Annual DIRC Meeting 2025

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Outline

- Performance Plots for hpDIRC with MCP-PMTs and HRPPDs in magnetic field
- Alternative width of bars without b-field and with b-field
- Evaluating the impacts of adding Dark noise to HRPPD on hpDIRC performance
- hpDIRC detector plane coverage study

Performance plots for the hpDIRC with MCP-PMTs and HRPPDs in a magnetic field

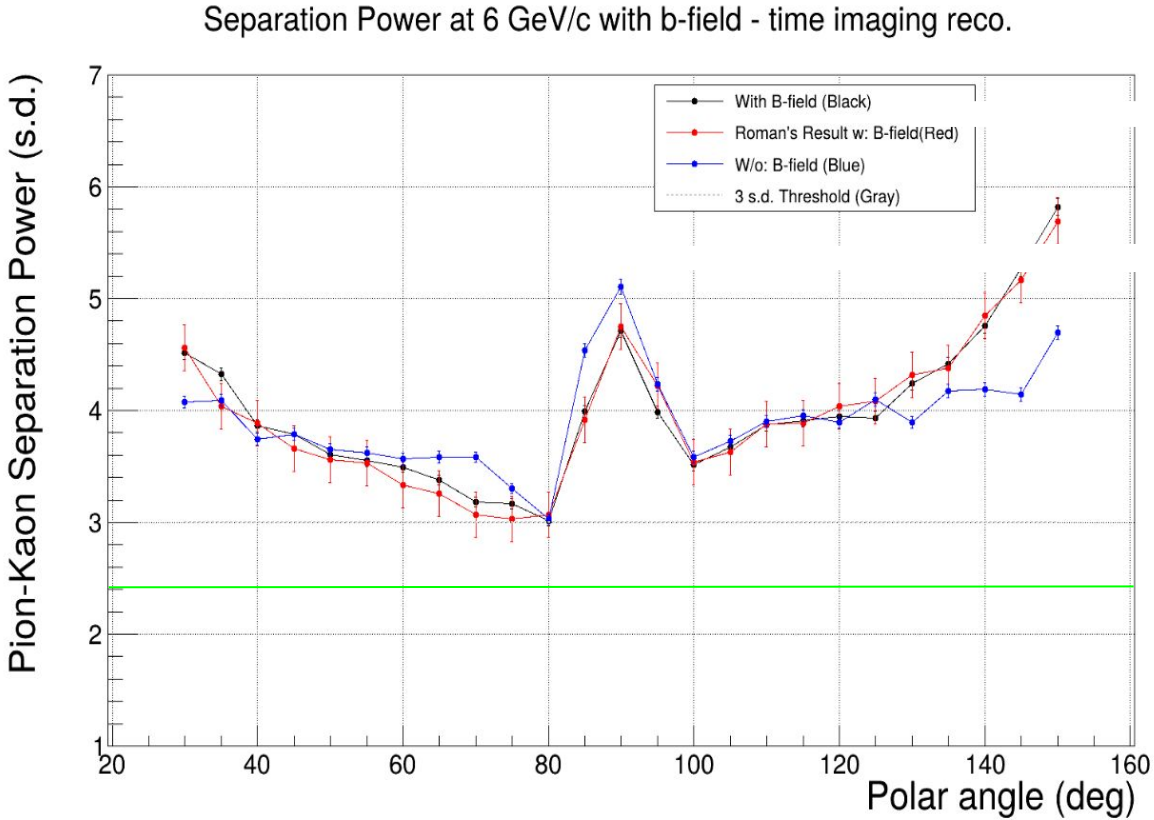
Details of hpDIRC bars and barbox

- Each barbox has 10 bars.
- Each bar has a width of 35 mm; the bar box width is 350.35 mm, with an air gap of 0.15 mm. The lens thickness is 11.75 mm, and the radius is 770.5 mm.
- For the MCP-PMT, the pixel size is 3.3125 mm, arranged in a 16 × 16 mm^2 array.
- For the HRPPD, the pixel size is 2.7 mm, arranged in a 40 × 40 mm^2 array."

