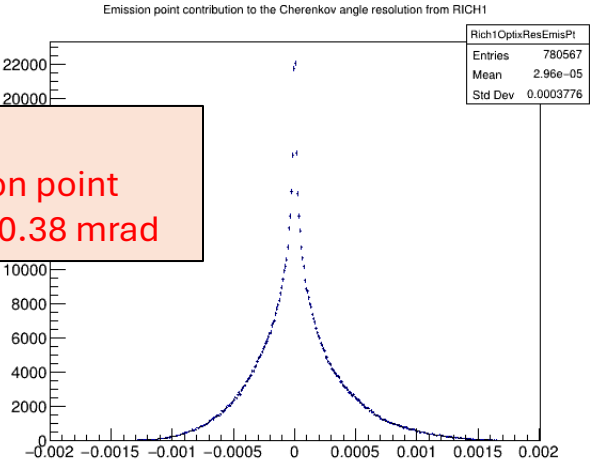
RICH1 Yield = 78



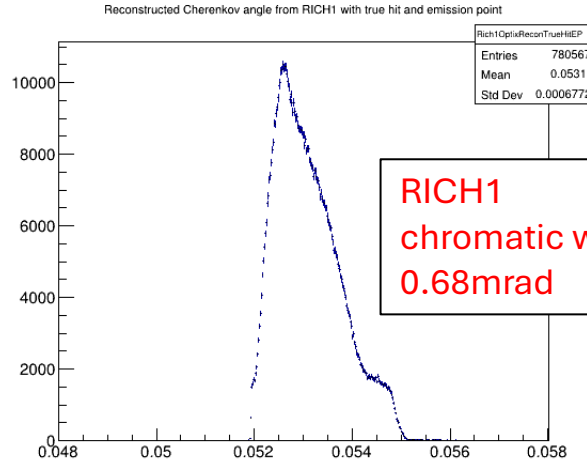
RICH1
Overall width= 0.80mrad



RICH1
Pixel width= 0.17 mrad



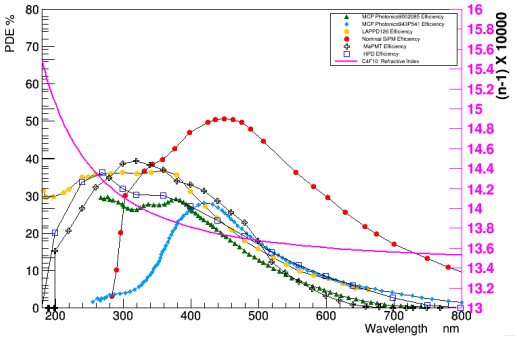
RICH1
Emission point width= 0.38 mrad

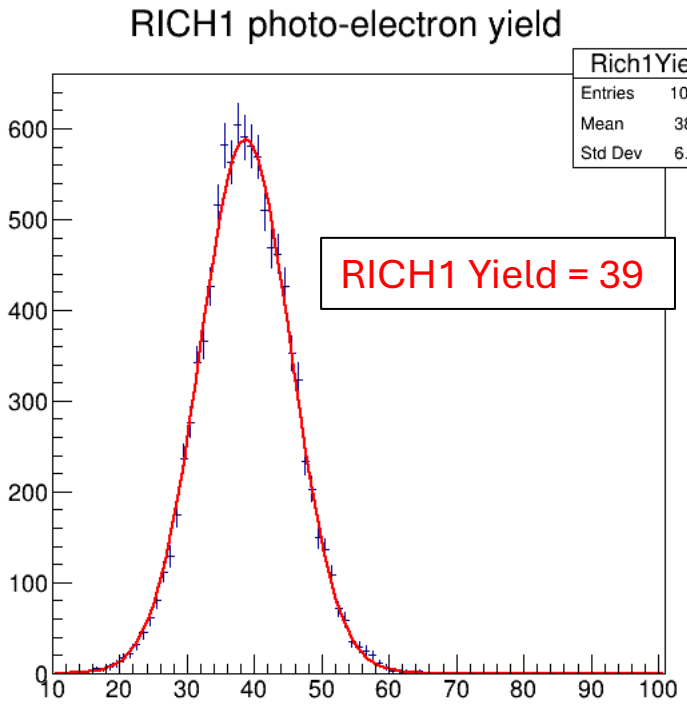


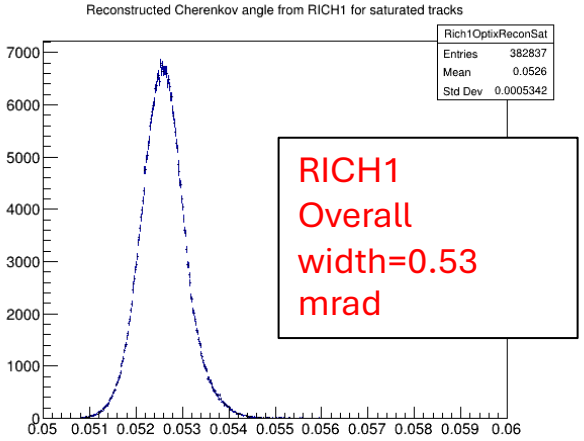
RICH1
chromatic width= 0.68mrad

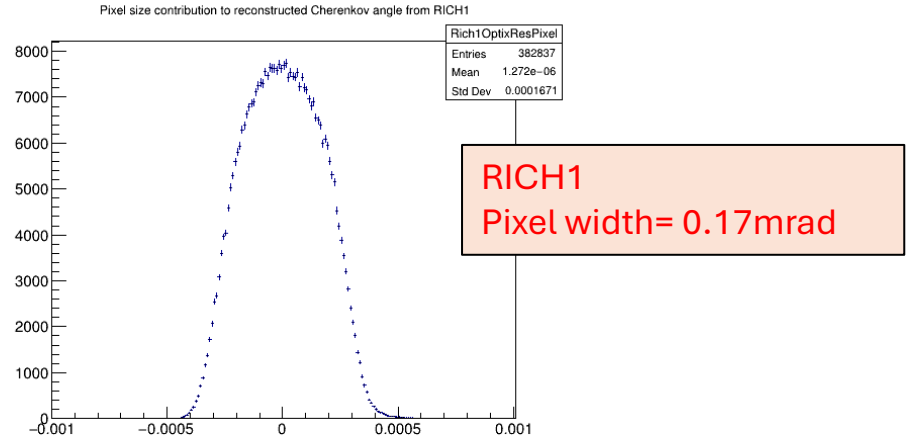
Run3 Geo – 300nm wavelength cut-off

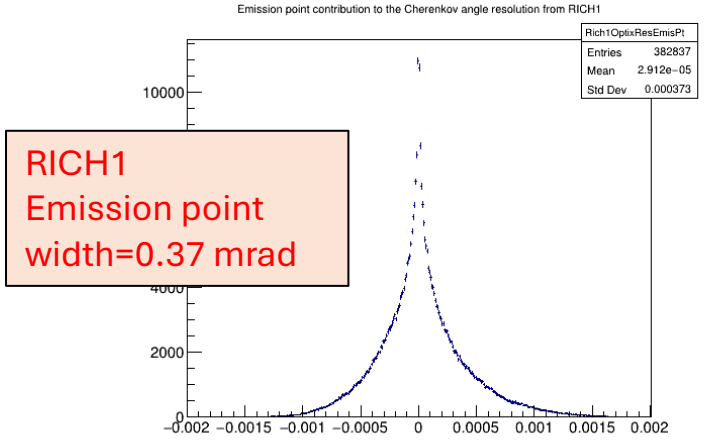
RICH 1 with LAPPD126(yellow curve)

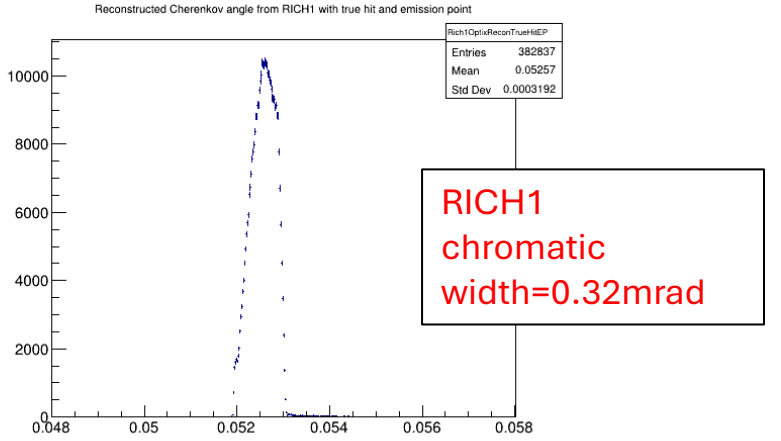








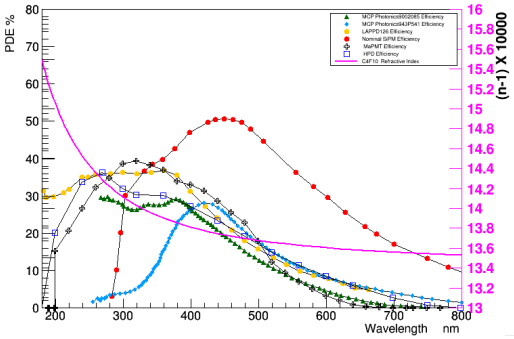




Run 3 Geometry
RICH2

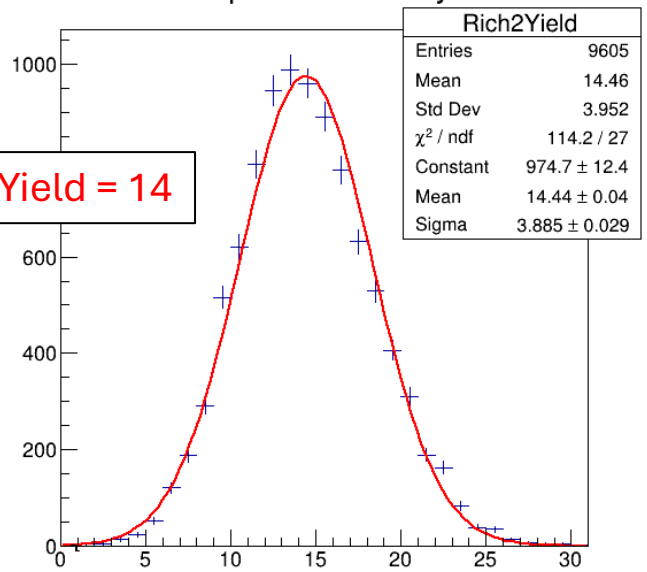
Run3 Geo - NO wavelength cut-off

RICH2 with Photonis 943P541 (blue curve)



Yields

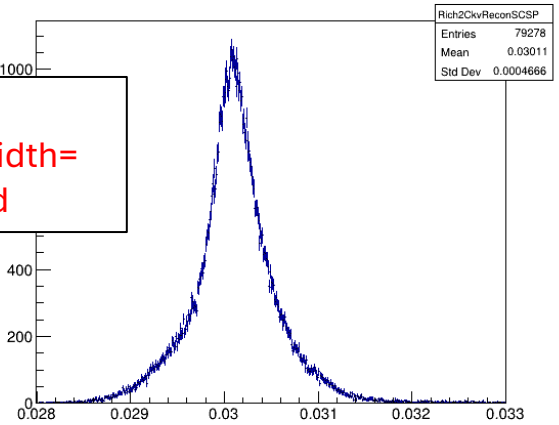
RICH2 photo-electron yield



RICH2 Yield = 14

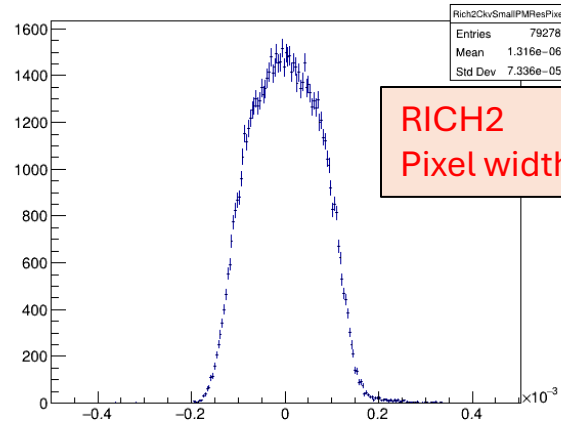
Resolutions

Reconstructed Cherenkov angle from RICH2 with small pmts



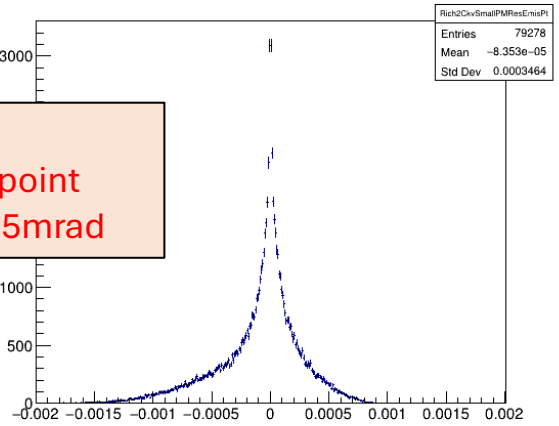
RICH2
Overall width=
0.47 mrad

Pixel size contribution to resolution from RICH2 with small pmts

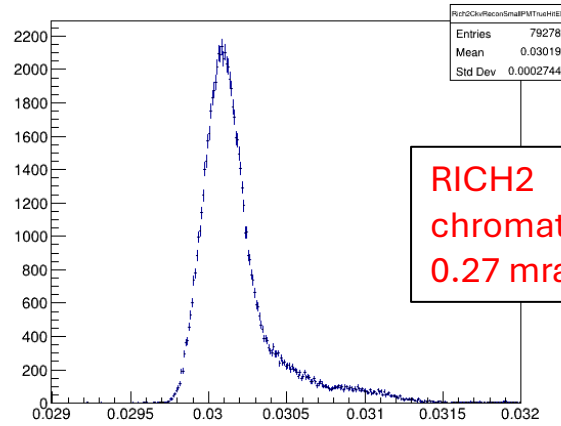


RICH2
Pixel width=0.07 mrad

Emission Point contribution to resolution from RICH2 with small pmts



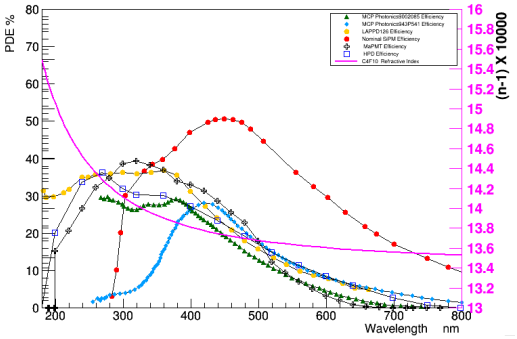
RICH2
Emission point
width=0.35mrad



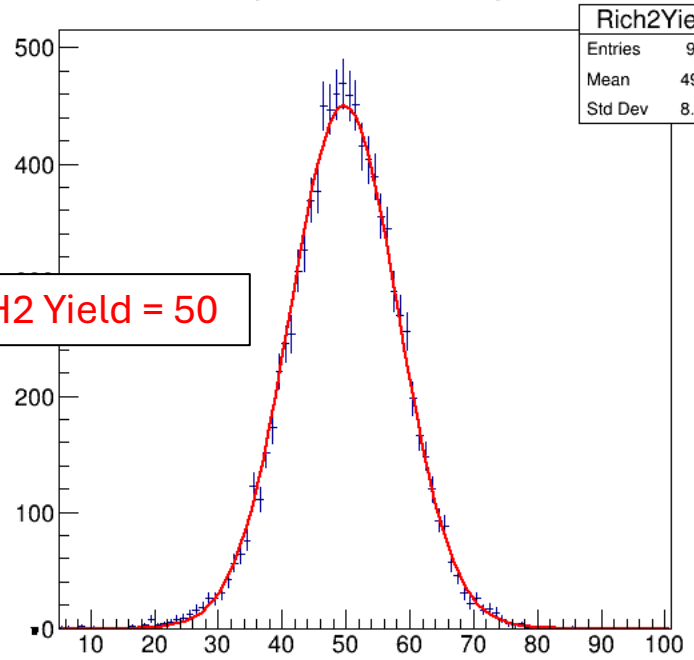
RICH2
chromatic width=
0.27 mrad

Run3 Geo - NO wavelength cut-off

RICH 2 with LAPPD126(yellow curve)

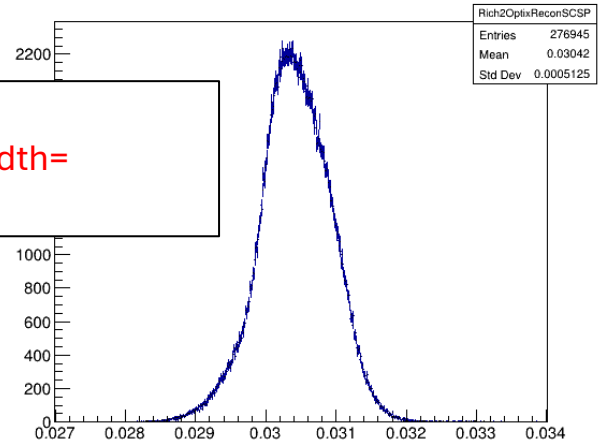


RICH2 photo-electron yield



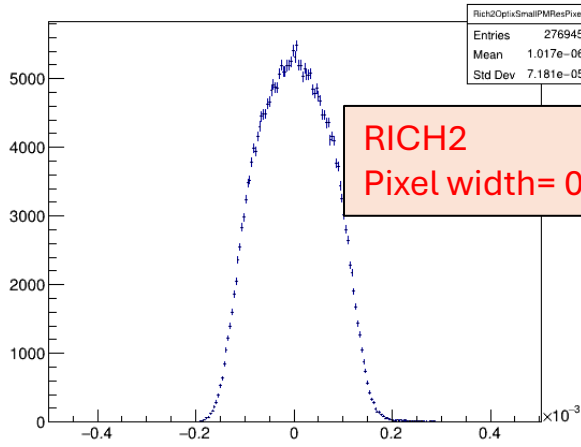
RICH2 Yield = 50

Reconstructed Cherenkov angle from RICH2 with small pmts



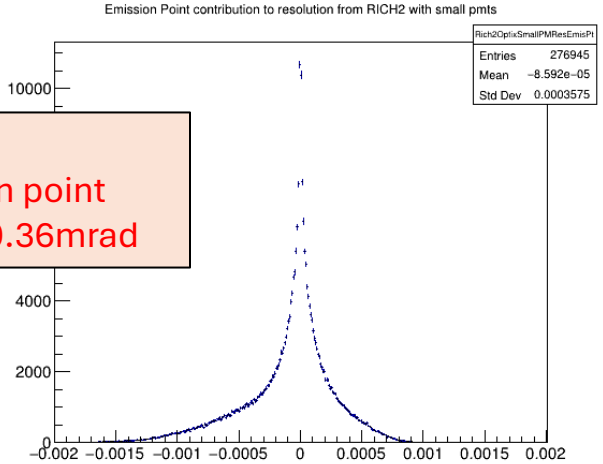
RICH2
Overall width=
0.51mrad

Pixel size contribution to resolution from RICH2 with small pmts

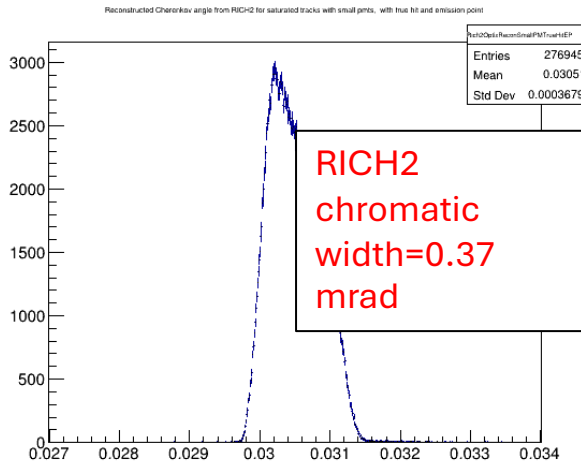


RICH2
Pixel width= 0.07mrad

Emission Point contribution to resolution from RICH2 with small pmts



RICH2
Emission point
width= 0.36mrad

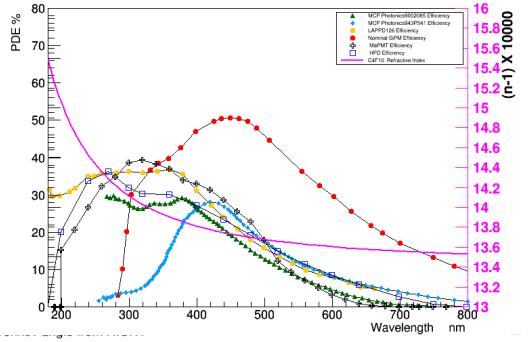


RICH2
chromatic
width=0.37
mrad

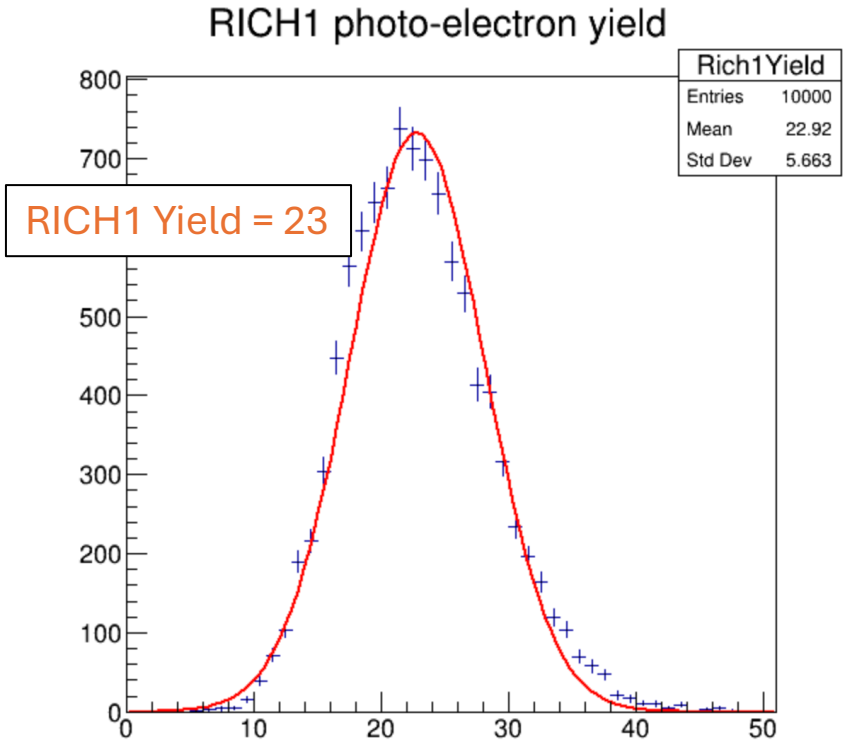
Upgraded Geometry (FTDR) RICH1

Run5 Geo - NO wavelength cut-off

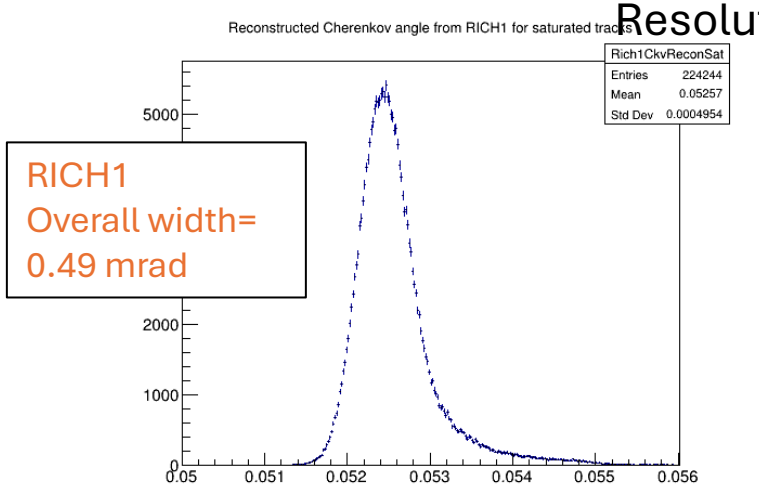
RICH 1 with Photonis 943P541 (blue curve)