Purpose of the study

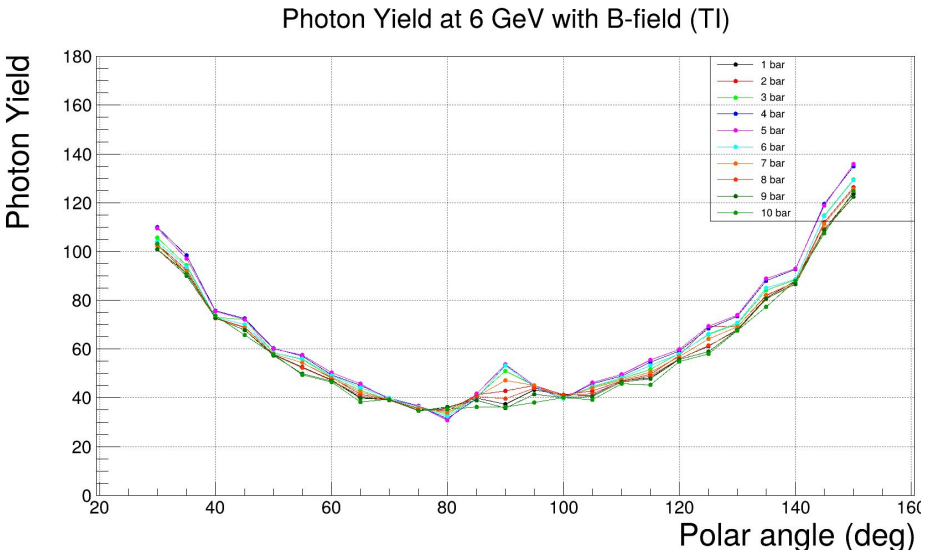
- To evaluate the performance across all bars, i.e., whether each bar maintains at least 3σ separation power with both mcp_Pmt and HRPPD sensor.

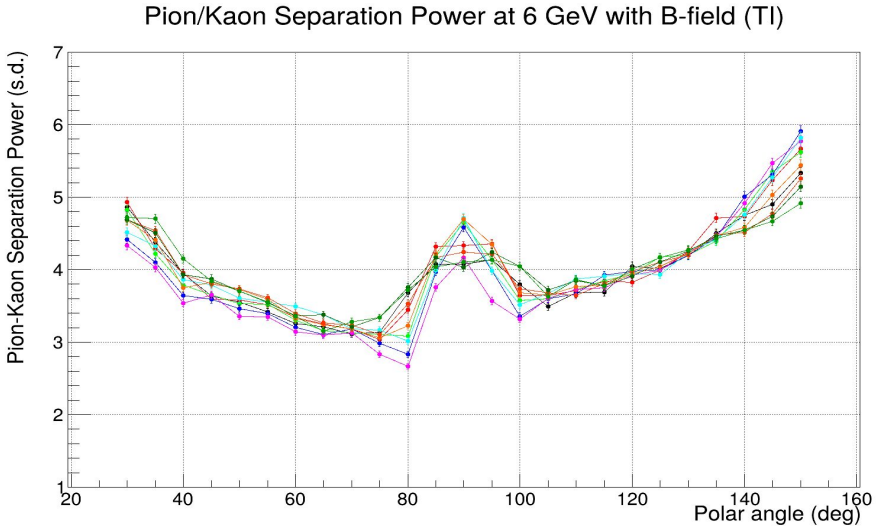
Comparison of my results with Roman's under a magnetic field for the MCP-PMT sensor.