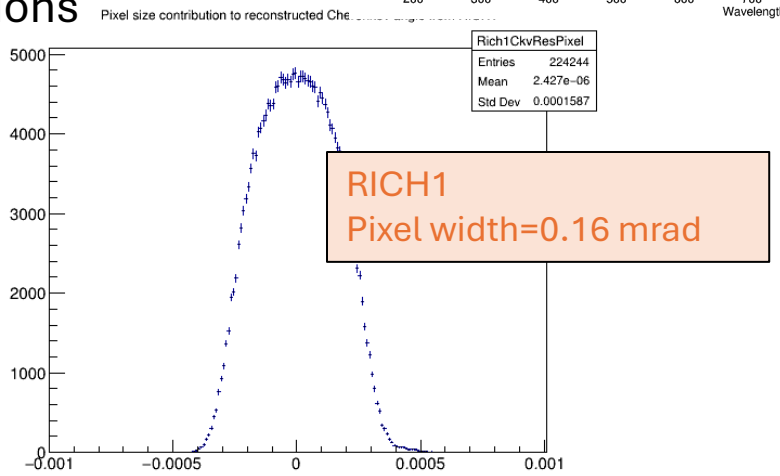


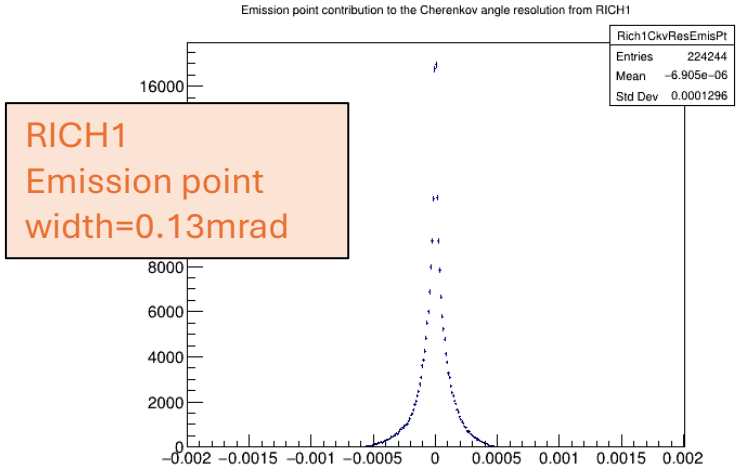
Yields

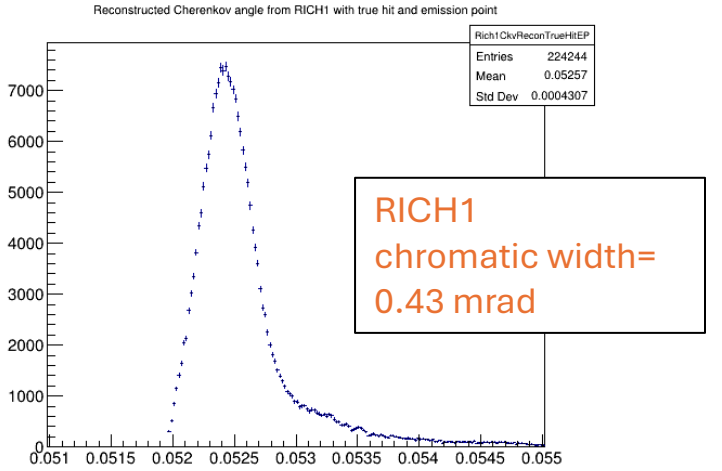


Resolutions



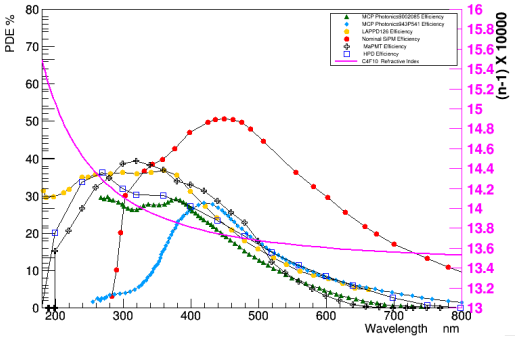


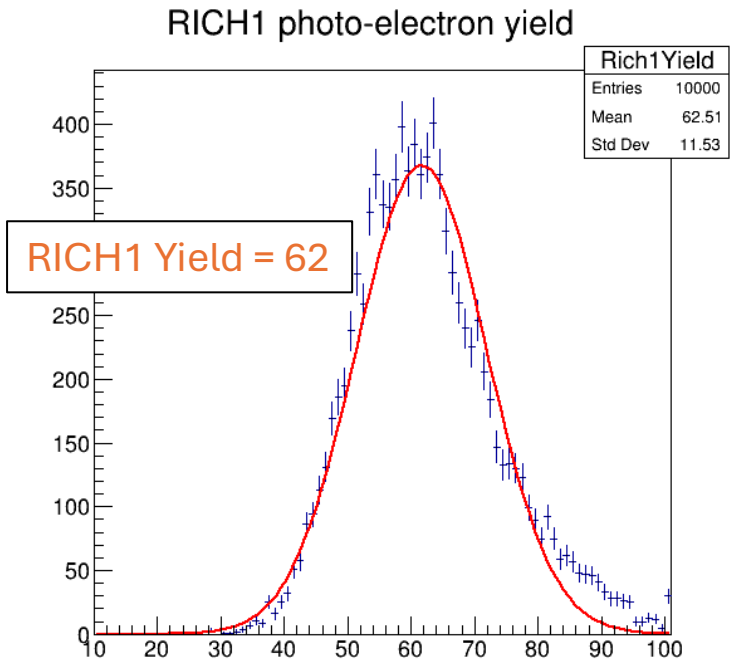




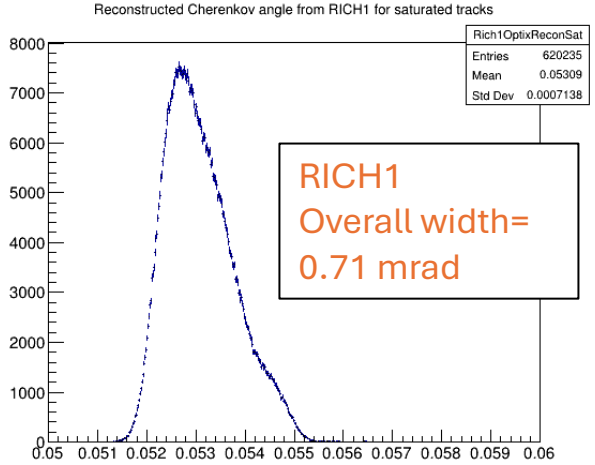
Run5 Geo - NO wavelength cut-off

RICH 1 with LAPPD126 (yellow curve)

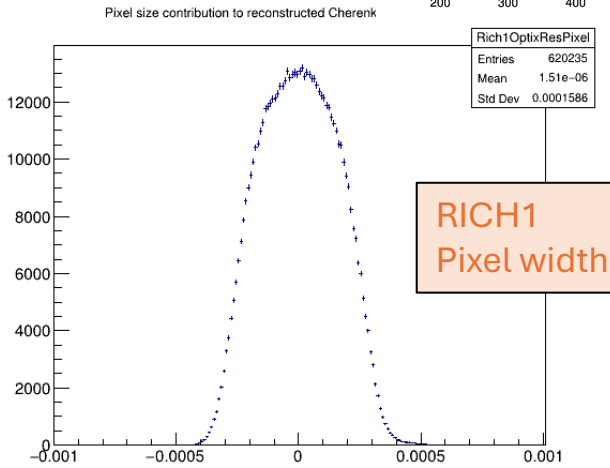




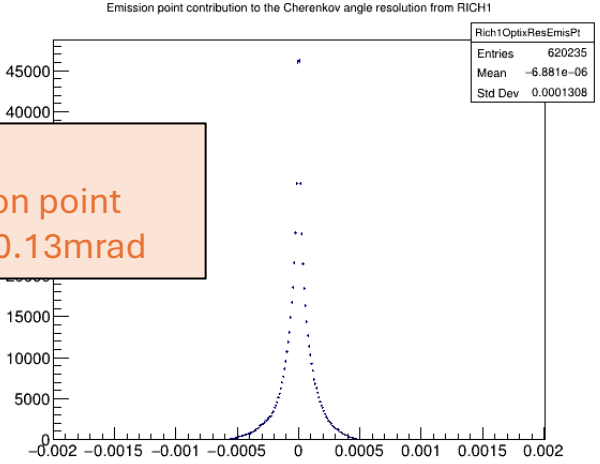
RICH1 Yield = 62



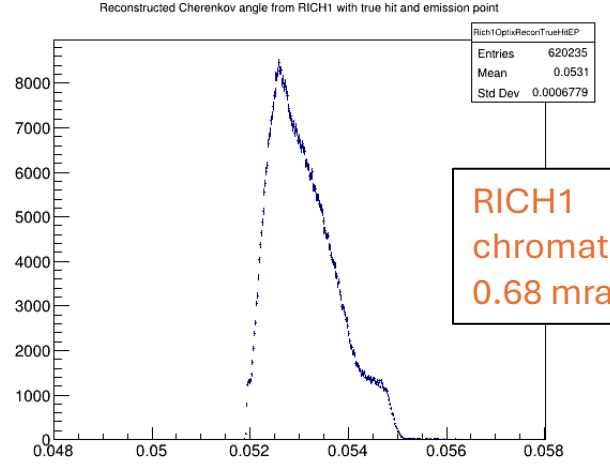
RICH1
Overall width=
0.71 mrad



RICH1
Pixel width=0.16 mrad



RICH1
Emission point
width=0.13mrad



RICH1
chromatic width=
0.68 mrad

RICH1

Nominal RUN3 geometry

RICH1 MCP 9002085 (green curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.81	0.69	64
300nm	0.53	0.30	33

RICH1 LAPPD126 (yellow curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.80	0.68	78
300nm	0.53	0.32	39

RICH1 MCP 943P541 (blue curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.61	0.43	27
300nm	0.57	0.33	25
400nm	0.46	0.18	16

RICH1 SiPM (red curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.50	0.36	70
300nm	0.48	0.28	65
400nm	0.39	0.11	33

Upgraded geometry (FTDR)

RICH1 MCP 9002085 (green curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.73	0.70	51
300nm	0.41	0.32	26

RICH1 LAPPD126 (yellow curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.71	0.68	62
300nm	0.41	0.32	31

RICH1 MCP 943P541 (blue curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.49	0.43	23
300nm	0.45	0.34	20
400nm	0.30	0.18	13

RICH1 SiPM (red curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.41	0.38	57
300nm	0.35	0.28	52
400nm	0.24	0.11	27

SiPM results taken from Sajan's presentation. See slide

RICH2

Upgraded/Run3 geometry

RICH2 MCP 9002085 (green curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.52	0.37	41
300nm	0.40	0.16	17

RICH2 LAPPD126 (yellow curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.51	0.37	50
300nm	0.41	0.20	21

RICH2 MCP 943P541 (blue curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.47	0.27	14
300nm	0.41	0.17	13
400nm	0.39	0.14	8

RICH2 SiPM (red curve)	Overall mrad	Chromatic mrad	Yield
180nm	0.46	0.29	37
300nm	0.40	0.19	33
400nm	0.38	0.09	16

Summary

Preliminary results: MCP comparison in simulation

- Geometry: FTDR, Run 3
- Wavelength cut-off: 180nm, 300nm
- 1mm pixel size

Next Steps:

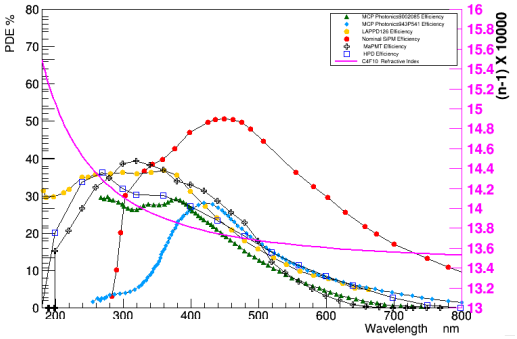
- Change pixel size
- Use Pythia

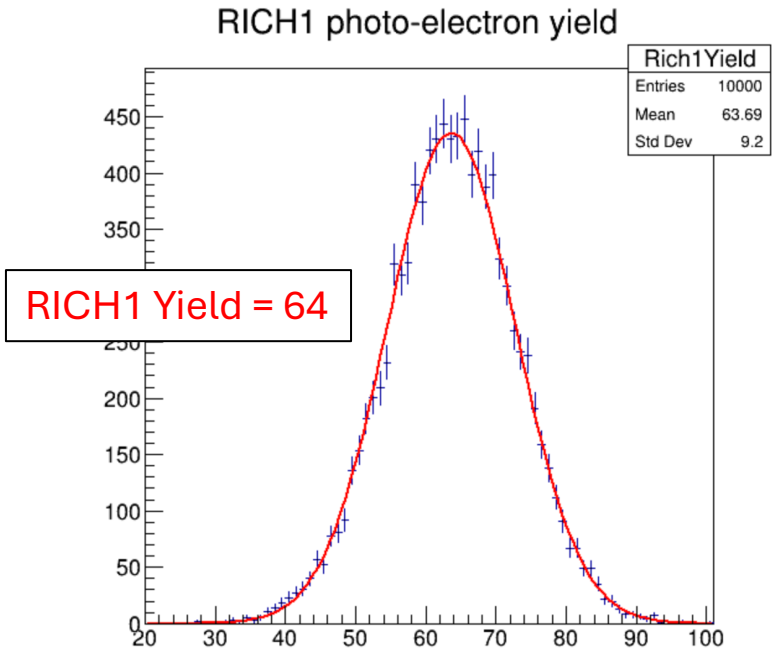
BACKUP SLIDES

Run 3 Geometry
RICH1

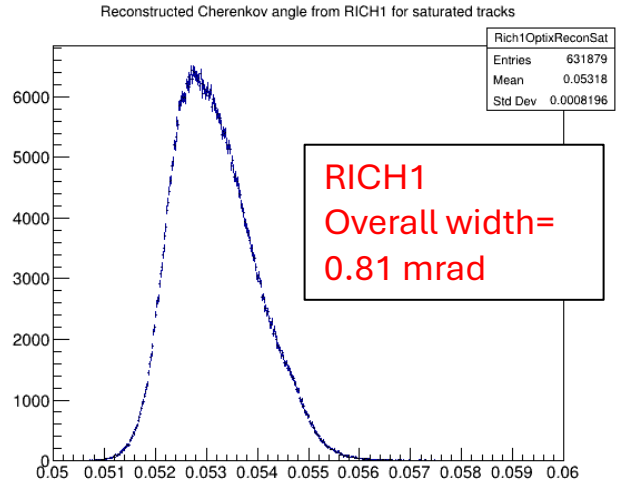
Run3 Geo - NO wavelength cut-off

RICH1 with Photonis 9002085(green curve)

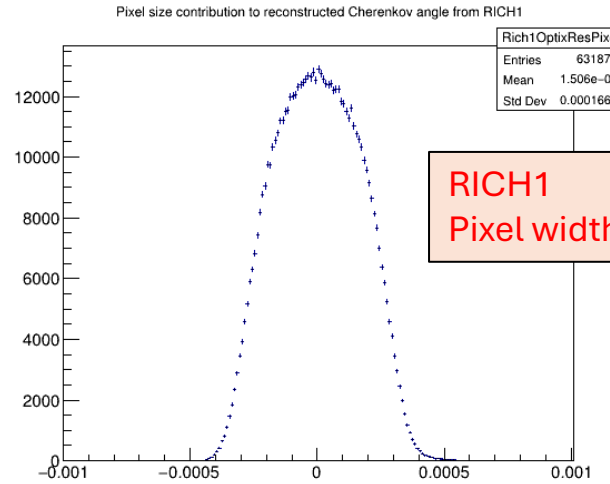




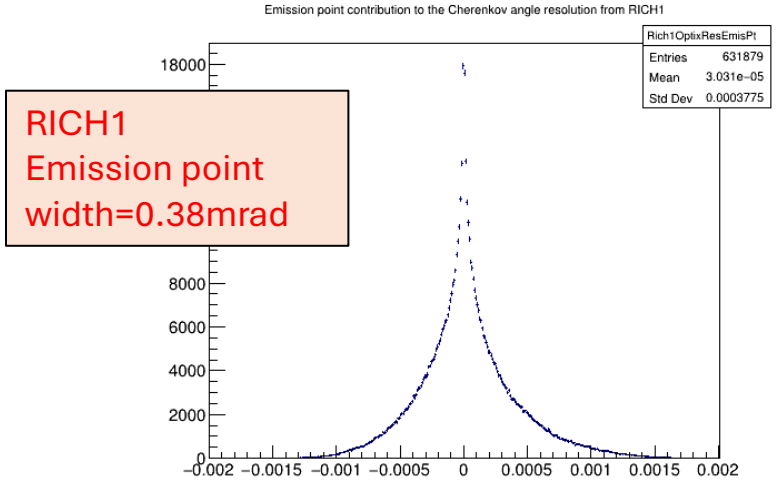
RICH1 Yield = 64



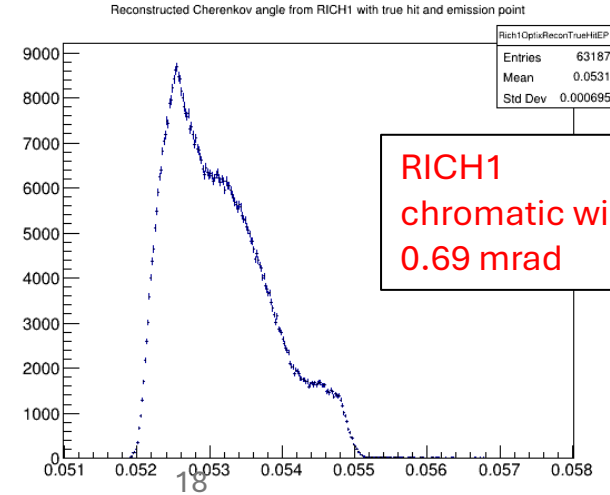
RICH1
Overall width=
0.81 mrad



RICH1
Pixel width=0.17 mrad



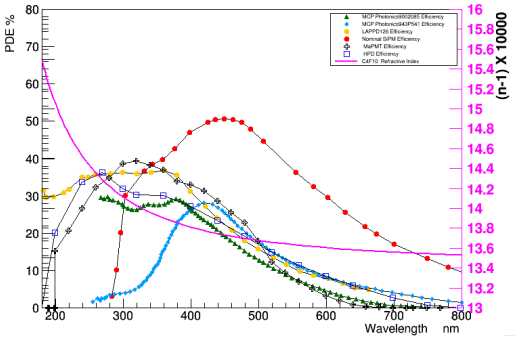
RICH1
Emission point
width=0.38mrad

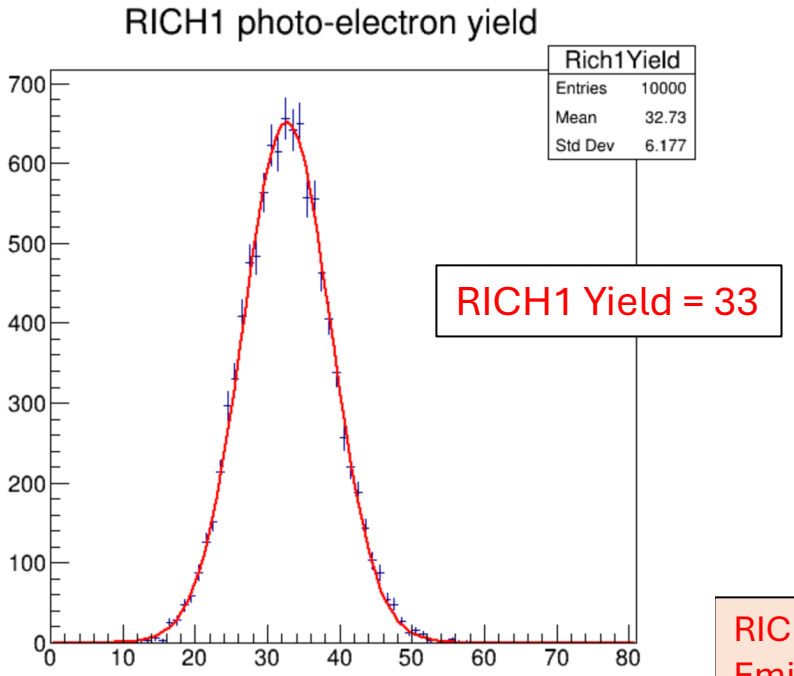


RICH1
chromatic width=
0.69 mrad

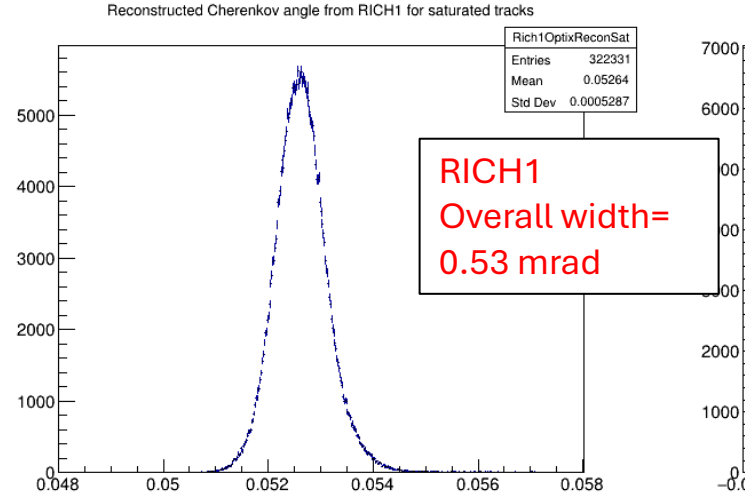
Run3 Geo – 300nm wavelength cut-off

RICH 1 with Photonis 9002085 (green curve)

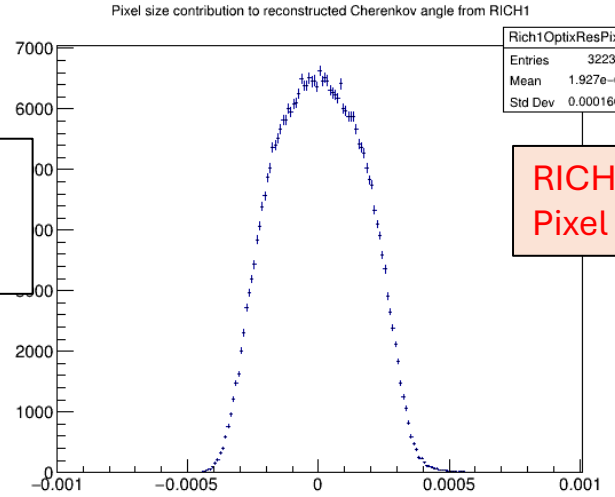




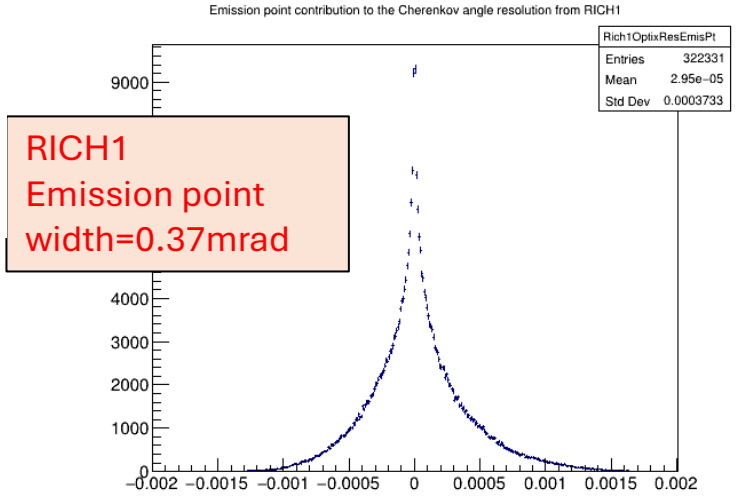
RICH1 Yield = 33



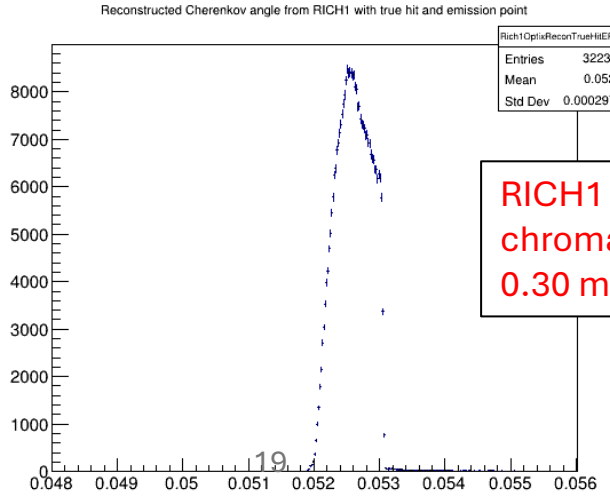
RICH1
Overall width=
0.53 mrad



RICH1
Pixel width=0.17 mrad



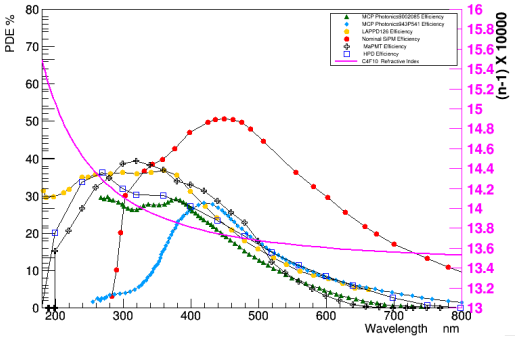
RICH1
Emission point
width=0.37mrad

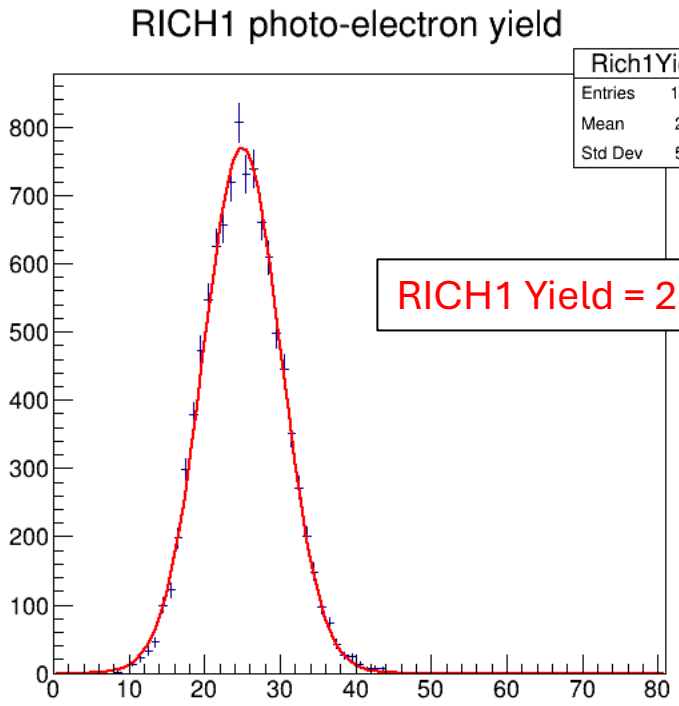


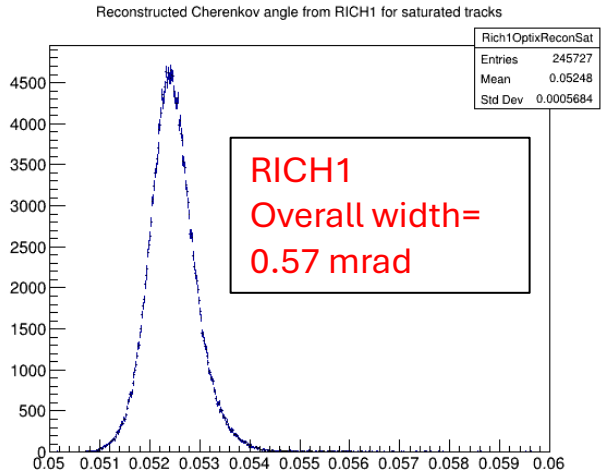
RICH1
chromatic width=
0.30 mrad

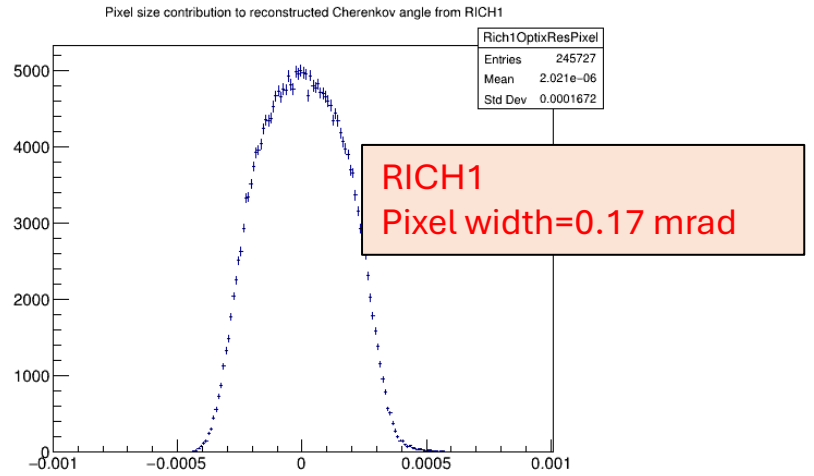
Run3 Geo – 300nm wavelength cut-off

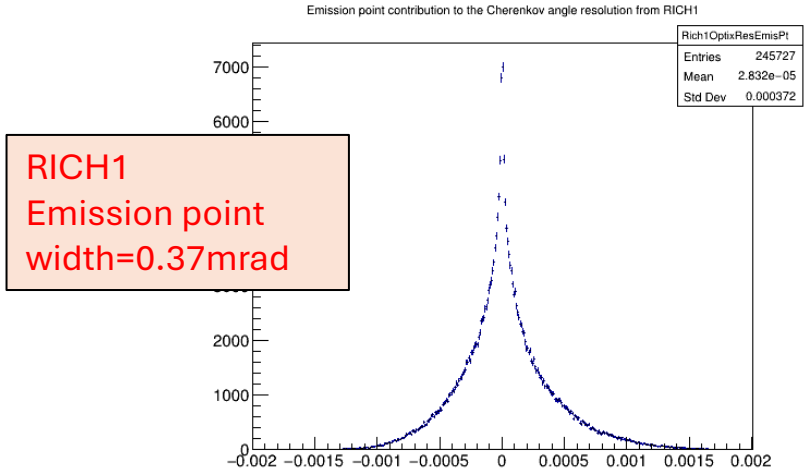
RICH 1 with Photonis 943P541 (blue curve)

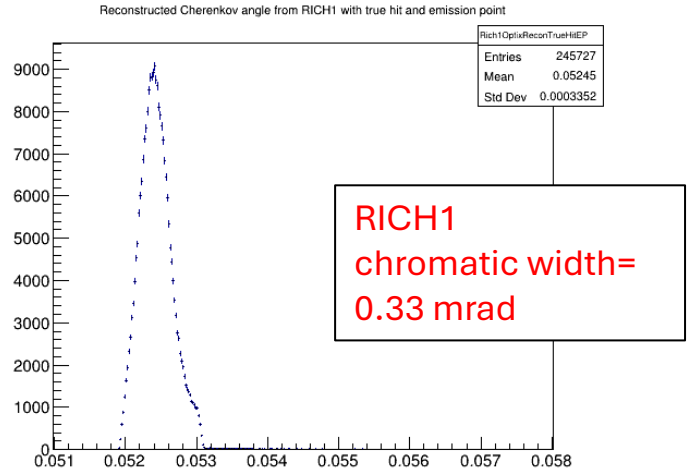






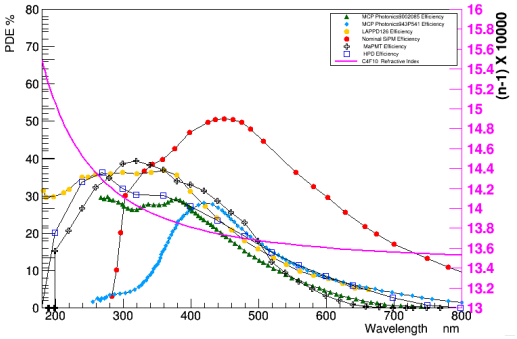




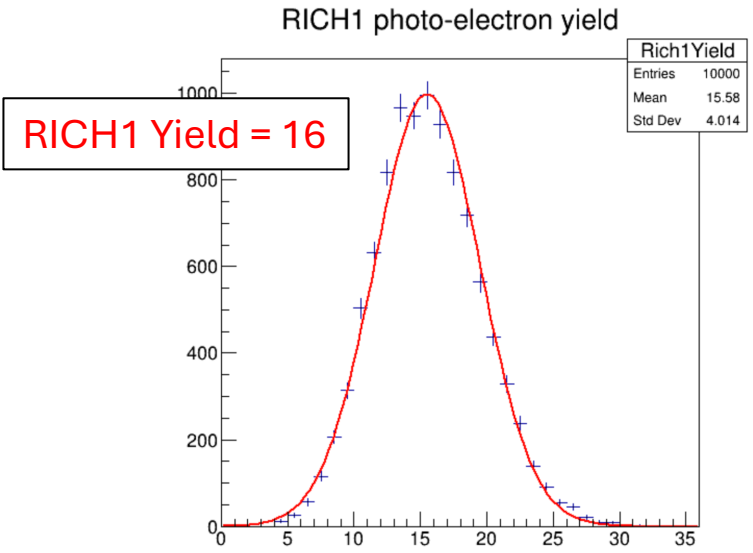


Run3 Geo – 400nm wavelength cut-off

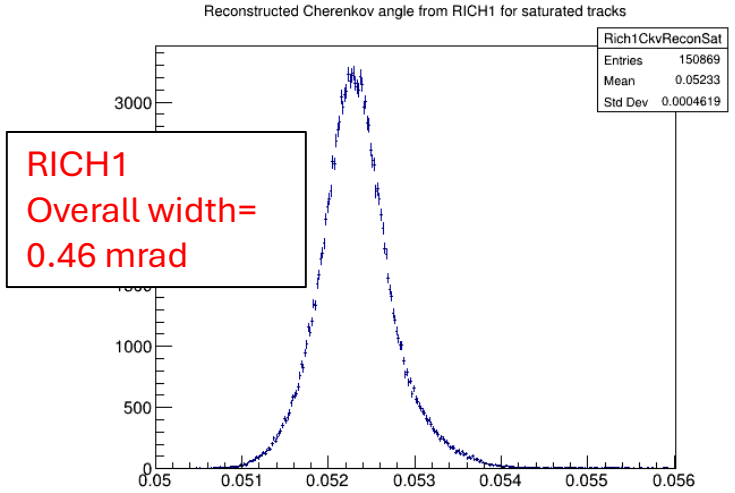
RICH1 with Photonis 943P541 (blue curve)



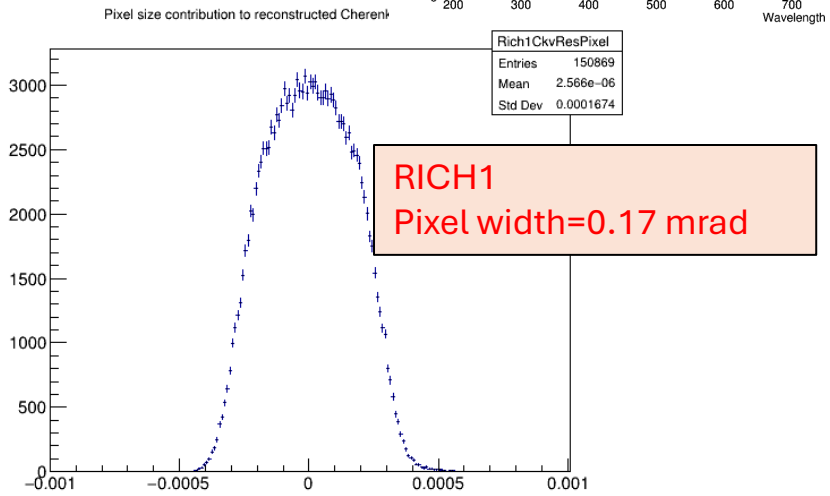
RICH1 Yield = 16



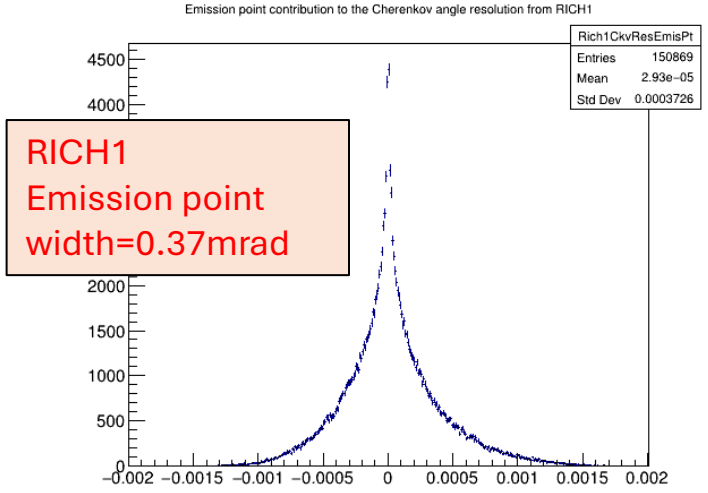
RICH1
Overall width=
0.46 mrad



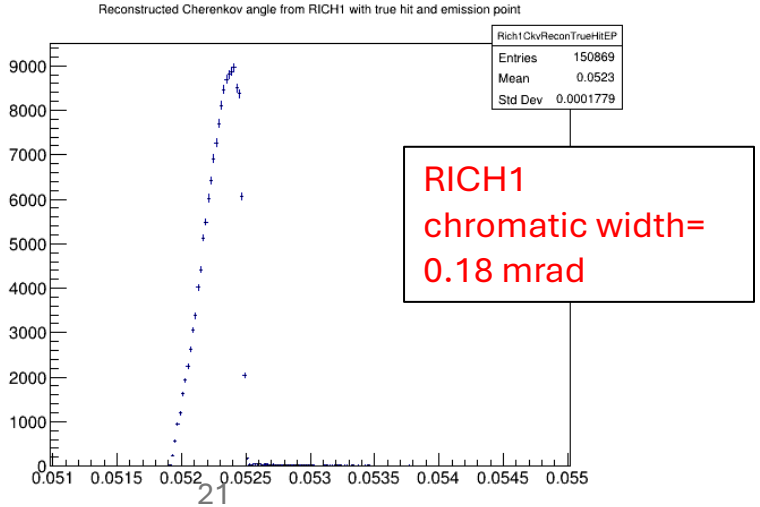
RICH1
Pixel width=0.17 mrad



RICH1
Emission point
width=0.37mrad



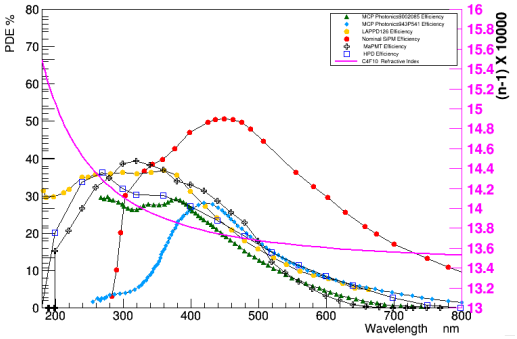
RICH1
chromatic width=
0.18 mrad



Run 3 Geometry
RICH2

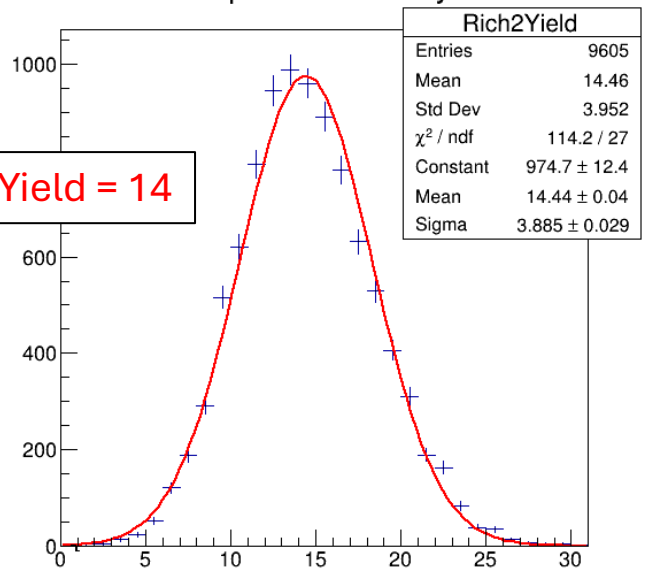
Run3 Geo - NO wavelength cut-off

RICH2 with Photonis 943P541 (blue curve)



Yields

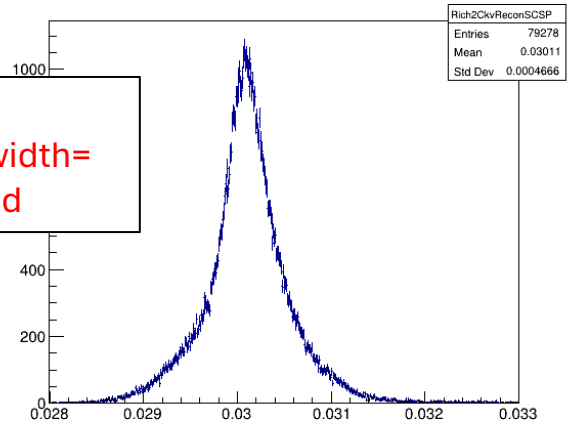
RICH2 photo-electron yield



RICH2 Yield = 14

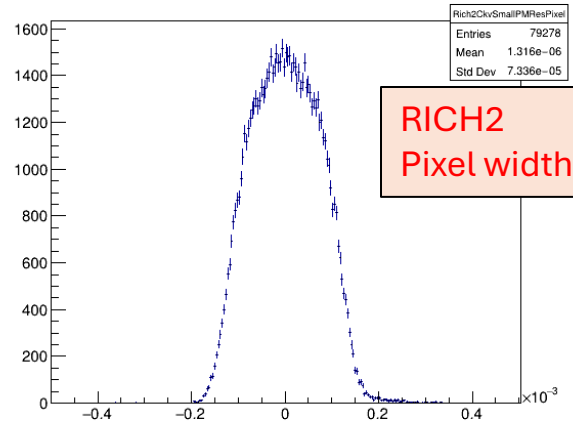
Resolutions

Reconstructed Cherenkov angle from RICH2 with small pmts



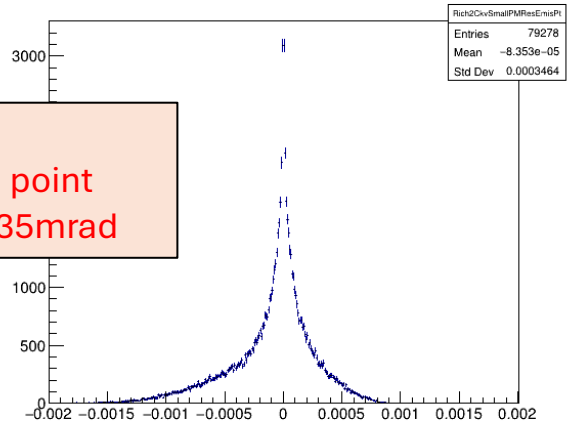
RICH2
Overall width=
0.47 mrad

Pixel size contribution to resolution from RICH2 with small pmts

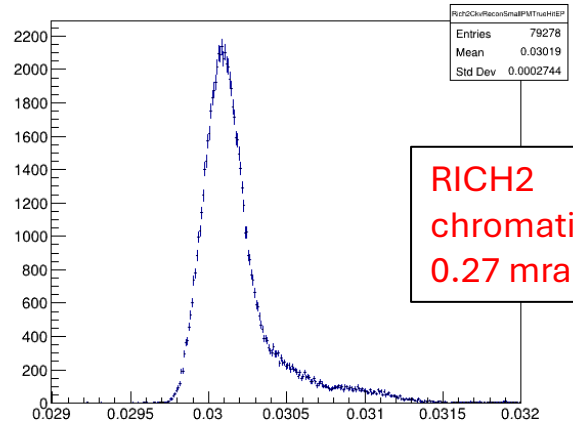


RICH2
Pixel width=0.07 mrad

Emission Point contribution to resolution from RICH2 with small pmts



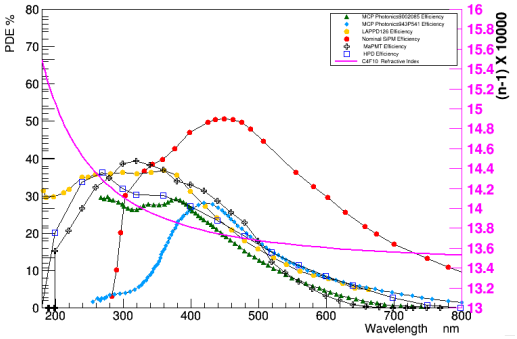
RICH2
Emission point
width=0.35mrad

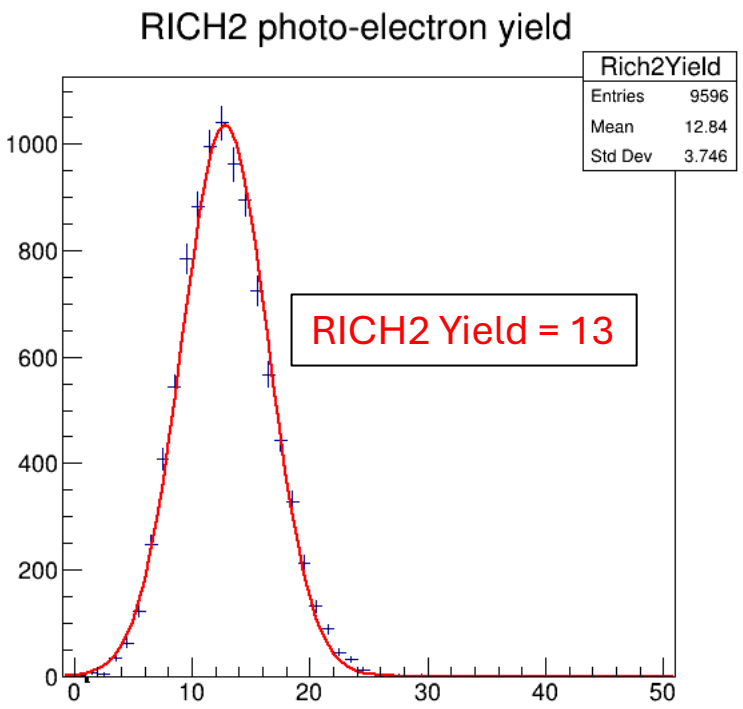


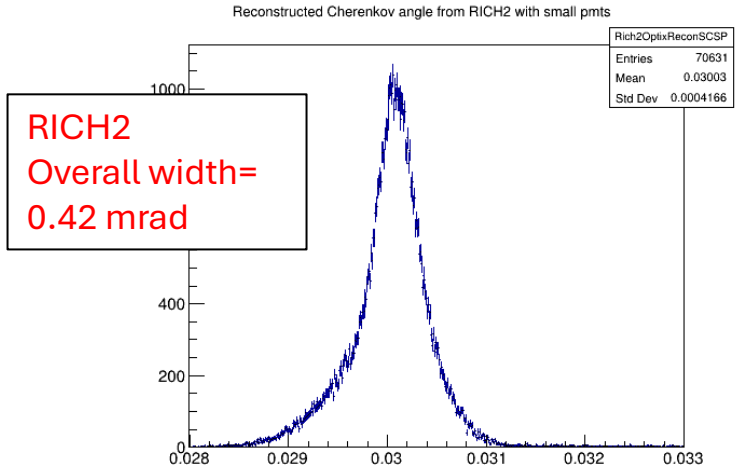
RICH2
chromatic width=
0.27 mrad

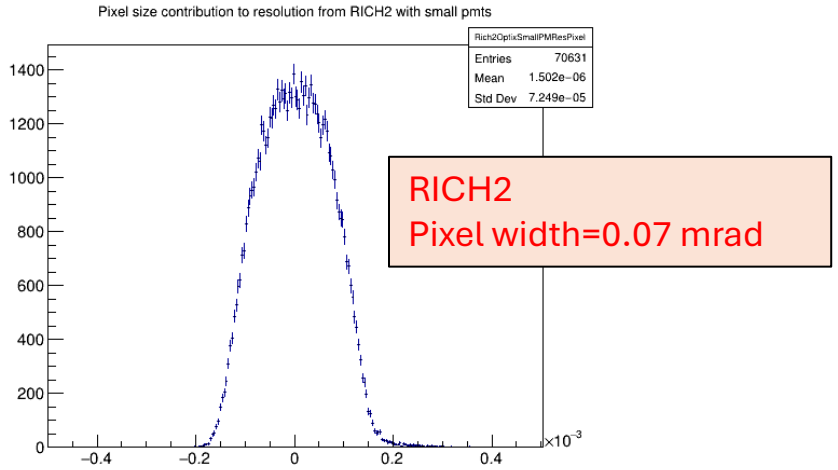
Run3 Geo – 300nm wavelength cut-off

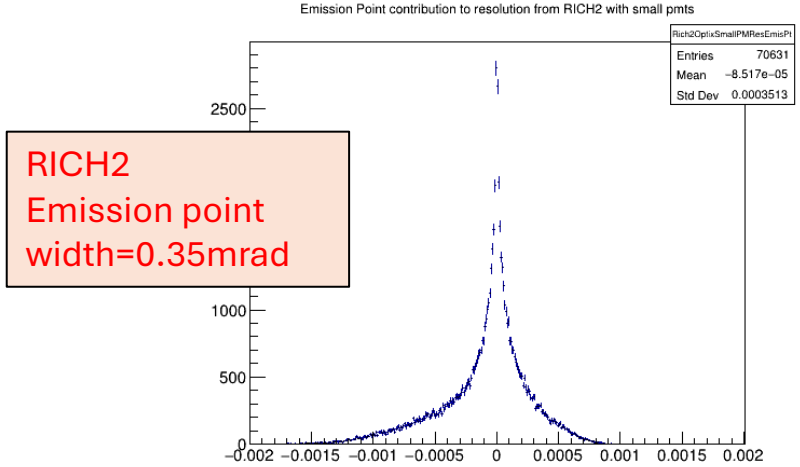
RICH 2 with Photonis 943P541 (blue curve)