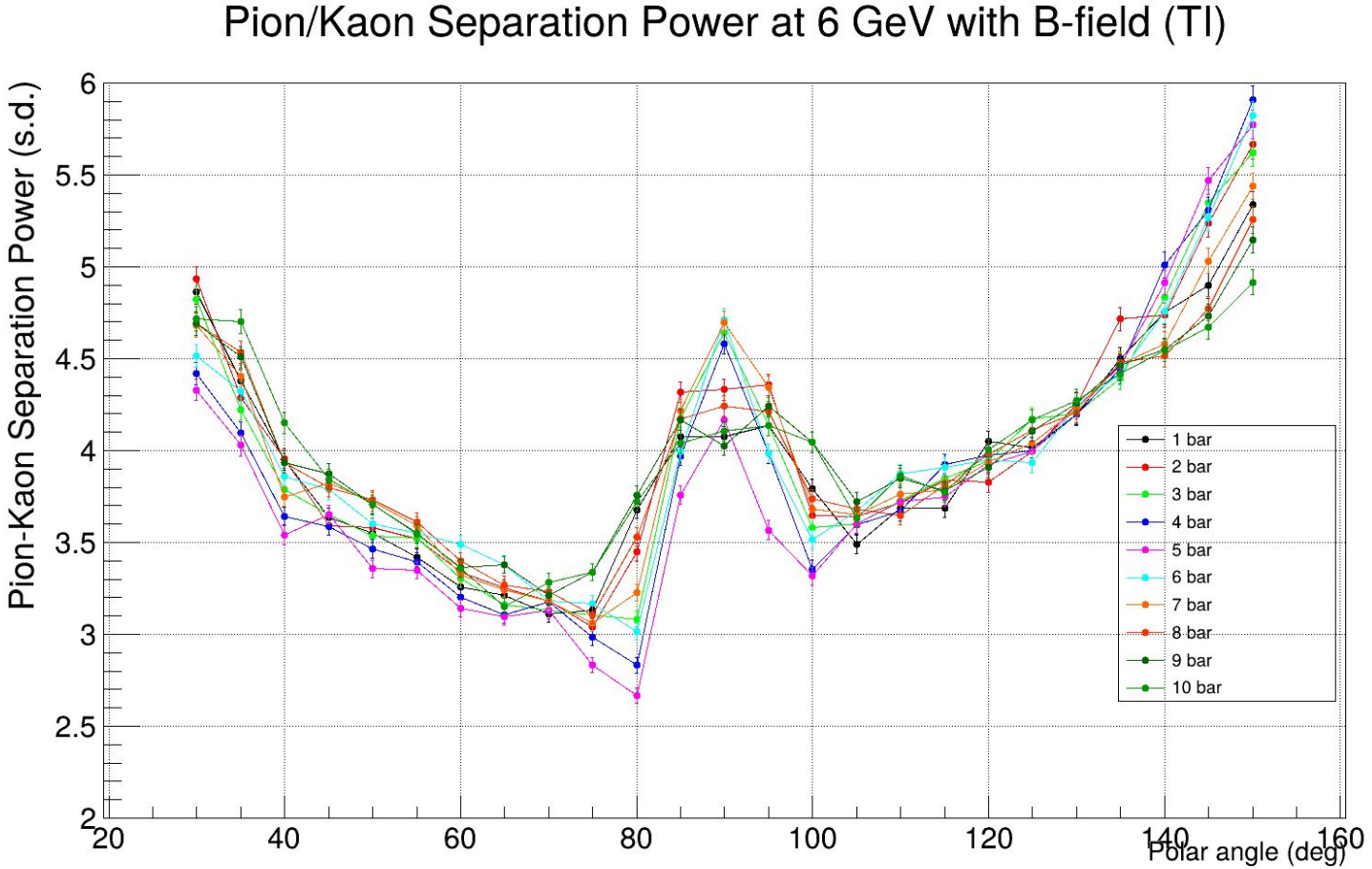
Sensor: Mcp_Pmt
Magnetic field: 1.7 T
Hitting bar: 6th

Performance plots at 1.7 T (time imaging) from the 1st to the 10th bar for the MCP-PMT