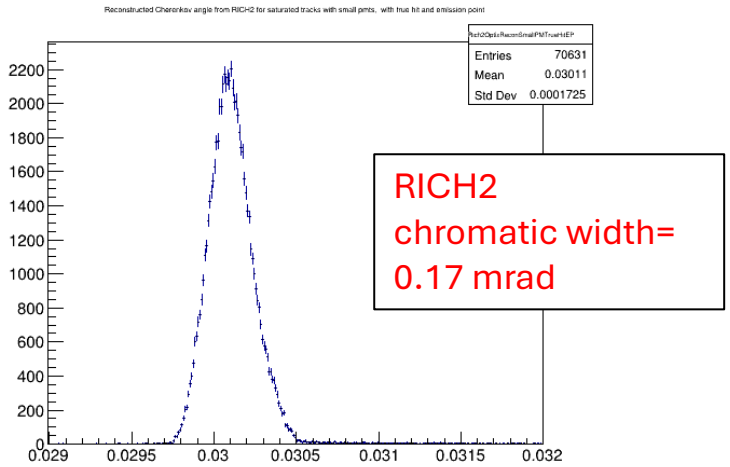






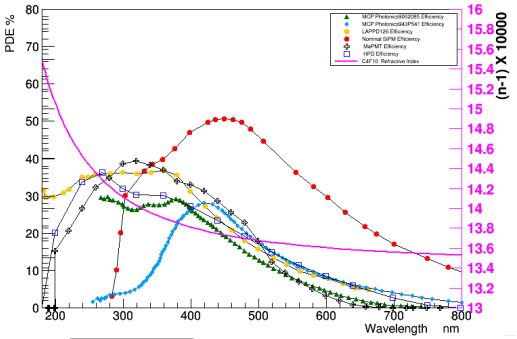




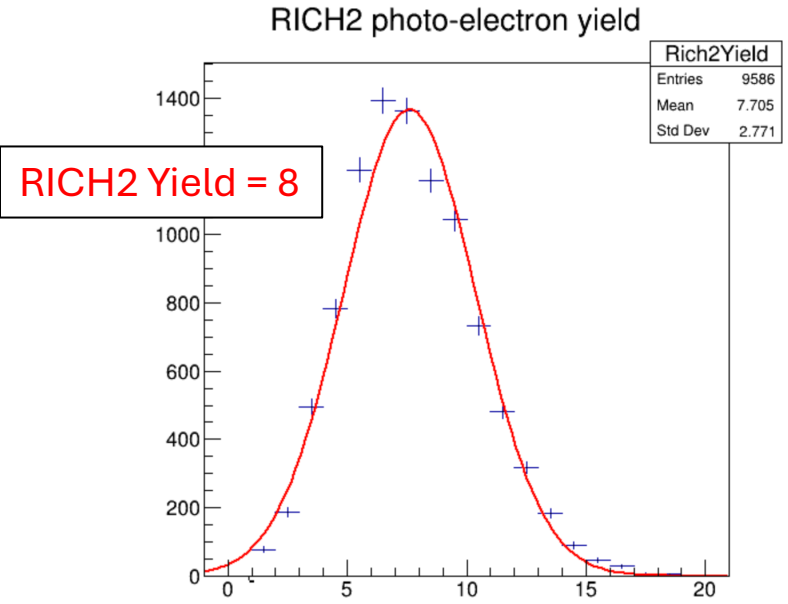


Run3 Geo – 400nm wavelength cut-off

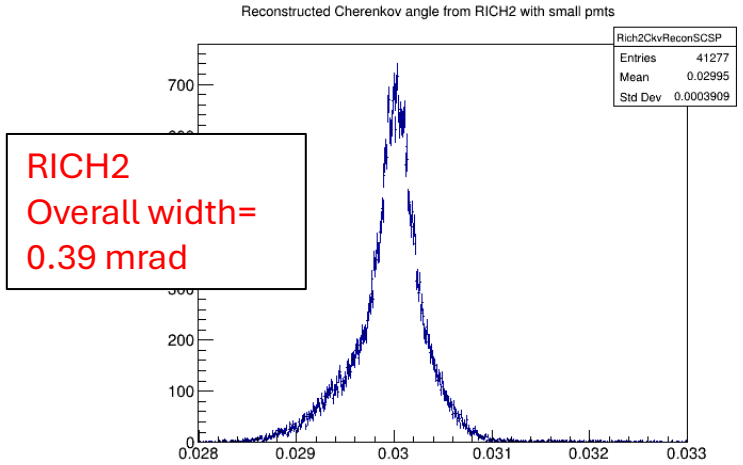
RICH2 with Photonis 943P541 (blue curve)



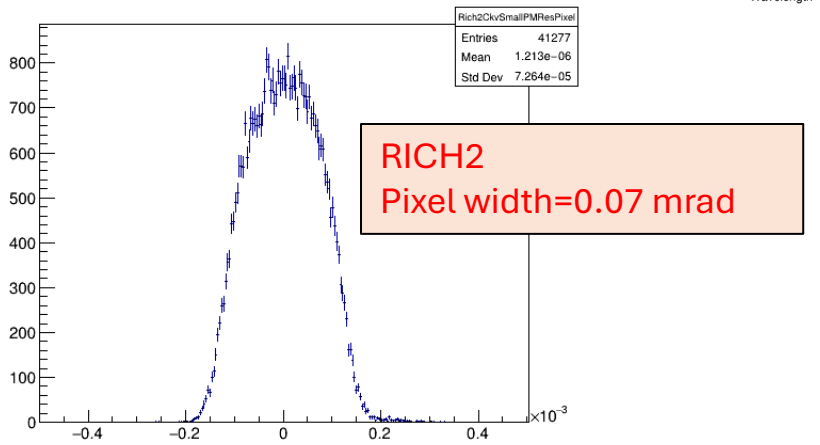
RICH2 Yield = 8



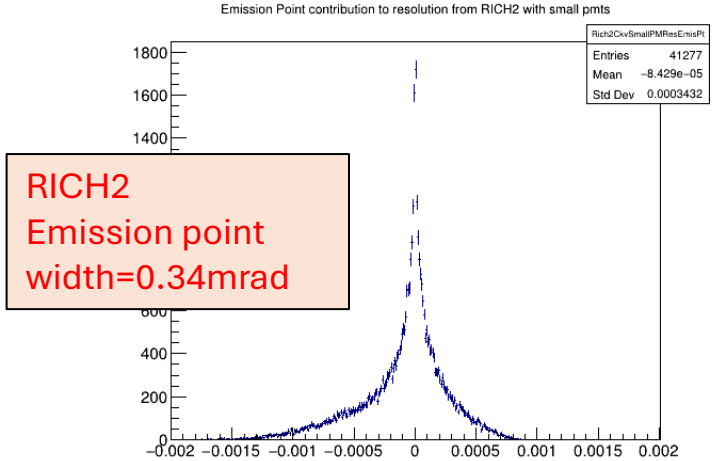
RICH2
Overall width=
0.39 mrad



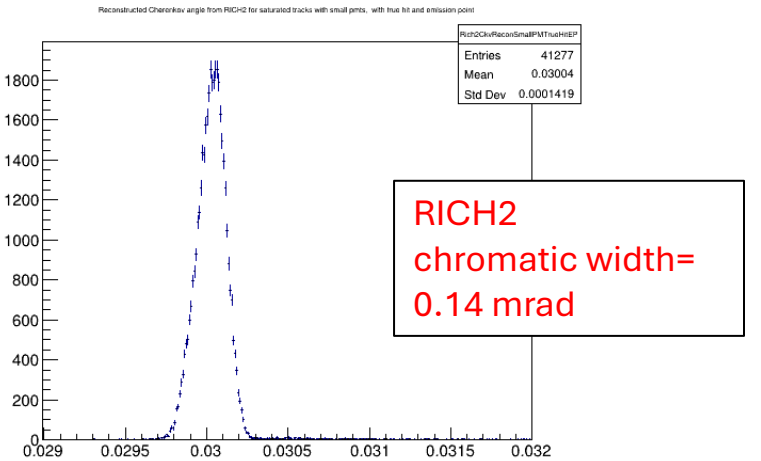
RICH2
Pixel width=0.07 mrad



RICH2
Emission point
width=0.34mrad

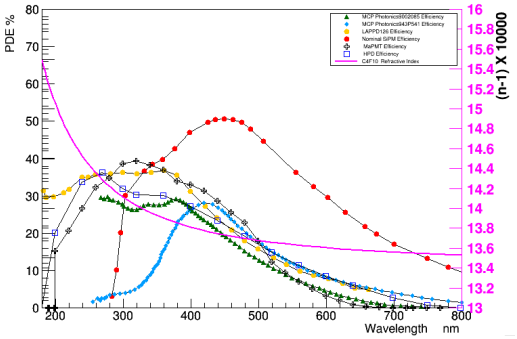


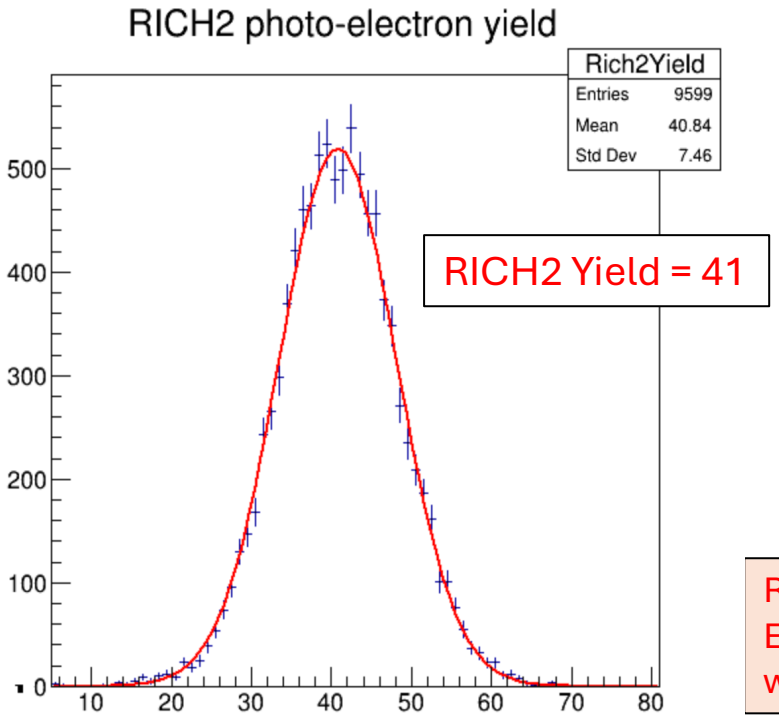
RICH2
chromatic width=
0.14 mrad



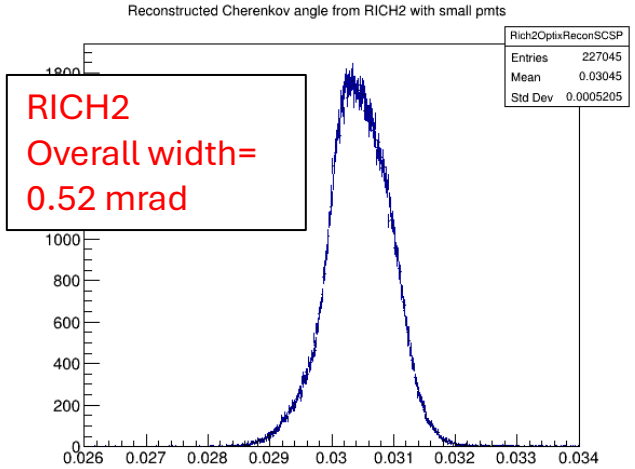
Run3 Geo - NO wavelength cut-off

RICH 2 with Photonis 9002085(green curve)

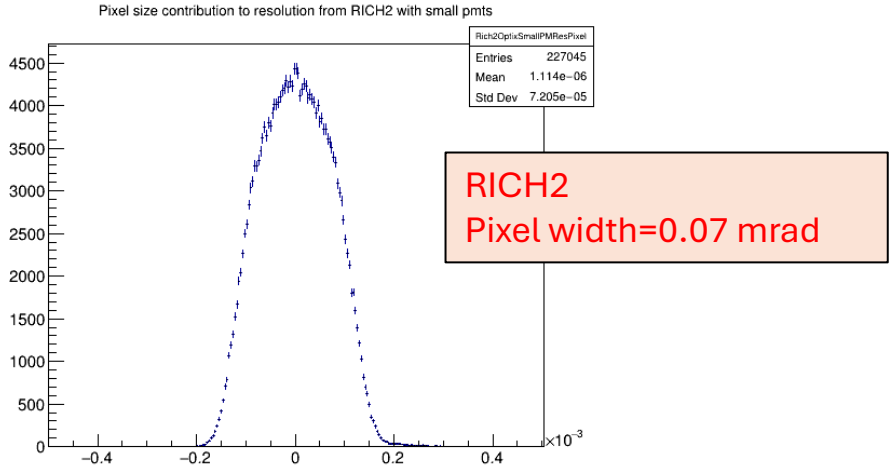




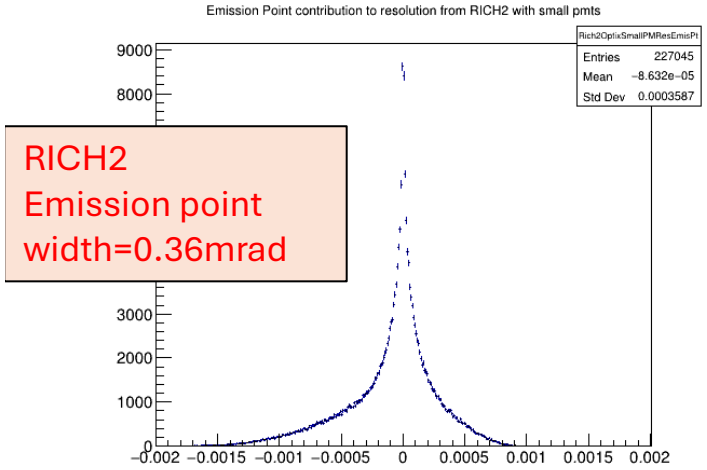
RICH2 Yield = 41



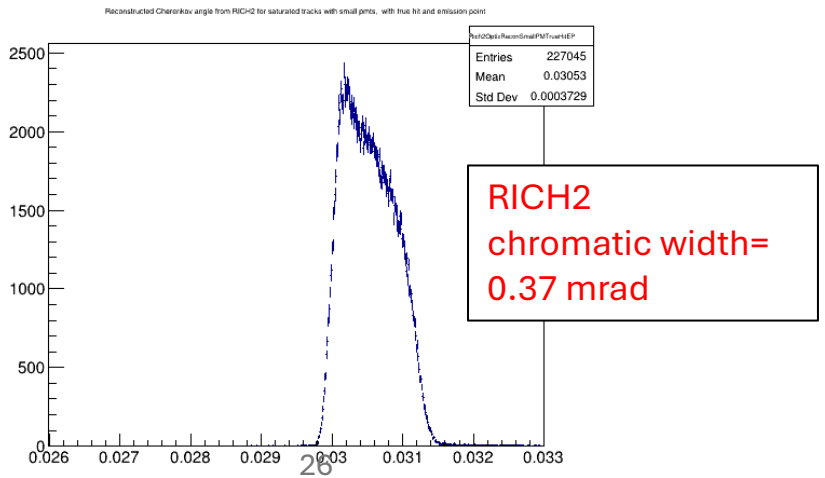
RICH2
Overall width=
0.52 mrad



RICH2
Pixel width=0.07 mrad



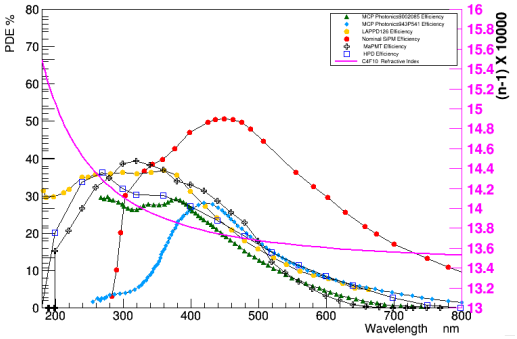
RICH2
Emission point
width=0.36mrad

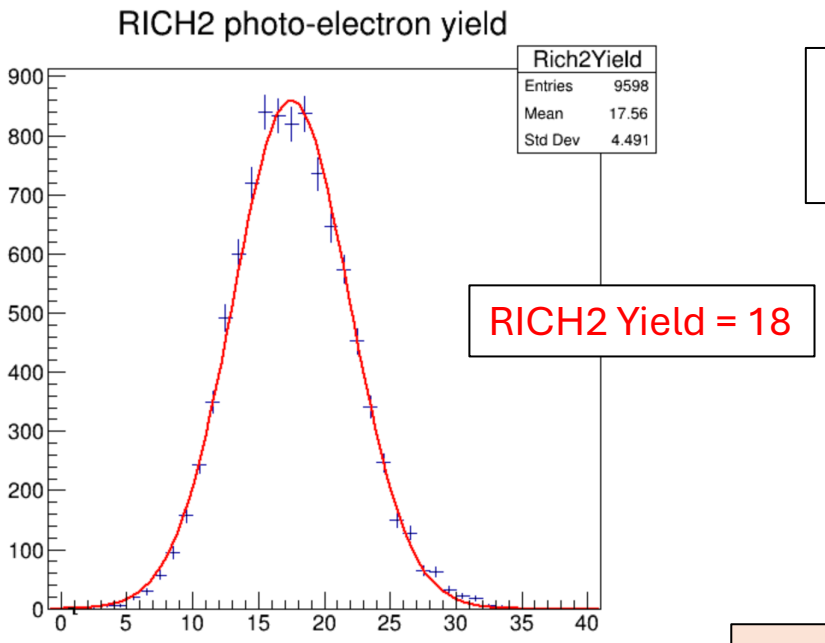


RICH2
chromatic width=
0.37 mrad

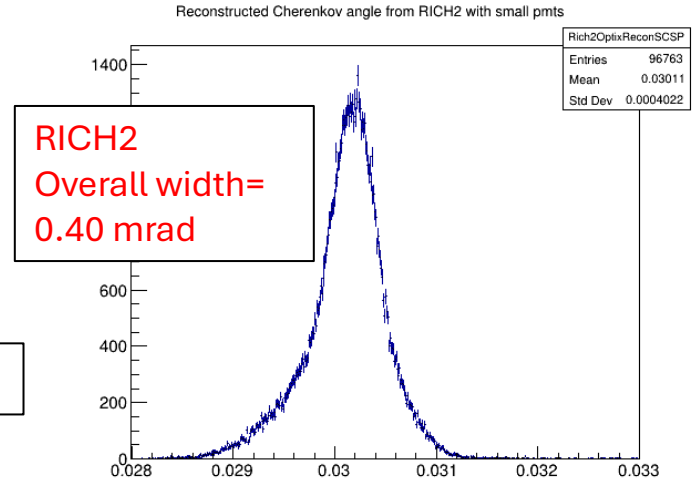
Run3 Geo – 300nm wavelength cut-off

RICH 2 with Photonis 9002085(green curve)

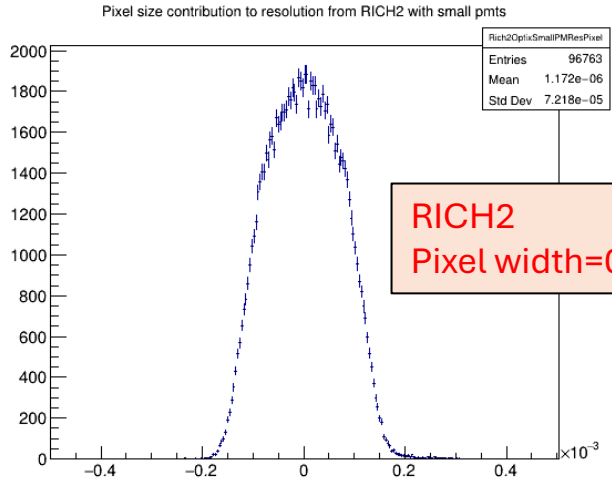




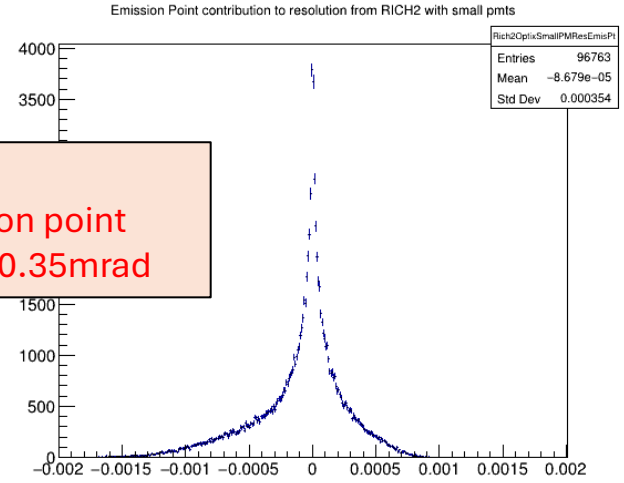
RICH2 Yield = 18



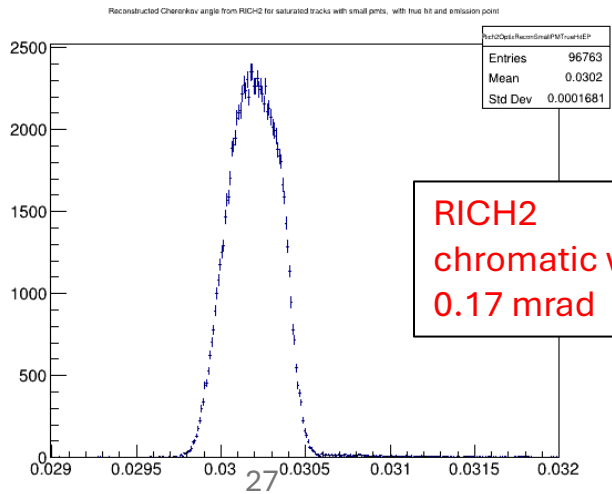
RICH2
Overall width=
0.40 mrad



RICH2
Pixel width=0.07 mrad



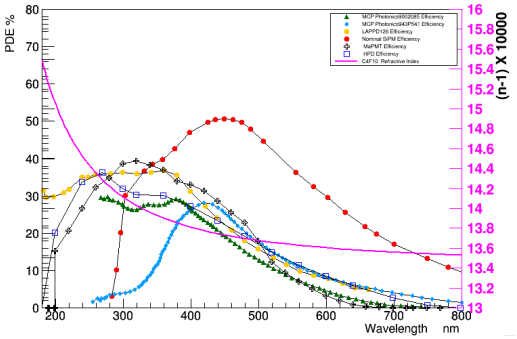
RICH2
Emission point
width=0.35mrad

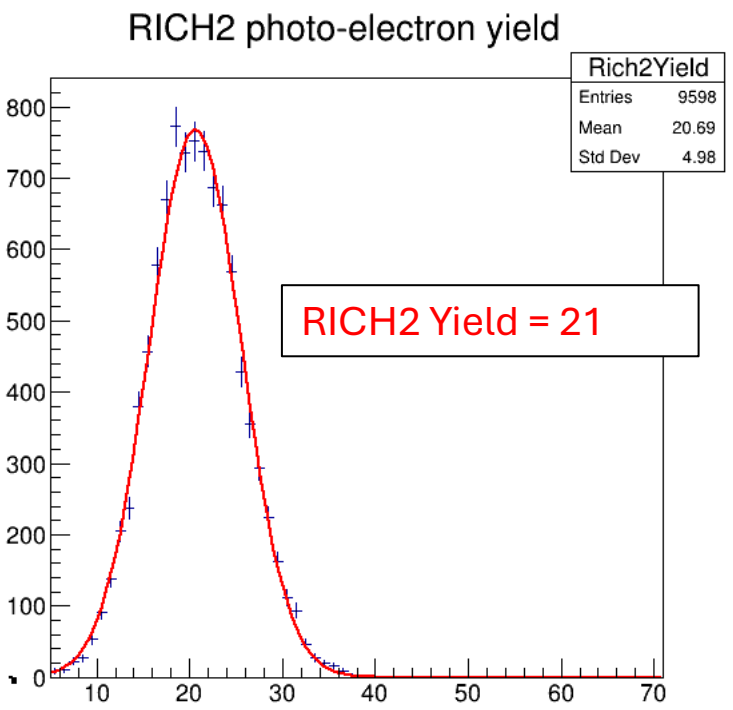


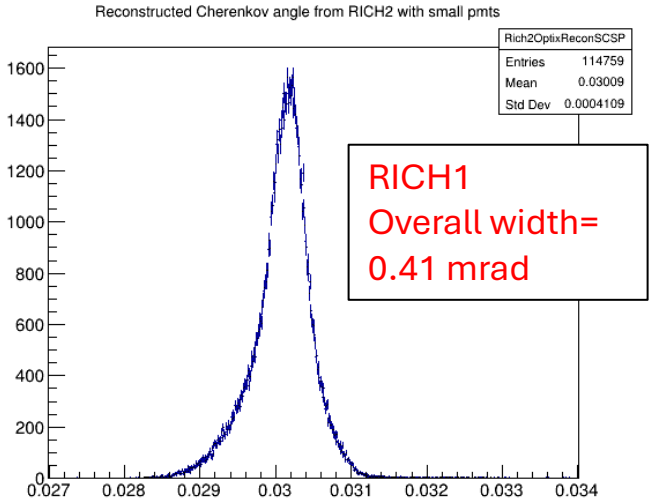
RICH2
chromatic width=
0.17 mrad

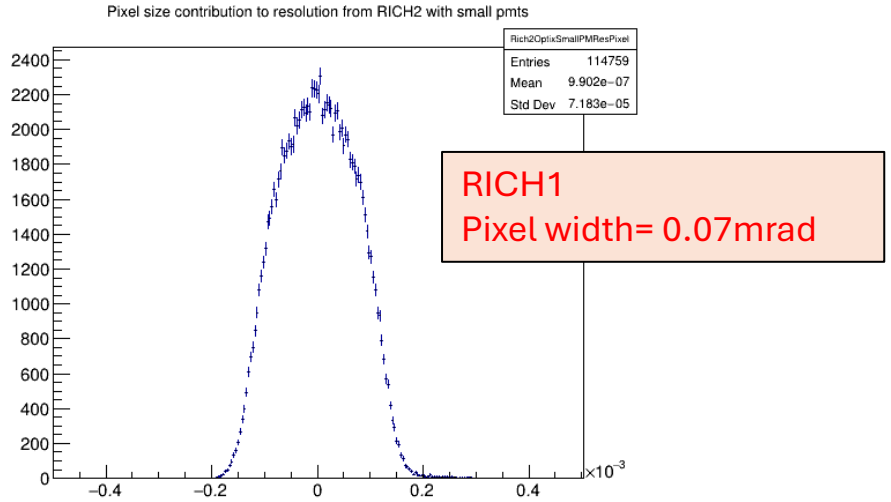
Run3 Geo – 300nm wavelength cut-off

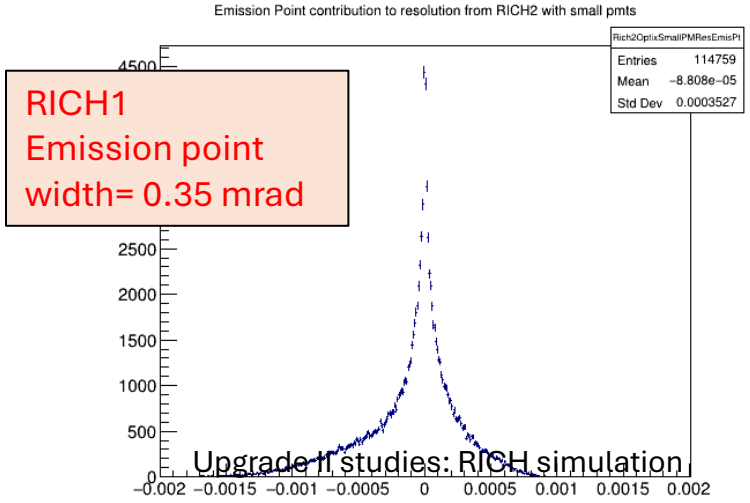
RICH 2 with LAPPD126(yellow curve)

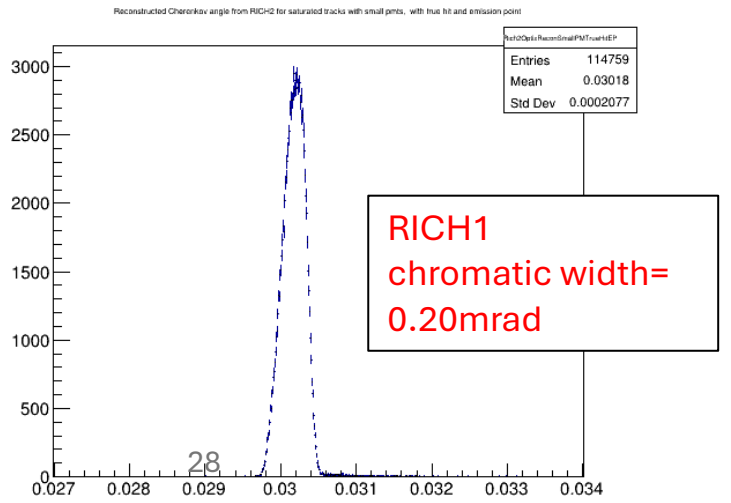








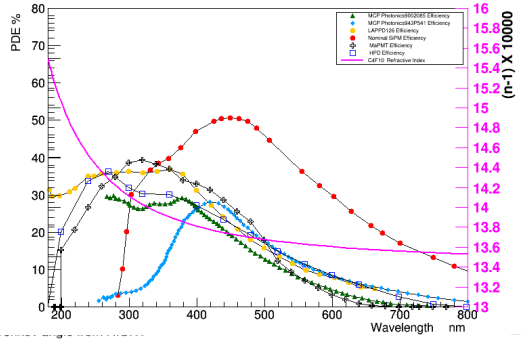




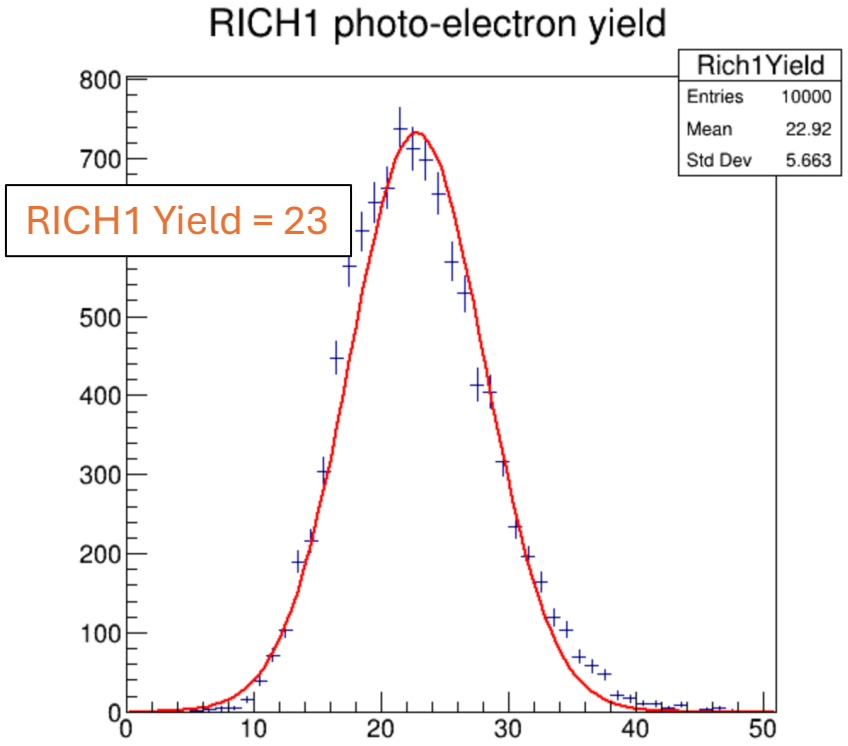
Upgraded Geometry (FTDR) RICH1

Run5 Geo - NO wavelength cut-off

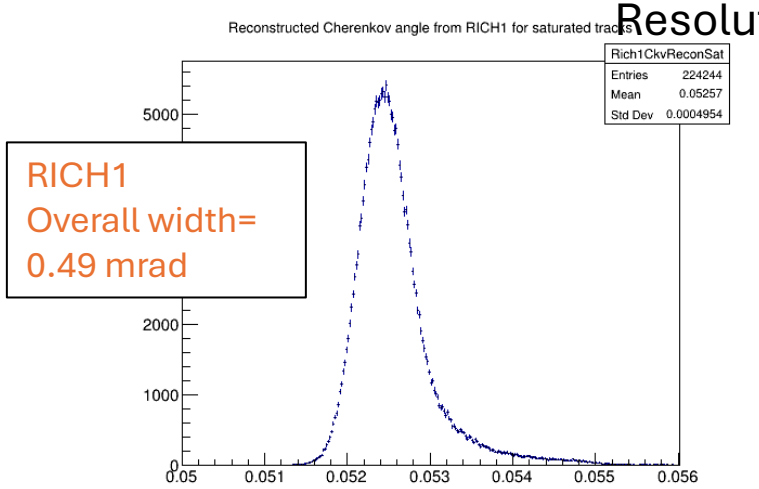
RICH 1 with Photonis 943P541 (blue curve)

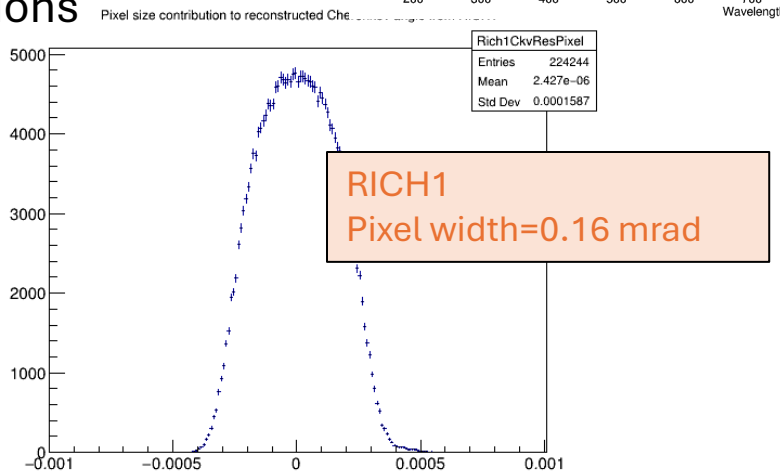


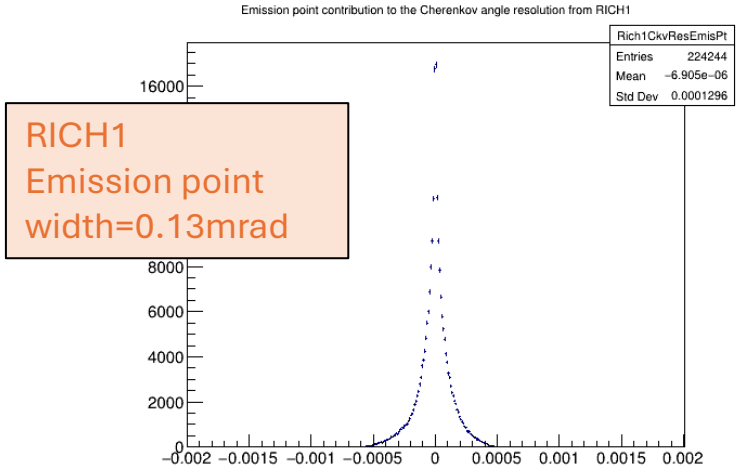
Yields

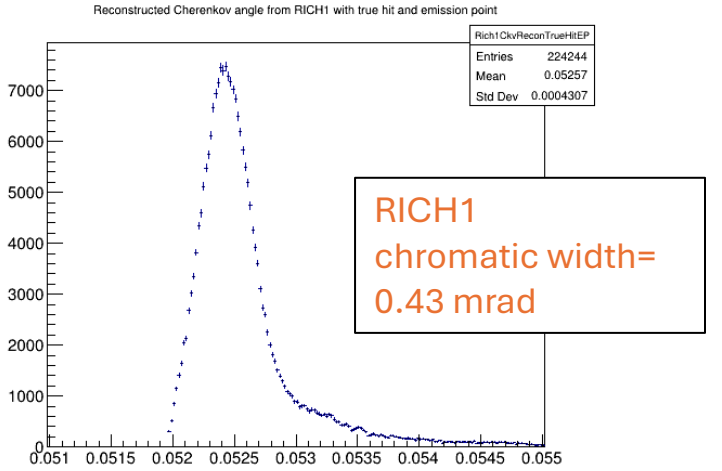


Resolutions



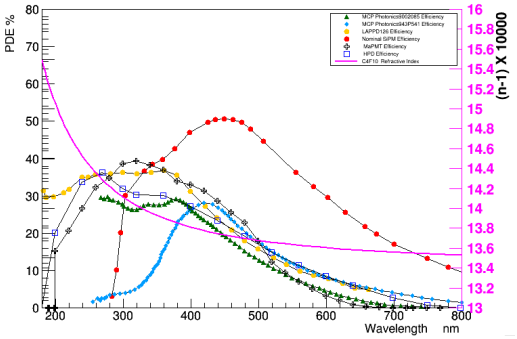


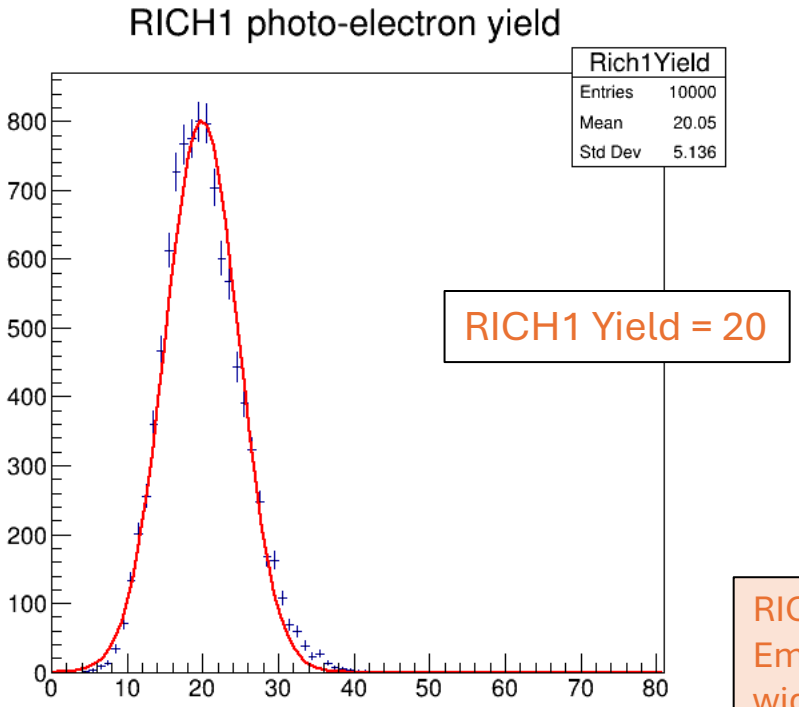




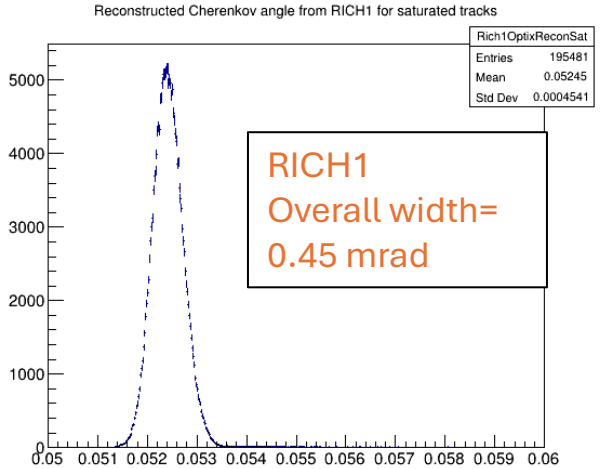
Run5 Geo – 300nm wavelength cut-off

RICH 1 with Photonis 943P541 (blue curve)

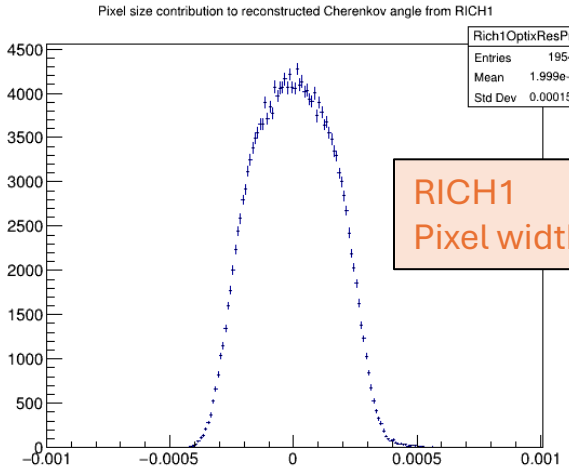




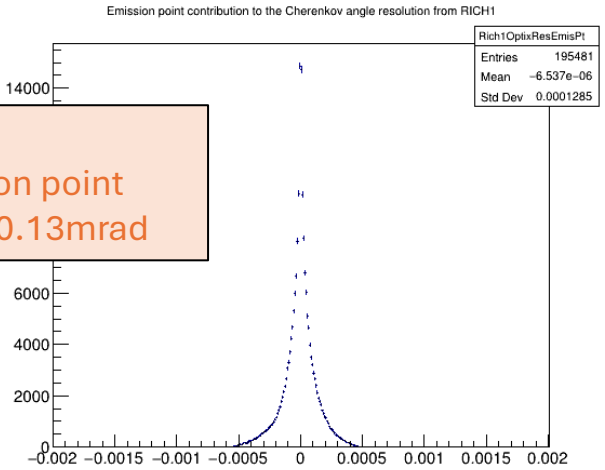
RICH1 Yield = 20



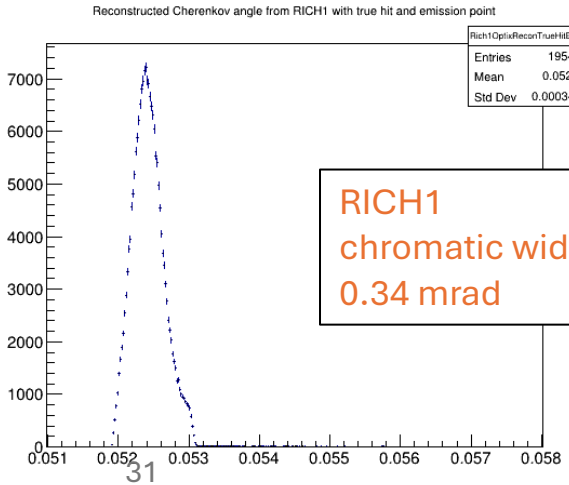
RICH1
Overall width=
0.45 mrad



RICH1
Pixel width=0.16 mrad

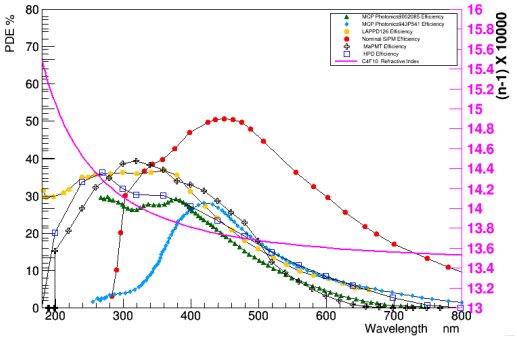


RICH1
Emission point
width=0.13mrad



RICH1
chromatic width=
0.34 mrad

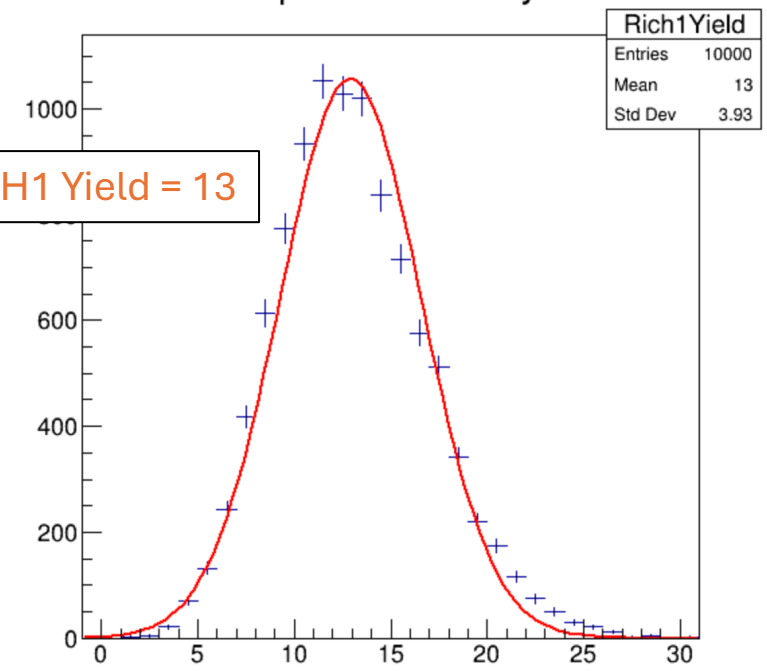
Run5 Geo – 400nm wavelength cut-of



RICH 1 with Photonis 943P541 (blue curve)