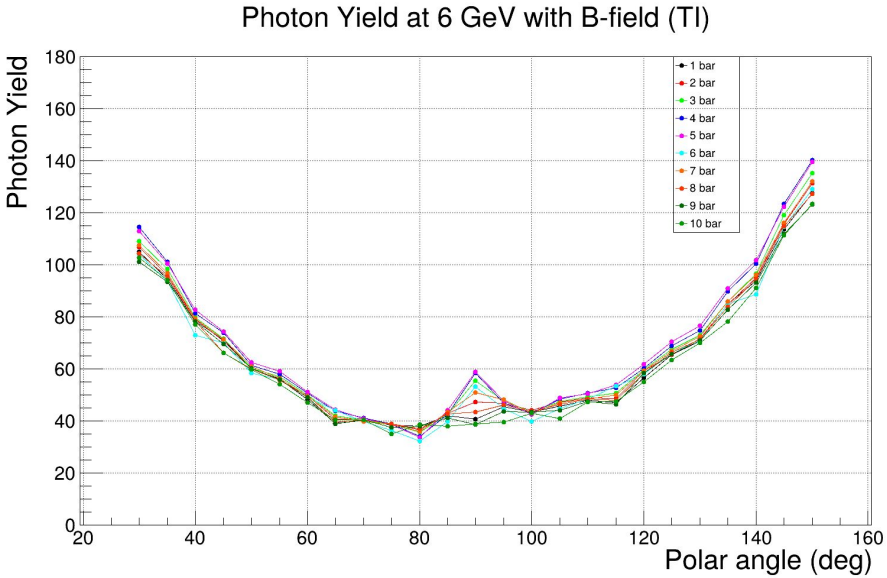


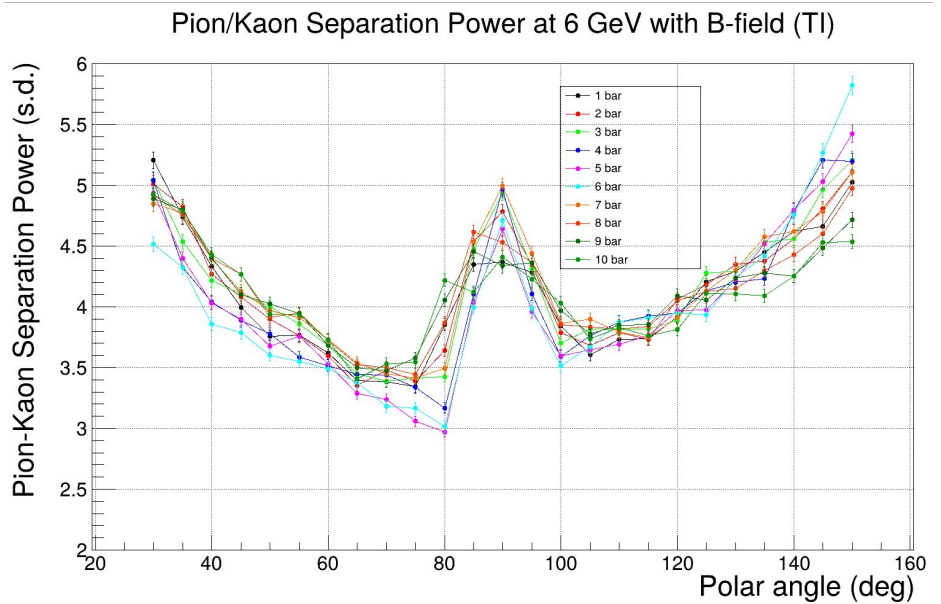
Sensor: Mcp_Pmt
Magnetic field: 1.7 T



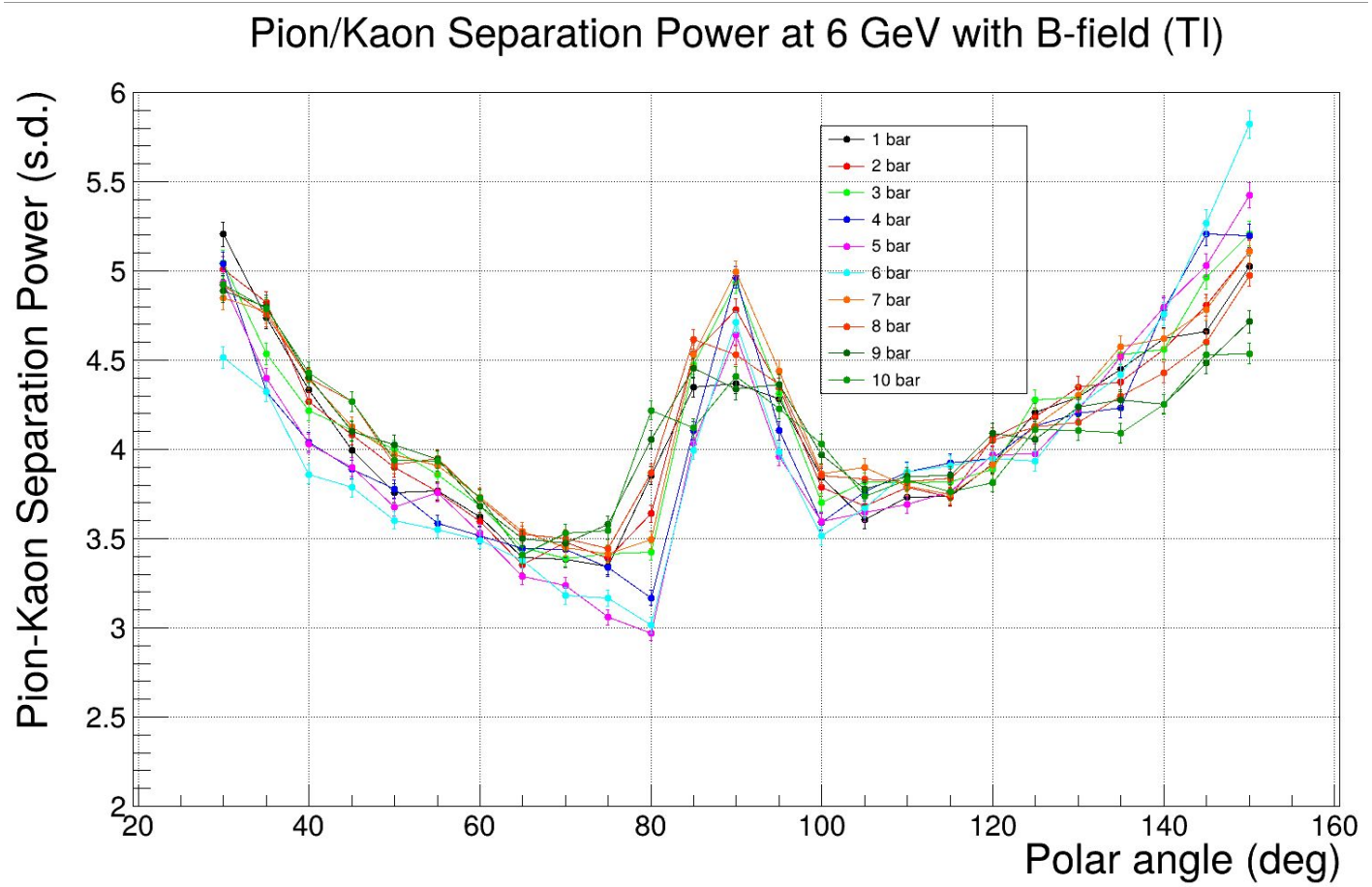
Bar N0.	Phi angle (deg.)
1	-15.0755
2	-12.5537
3	-10.0043
4	-7.43667
5	-4.86081
6	-2.28698
7	0.274463
8	2.81331
9	5.31979
10	7.78473

Pion/Kaon separation power at 1.7 T (time imaging) from the 1st to the 10th bar for the HRPPD sensor





HRPPD Sensor
Magnetic field: 1.7 T


Pion/Kaon Separation Power at 6 GeV with B-field (TI)
Pion-Kaon Separation Power (s.d.)
Polar angle (deg)
1 bar
2 bar
3 bar
4 bar
5 bar
6 bar
7 bar
8 bar
9 bar
10 bar
2
2.5
3
3.5
4
4.5
5
5.5
6
20
40
60
80
100
120
140
160

Conclusion

- With geometric reconstruction, all polar angles maintain at least 3σ separation power, except for bars 4 and 5 at polar angles 75° and 80°.

- With time imaging reconstruction, both the MCP-PMT and HRPPD sensors show at least 3σ separation power for all polar angles.

Performance plots for range of bar widths, without and with magnetic field.

Study Approach and Objectives

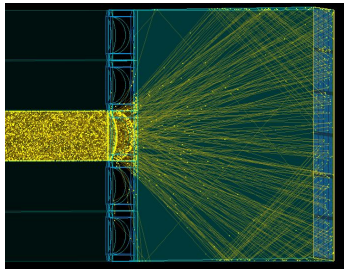
Approach:

In the current configuration, the bar box contains 10 bars, each with a width of 35 mm. To study how performance varies with bar width, we modified the number of bars per bar box from 5 to 13, while keeping the total bar box width fixed at 351.35 mm. The lens geometry was also adjusted accordingly for each bar width configuration.