Yields

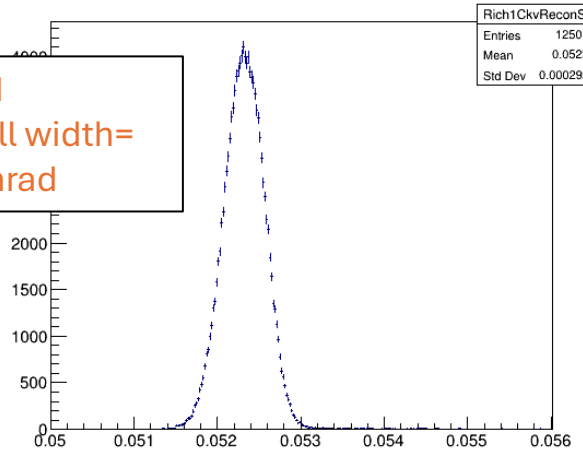
RICH1 photo-electron yield



RICH1 Yield = 13

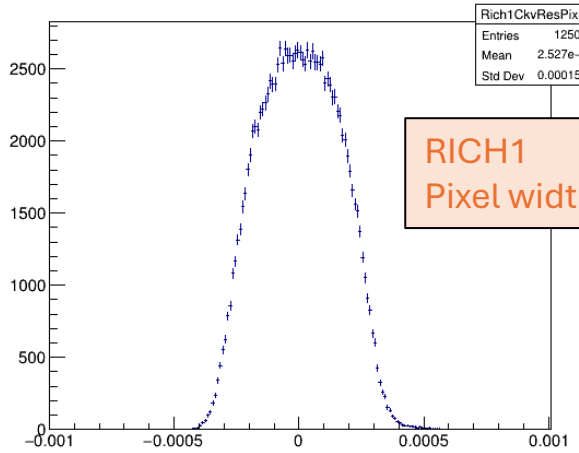
Resolutions

Reconstructed Cherenkov angle from RICH1 for saturated tracks



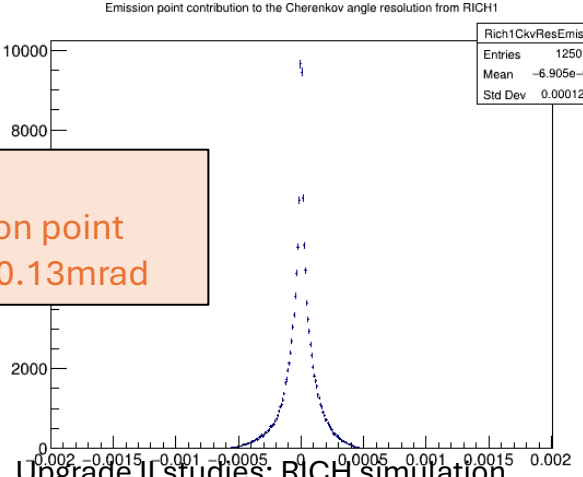
RICH1
Overall width=
0.30mrad

Pixel size contribution to reconstructed Cherenkov angle from RICH1



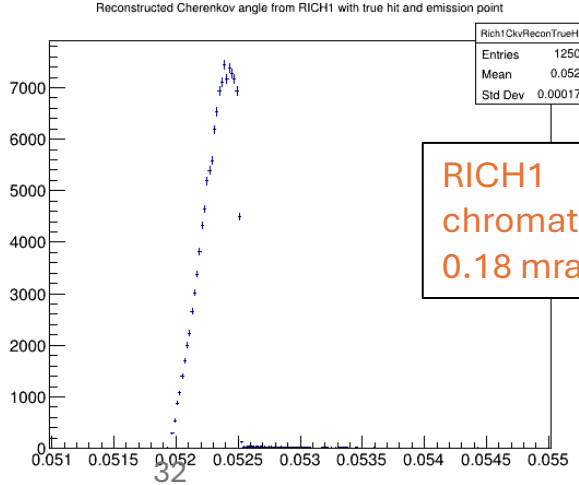
RICH1
Pixel width=0.16 mrad

Emission point contribution to the Cherenkov angle resolution from RICH1



RICH1
Emission point
width=0.13mrad

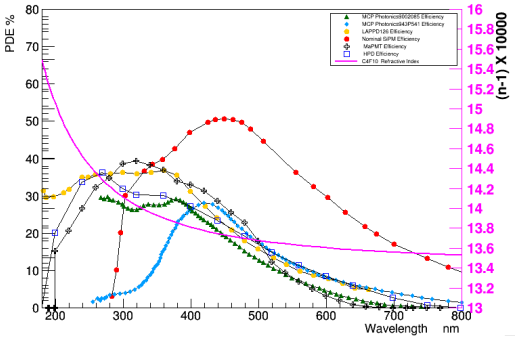
Reconstructed Cherenkov angle from RICH1 with true hit and emission point

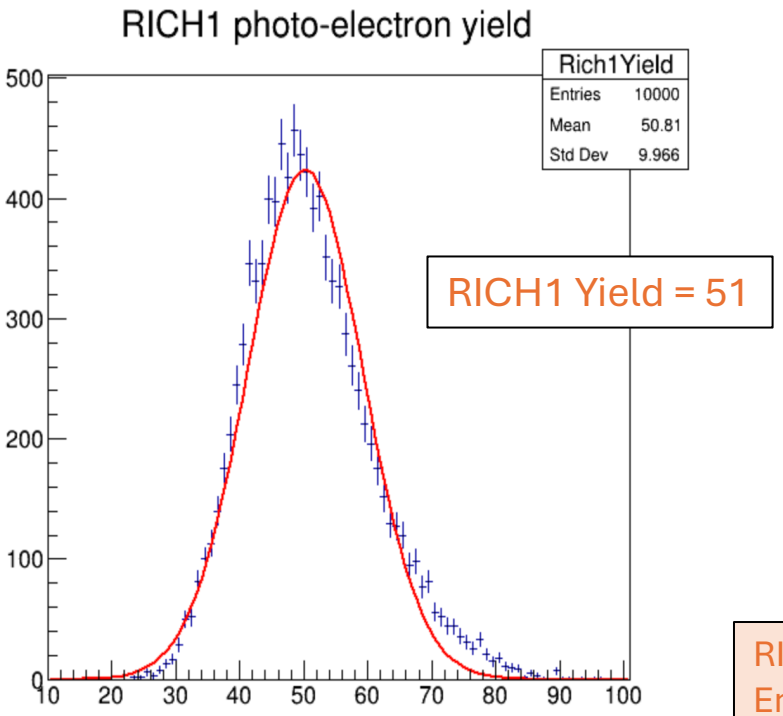


RICH1
chromatic width=
0.18 mrad

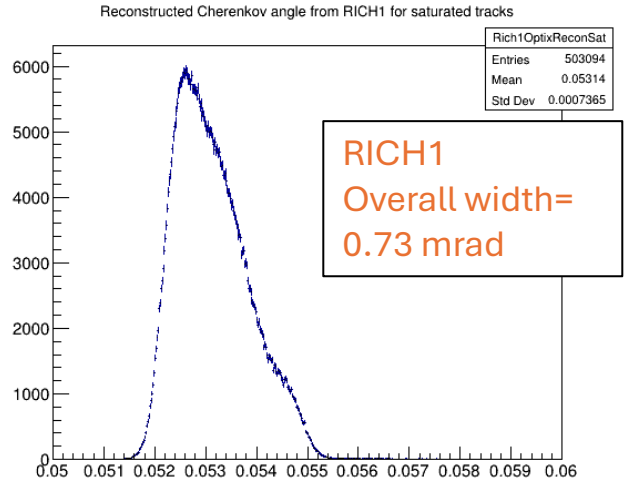
Run5 Geo - NO wavelength cut-off

RICH 1 with Photonis 9002085(green curve)

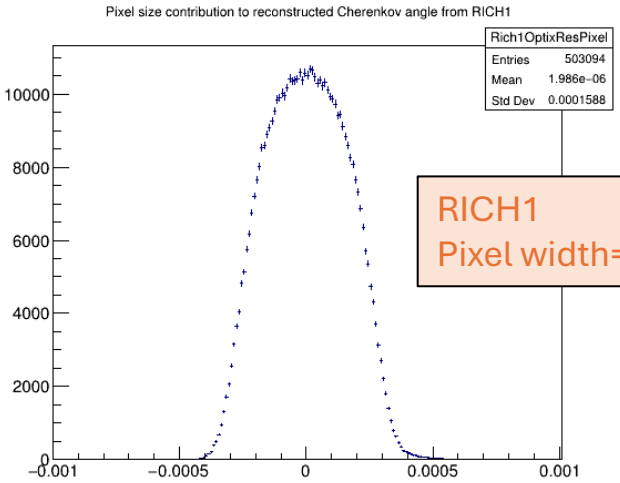




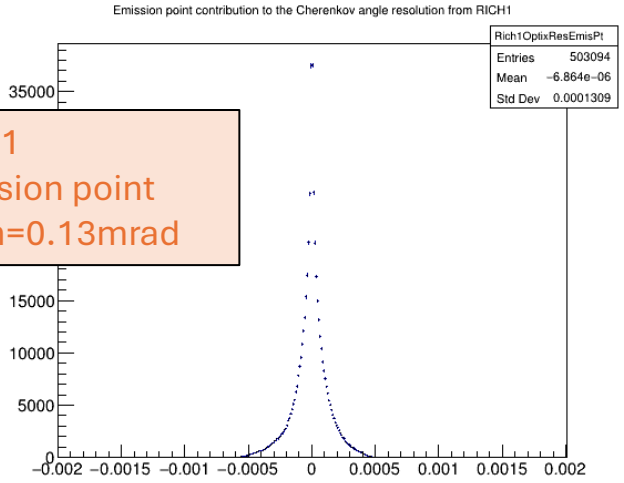
RICH1 Yield = 51



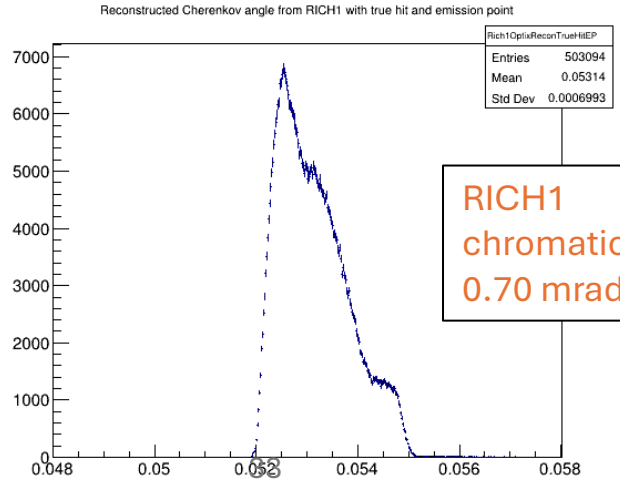
RICH1
Overall width=
0.73 mrad



RICH1
Pixel width=0.16 mrad



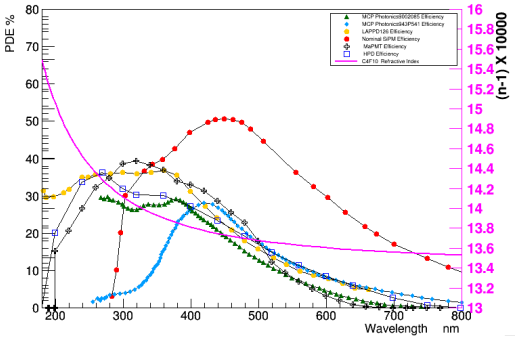
RICH1
Emission point
width=0.13mrad

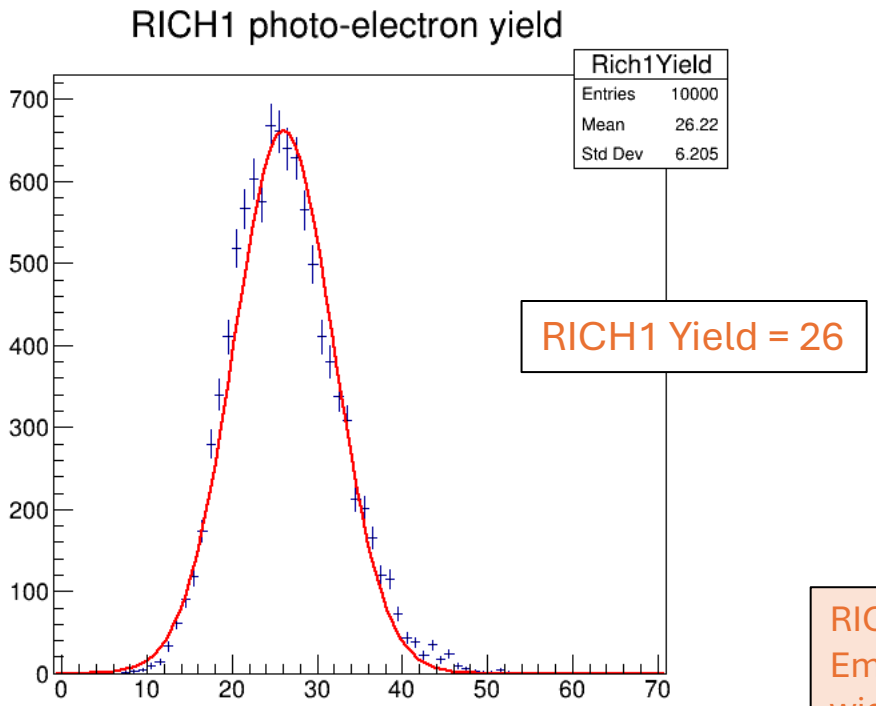


RICH1
chromatic width=
0.70 mrad

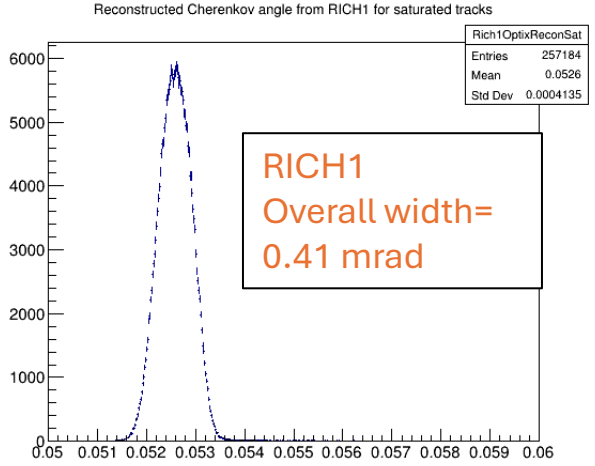
Run5 Geo – 300nm wavelength cut-off

RICH 1 with Photonis 9002085 (green curve)

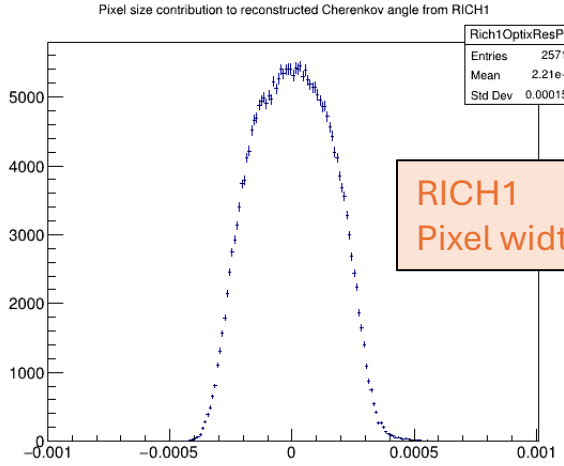




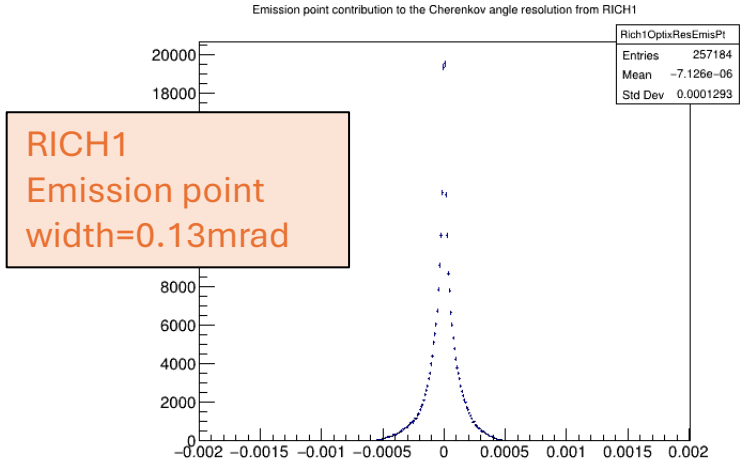
RICH1 Yield = 26



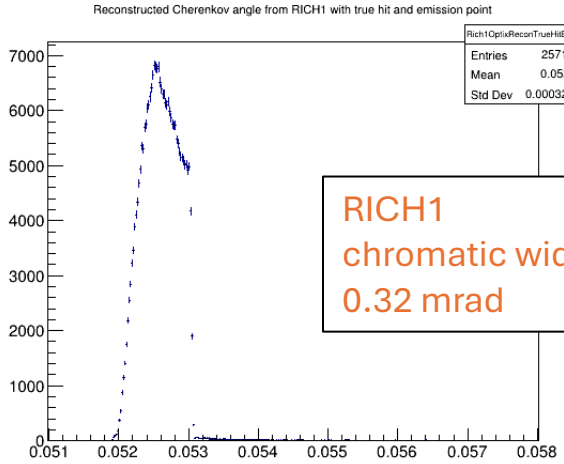
RICH1
Overall width=
0.41 mrad



RICH1
Pixel width=0.16 mrad



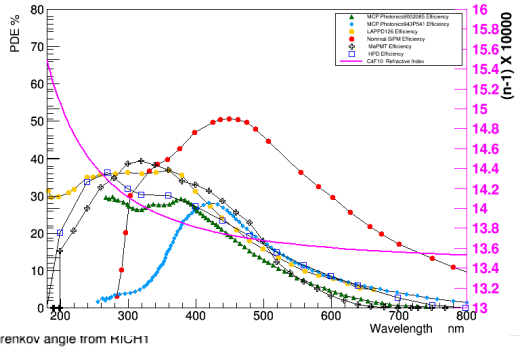
RICH1
Emission point
width=0.13mrad

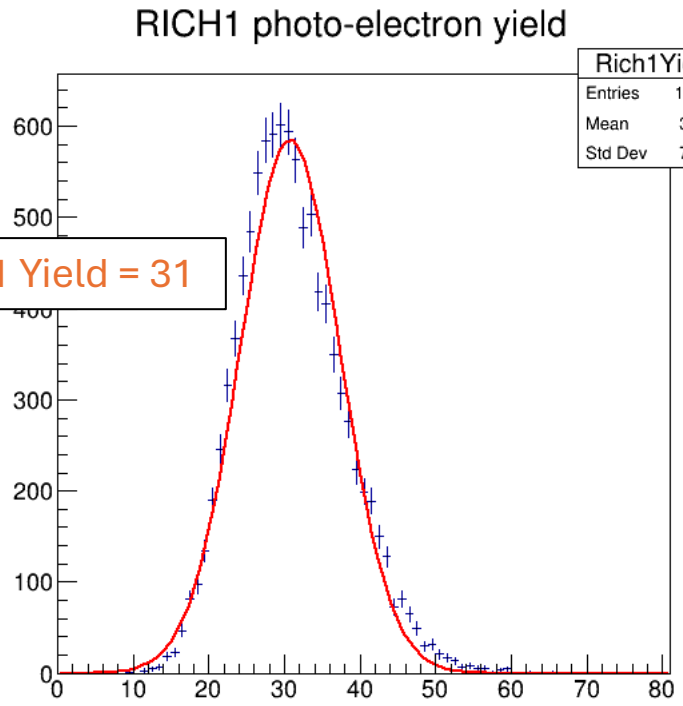


RICH1
chromatic width=
0.32 mrad

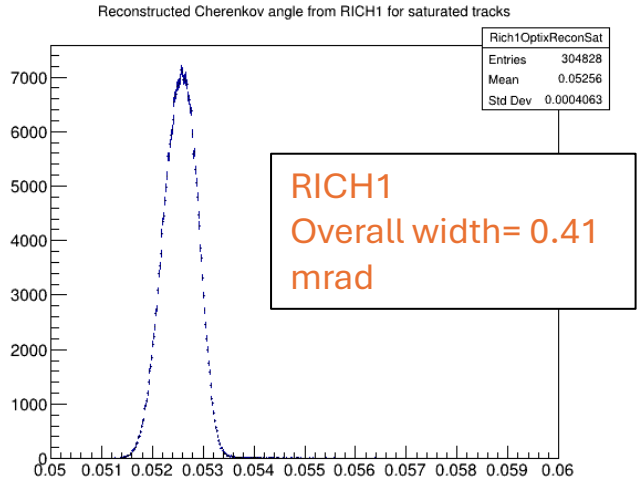
Run5 Geo – 300nm wavelength cut-off

RICH 1 with LAPPD126 (yellow curve)

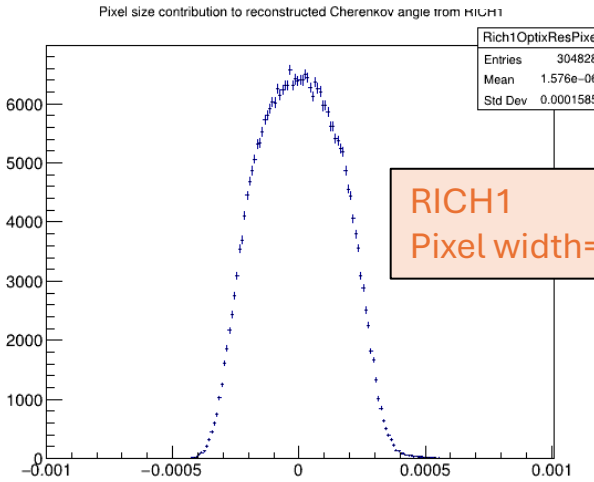




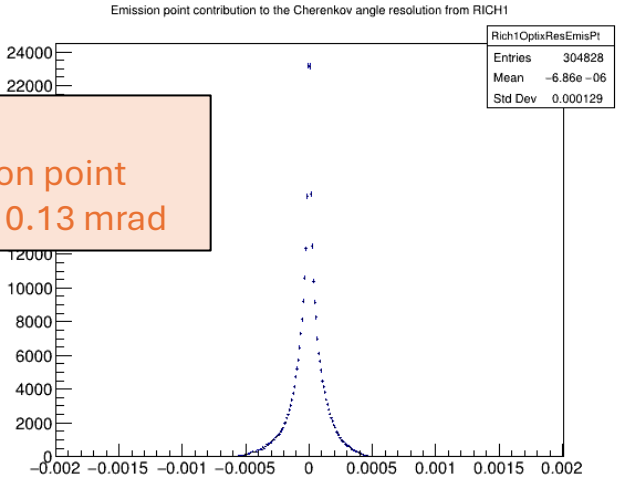
RICH1 Yield = 31



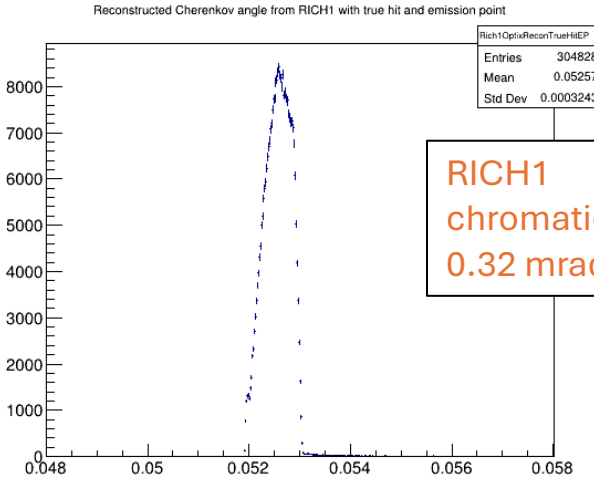
RICH1
Overall width= 0.41 mrad



RICH1
Pixel width= 0.16mrad



RICH1
Emission point width= 0.13 mrad

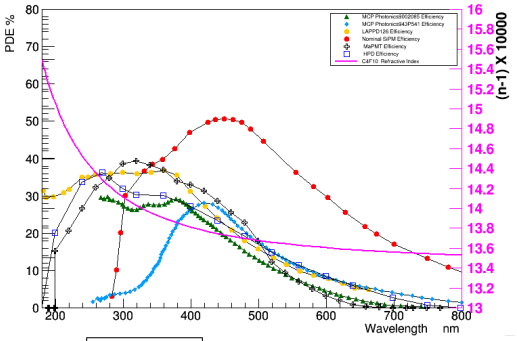


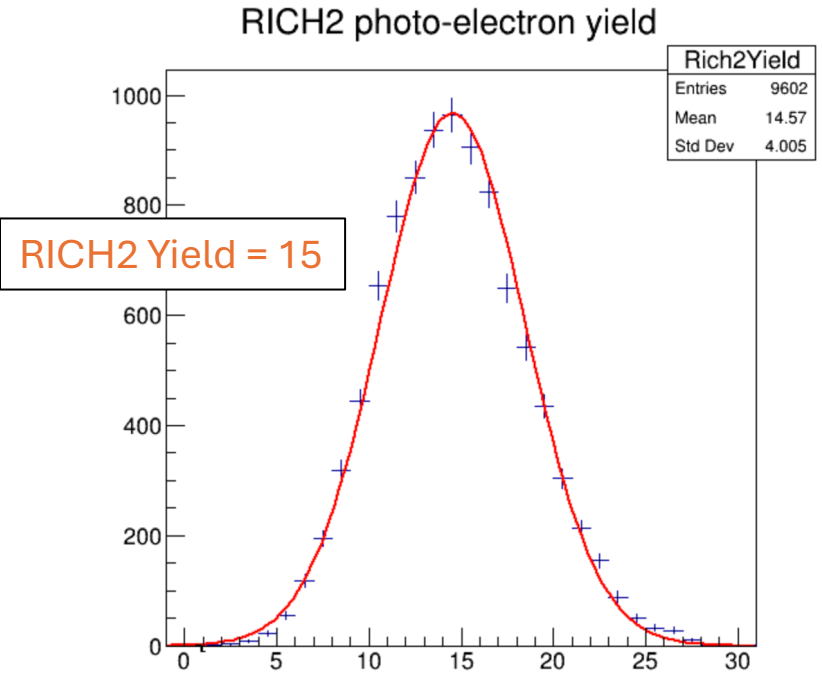
RICH1
chromatic width= 0.32 mrad

Upgraded Geometry (FTDR) RICH2

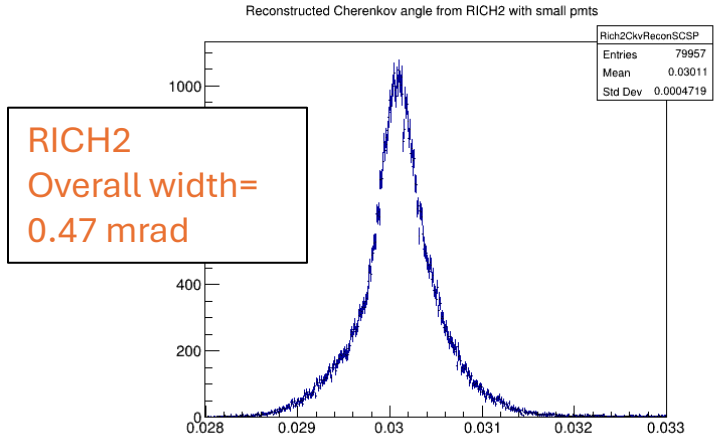
Run5 Geo - NO wavelength cut-off

RICH 2 with Photonis 943P541 (blue curve)

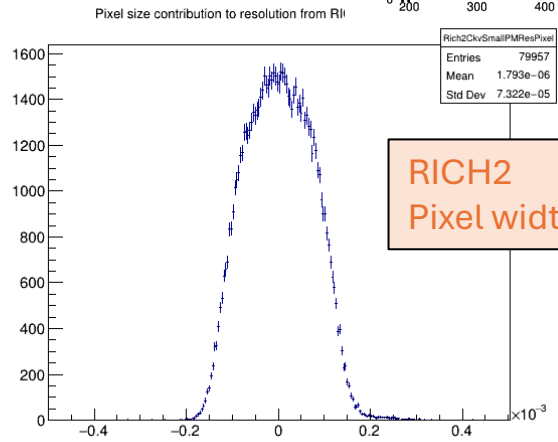




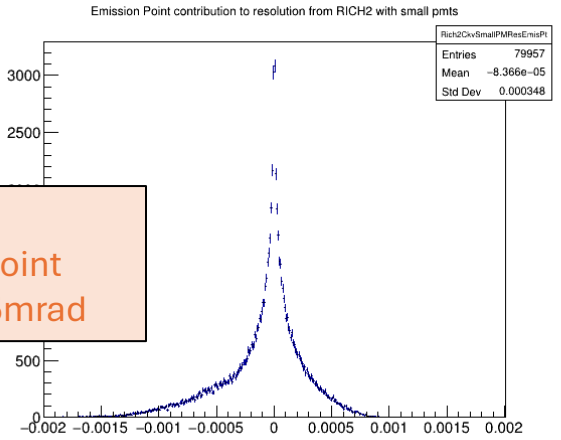
RICH2 Yield = 15



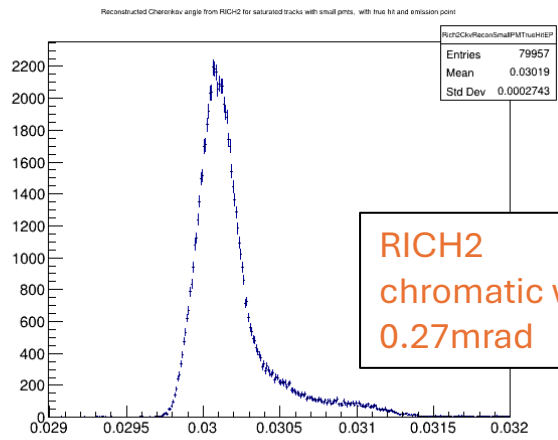
RICH2
Overall width=
0.47 mrad



RICH2
Pixel width=0.07 mrad



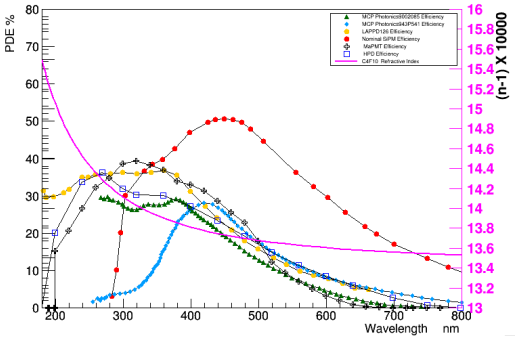
RICH2
Emission point
width=0.35mrad

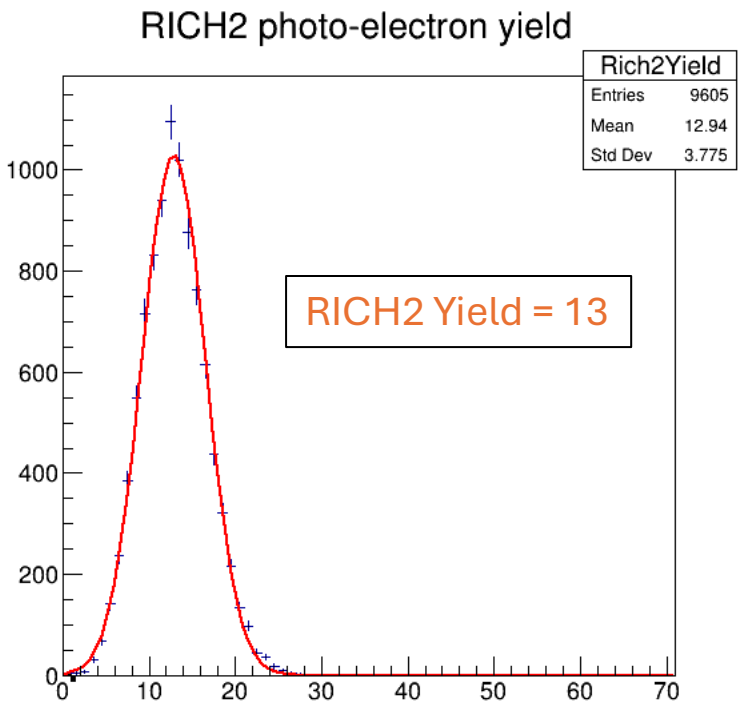


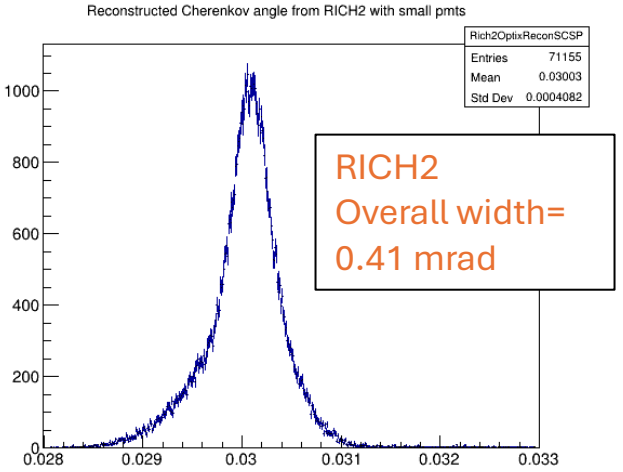
RICH2
chromatic width=
0.27mrad

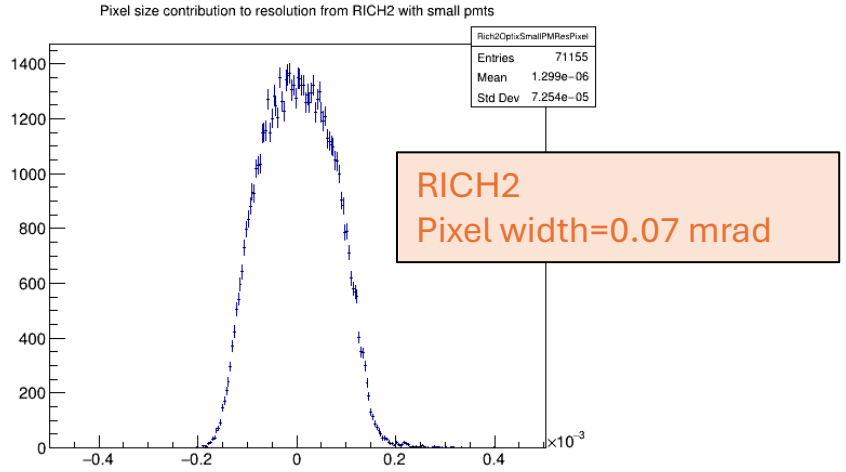
Run5 Geo – 300nm wavelength cut-off

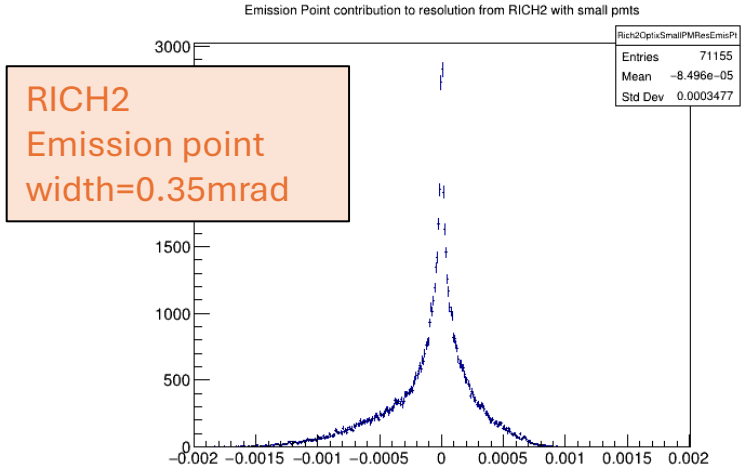
RICH 2 with Photonis 943P541 (blue curve)

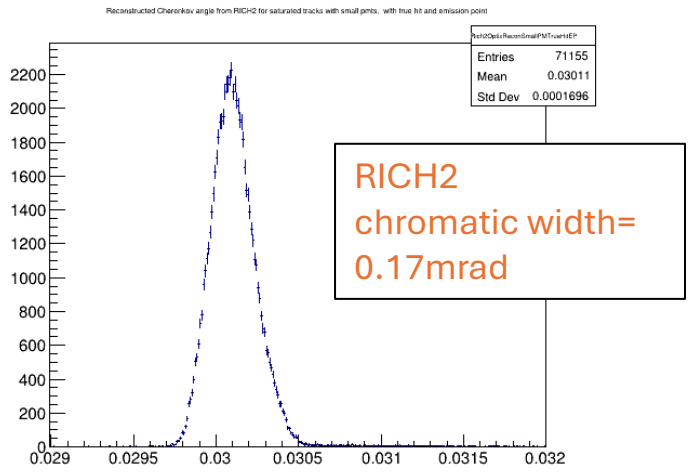






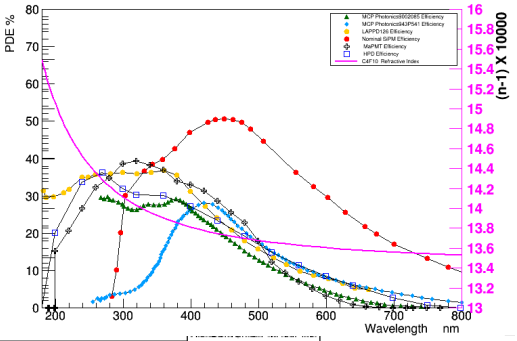


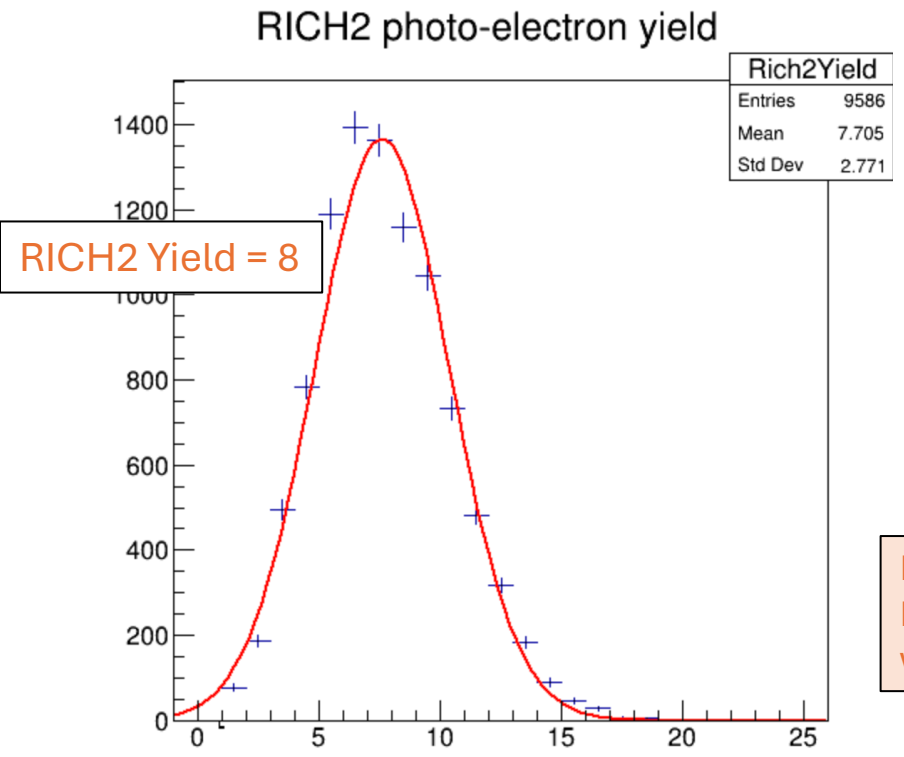




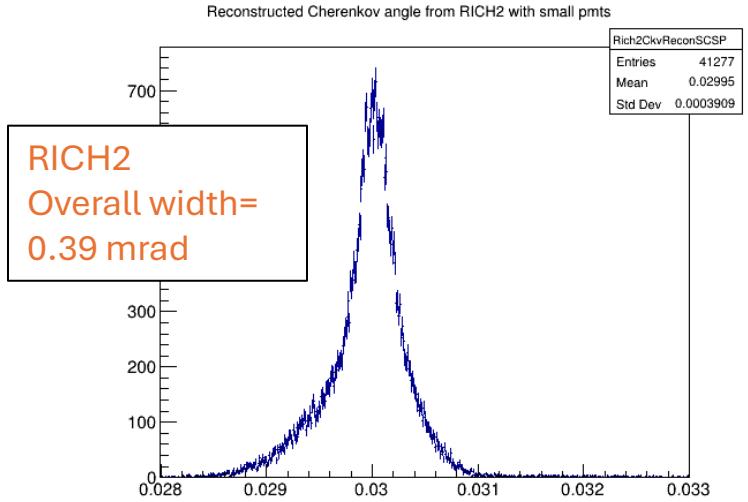
Run5 Geo – 400nm wavelength cut-off

RICH 2 with Photonis 943P541 (blue curve)

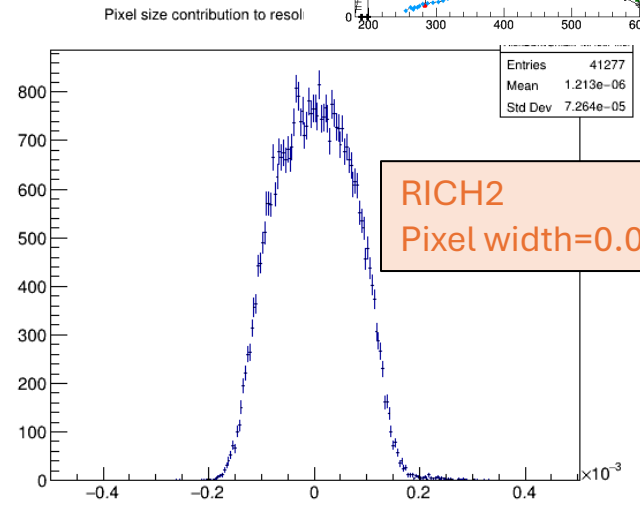




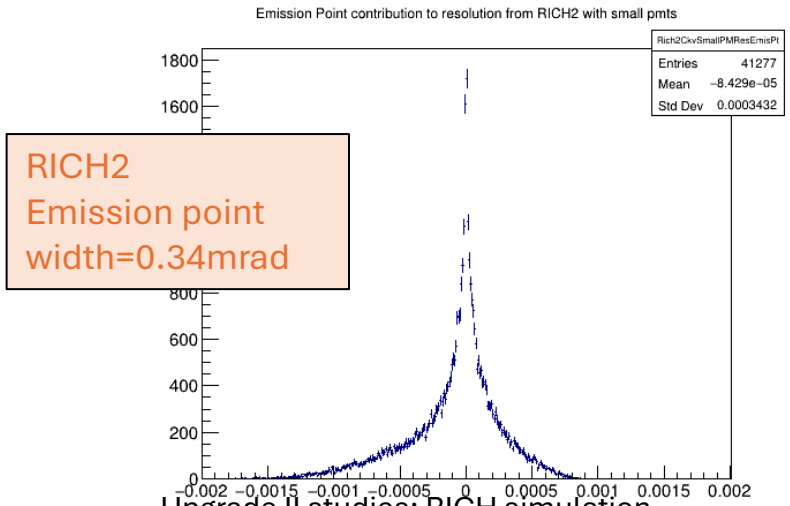
RICH2 Yield = 8



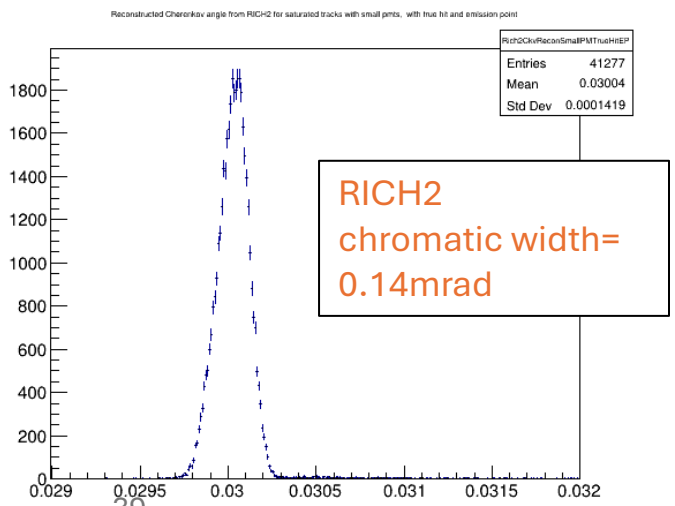
RICH2
Overall width=
0.39 mrad



RICH2
Pixel width=0.07 mrad



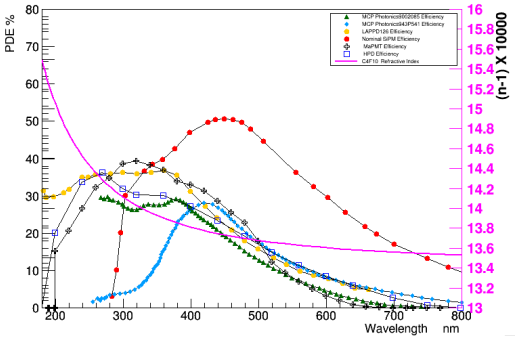
RICH2
Emission point
width=0.34mrad

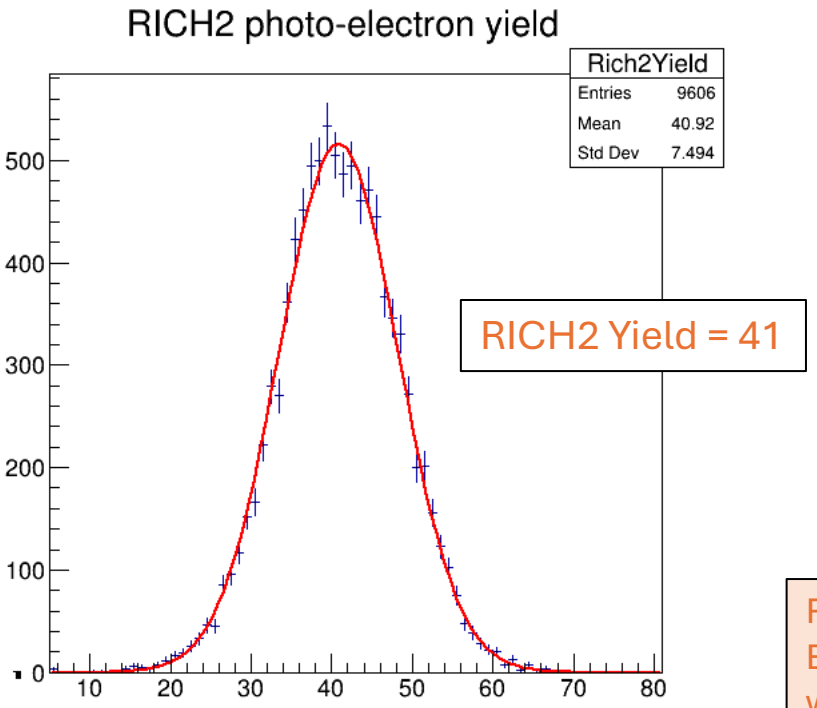


RICH2
chromatic width=
0.14mrad

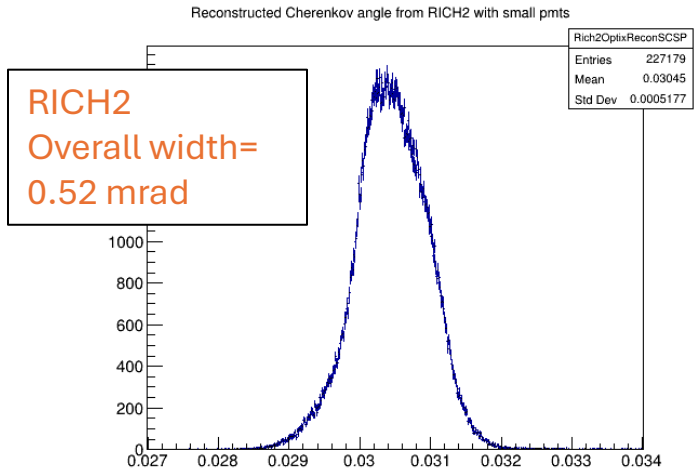
Run5 Geo - NO wavelength cut-off

RICH 2 with Photonis 9002085(green curve)

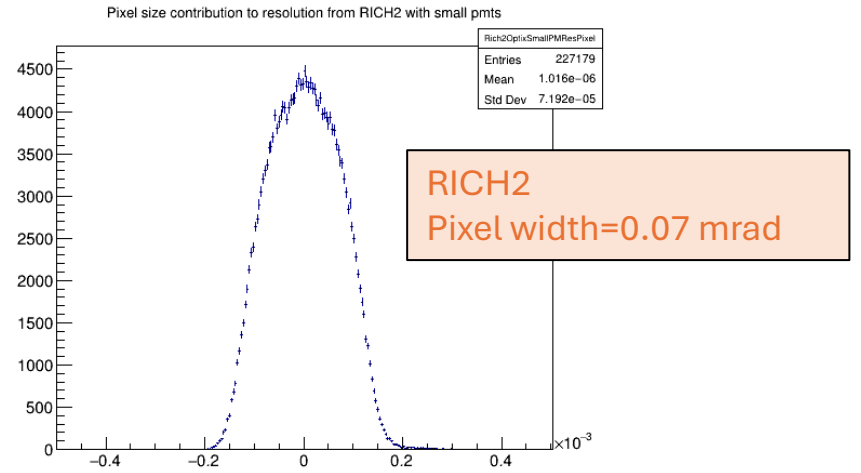




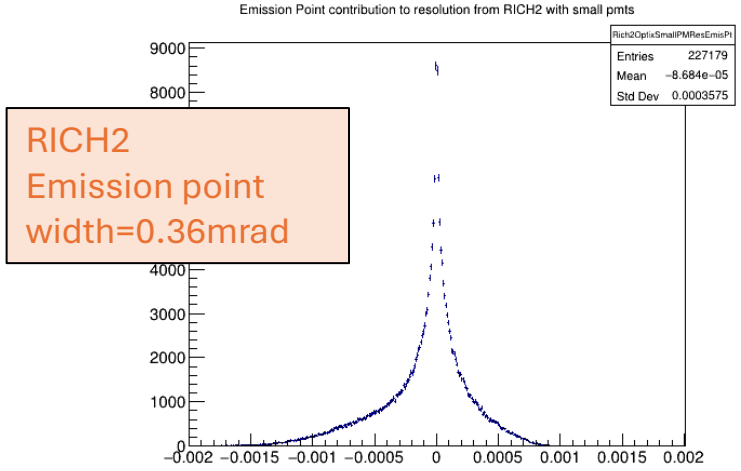
RICH2 Yield = 41



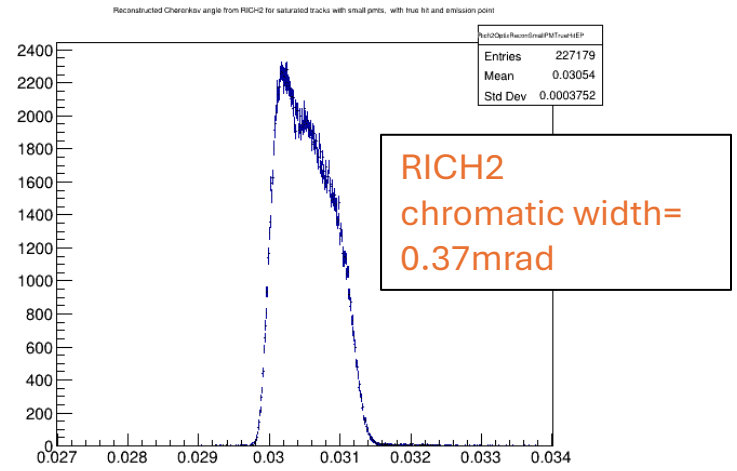
RICH2
Overall width=
0.52 mrad



RICH2
Pixel width=0.07 mrad



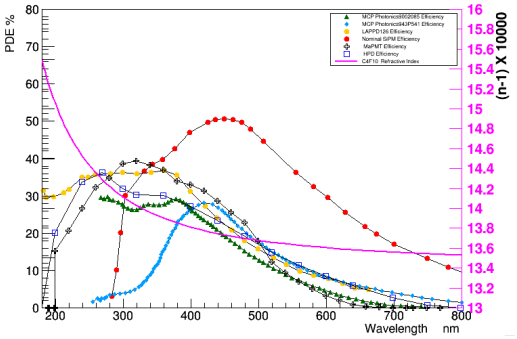
RICH2
Emission point
width=0.36mrad

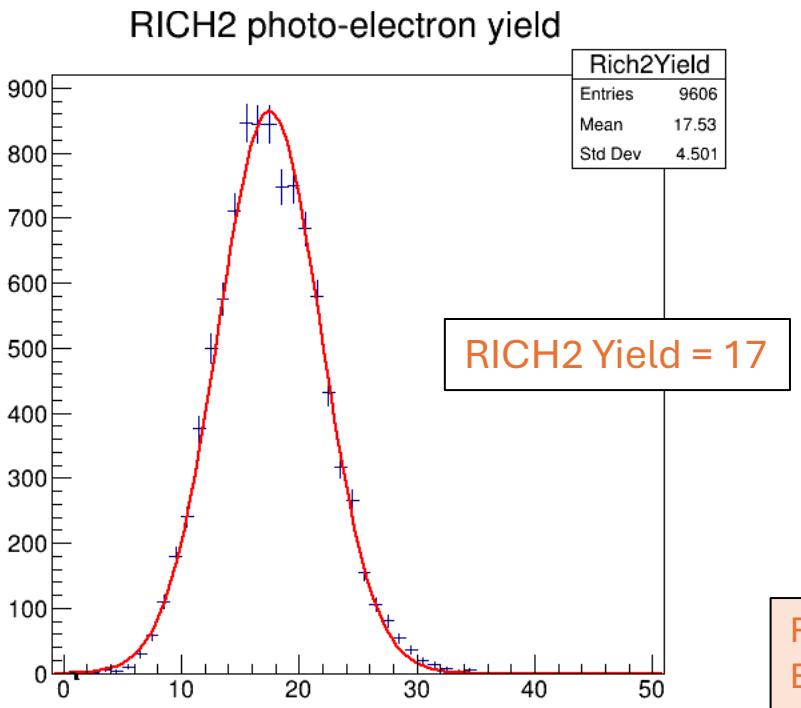


RICH2
chromatic width=
0.37mrad

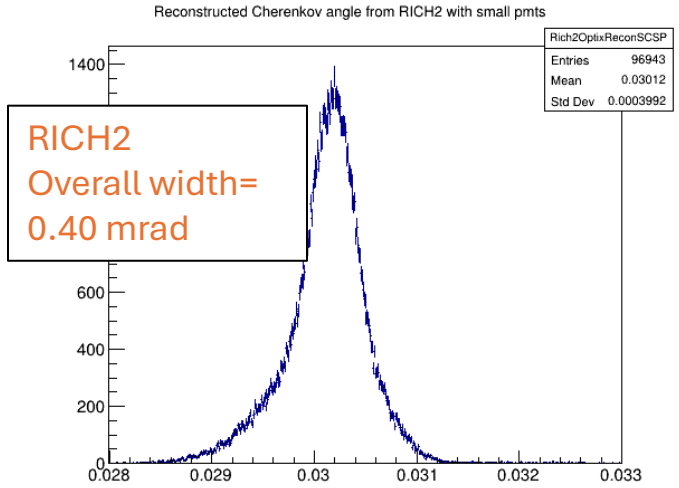
Run5 Geo – 300nm wavelength cut-off

RICH 2 with Photonis 9002085 (green curve)

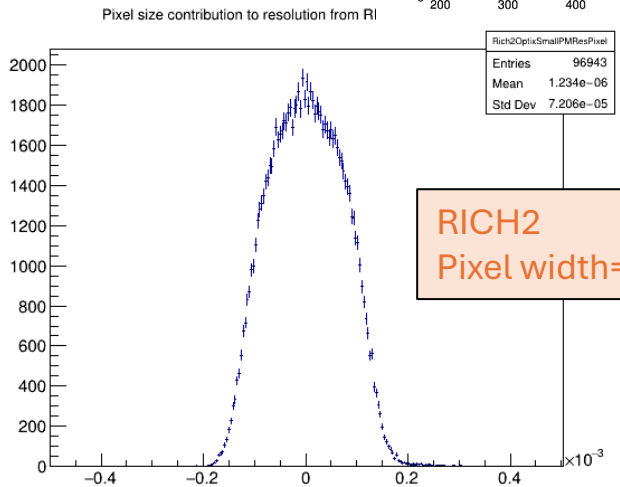




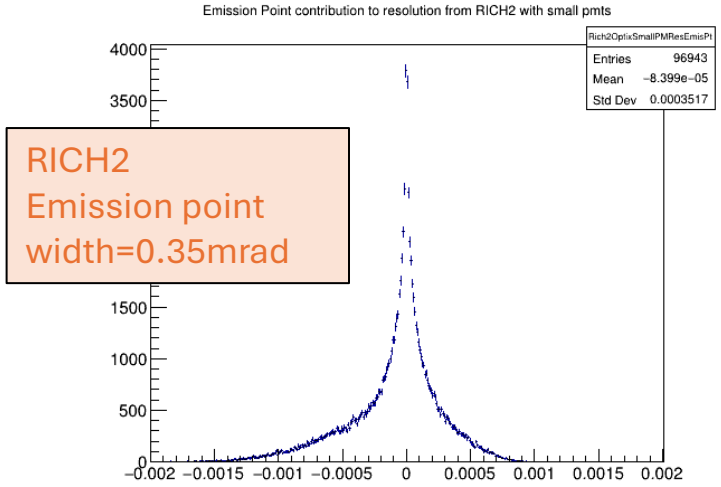
RICH2 Yield = 17



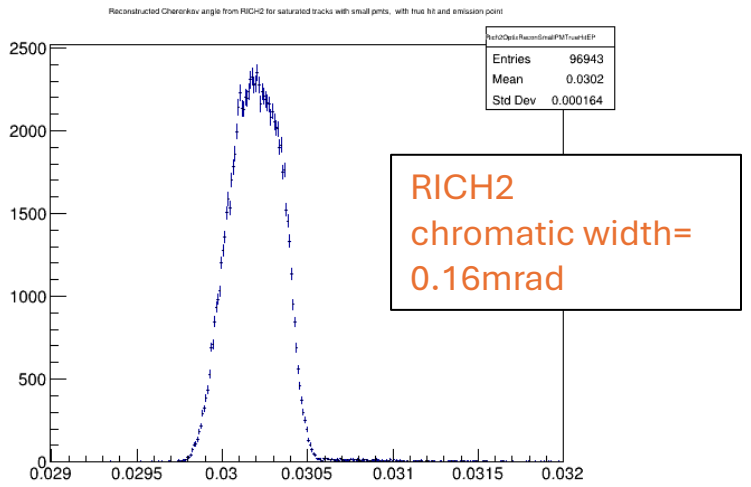
RICH2
Overall width=
0.40 mrad



RICH2
Pixel width=0.07 mrad



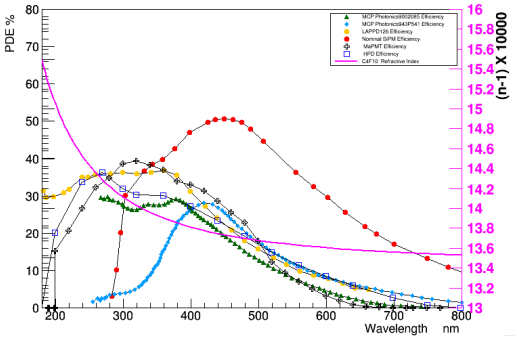
RICH2
Emission point
width=0.35mrad

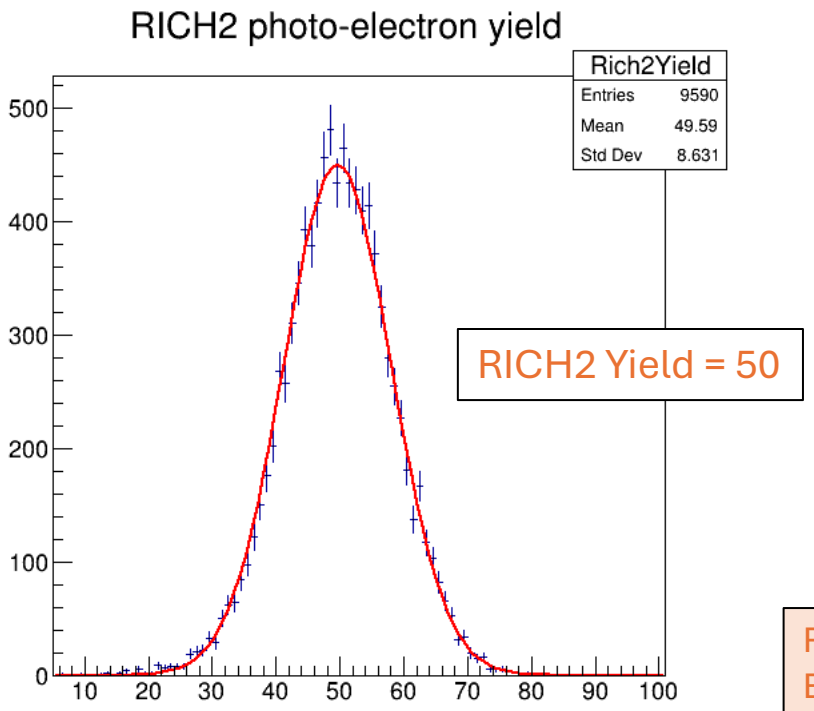


RICH2
chromatic width=
0.16mrad

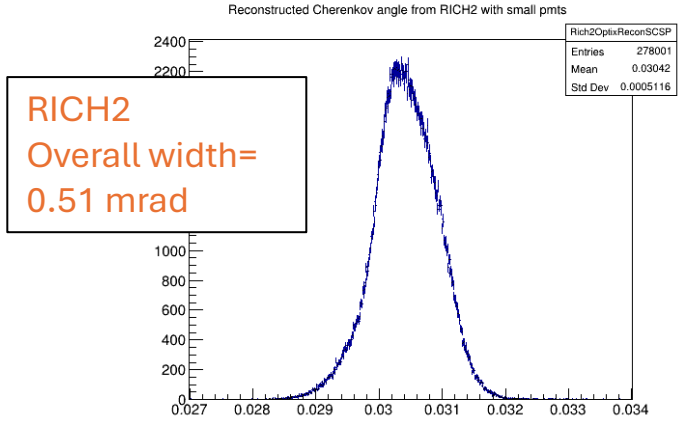
Run5 Geo - NO wavelength cut-off

RICH 2 with LAPPD126 (yellow curve)

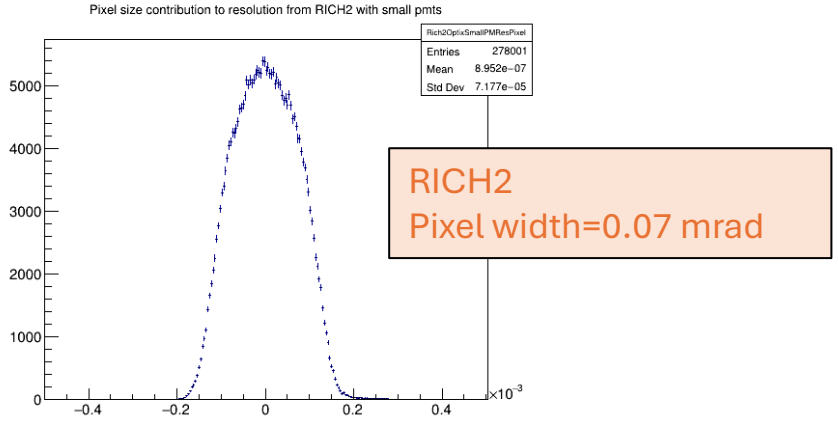




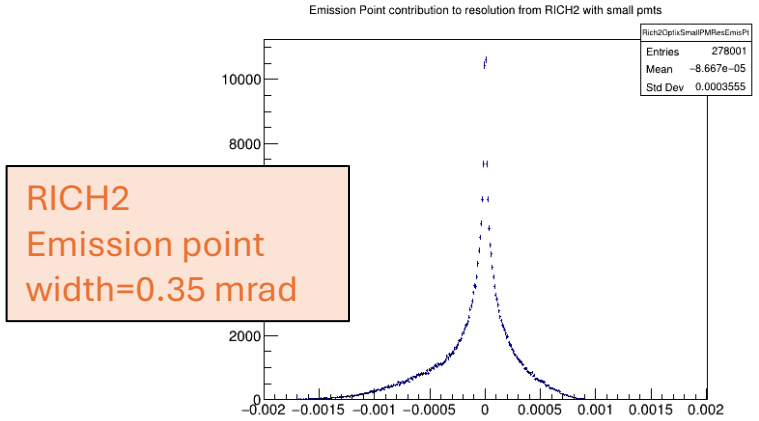
RICH2 Yield = 50



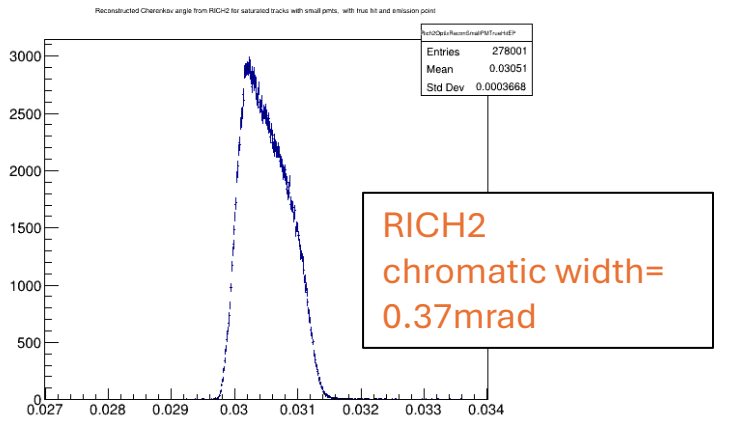
RICH2
Overall width=
0.51 mrad



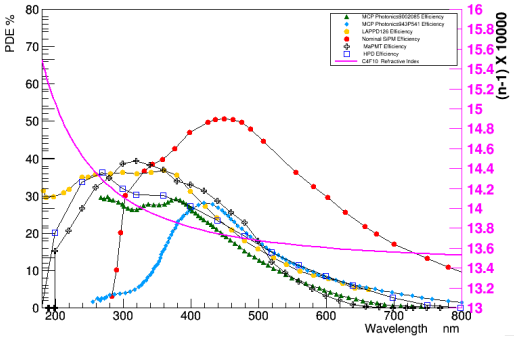
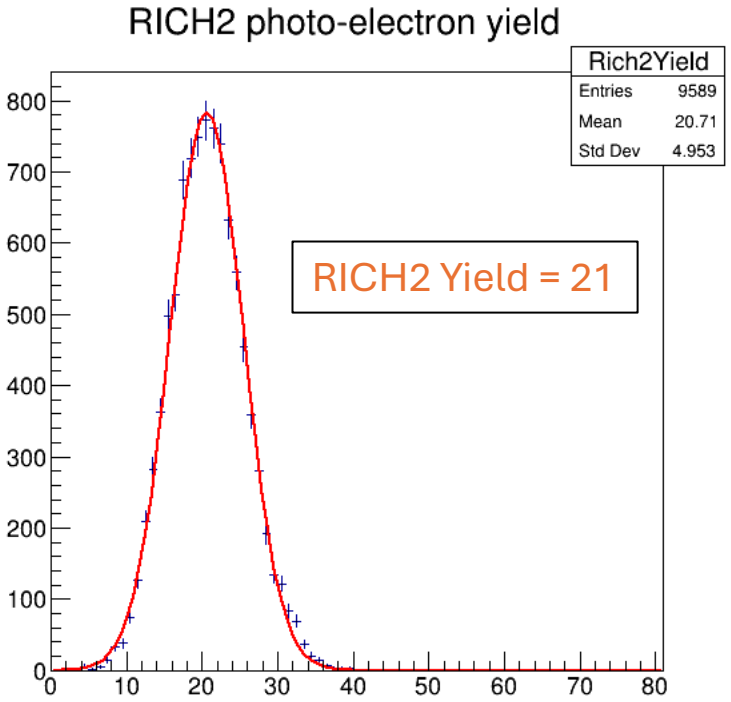
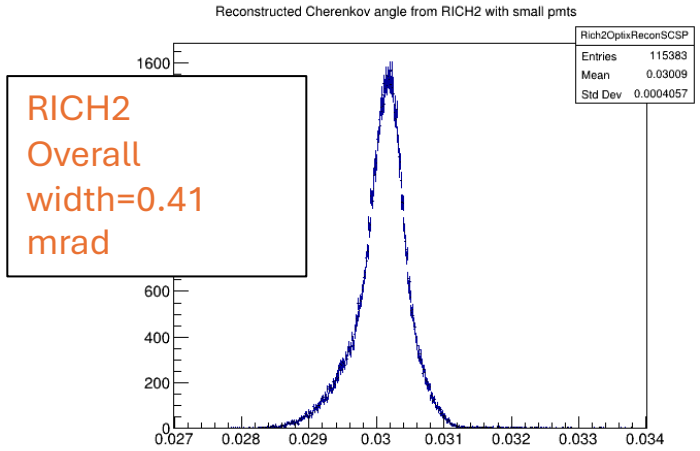
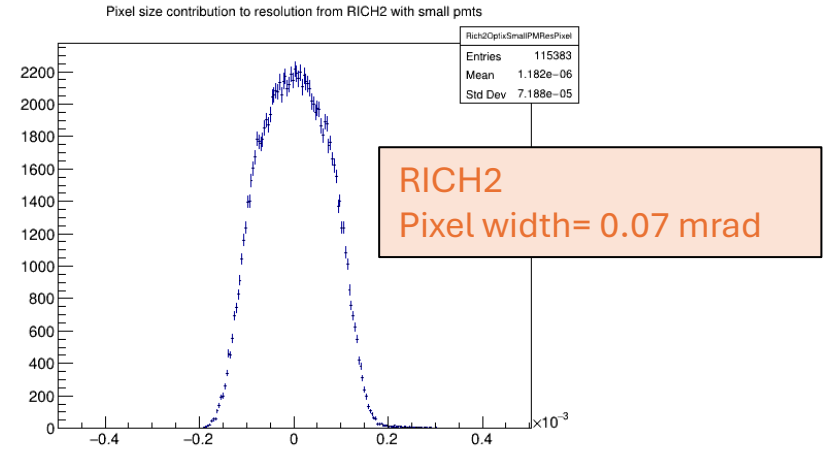
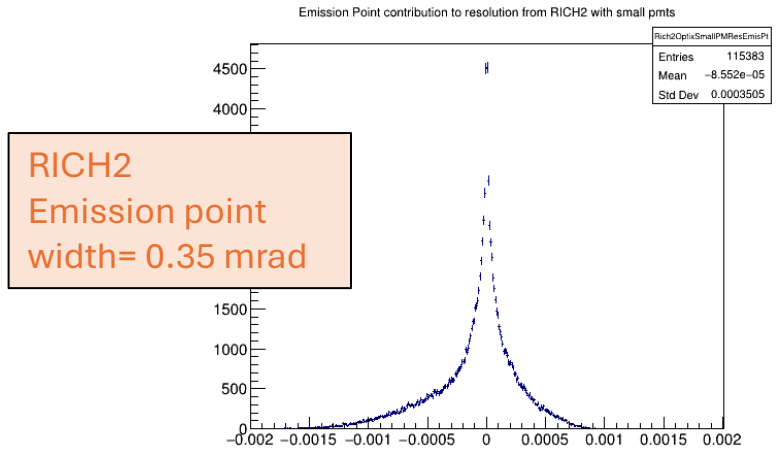
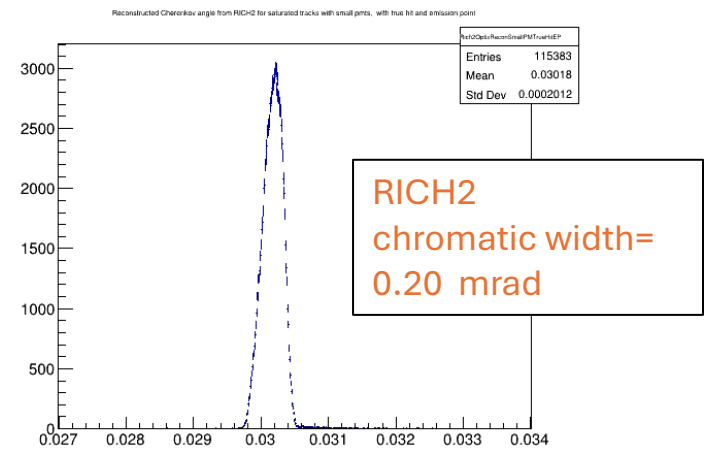
RICH2
Pixel width=0.07 mrad



RICH2
Emission point
width=0.35 mrad



RICH2
chromatic width=
0.37mrad

Run5 Geo – 300nm wavelength cut-off

RICH 2 with LAPPD126 (yellow curve)