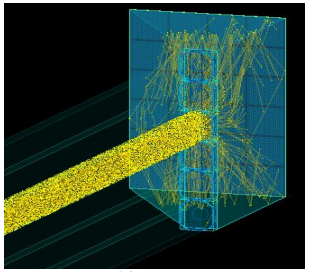
Objectives:

The goal is to determine the range of bar configurations that achieve a separation power of at least 3σ for pion–kaon identification at 6 GeV/c momentum.

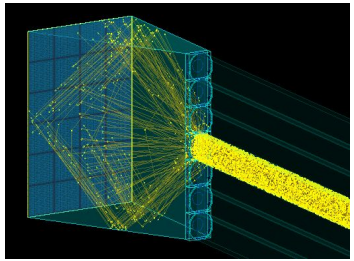
Event Display of different number of bars in a barbox



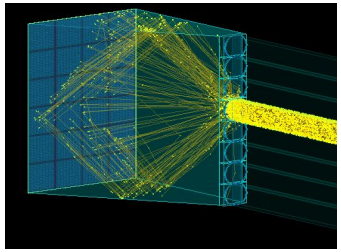
5 bars



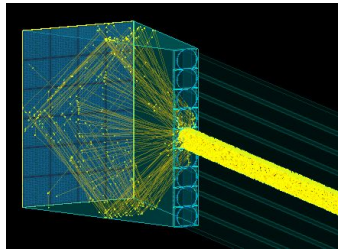
6bars



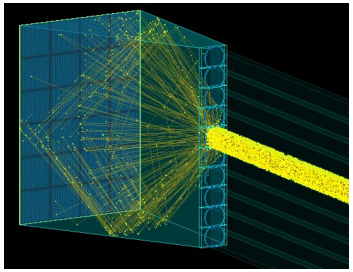
7 bars



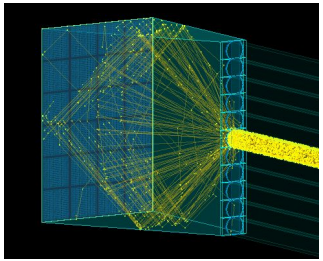
8 bars



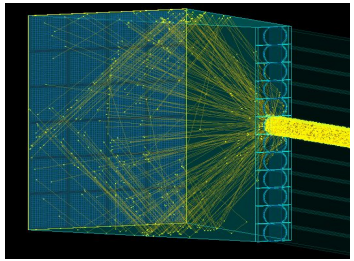
9 bars



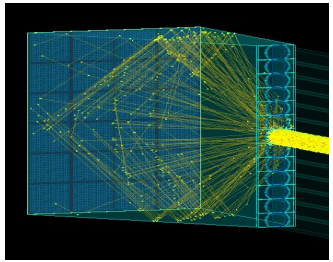
10 bars



11 bars



12 bars



13 bars

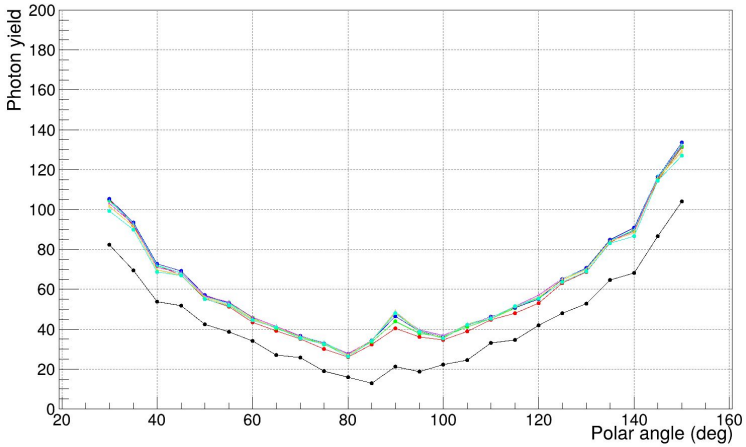
Event display for different bar widths

Bar Width and lens thickness in different configurations

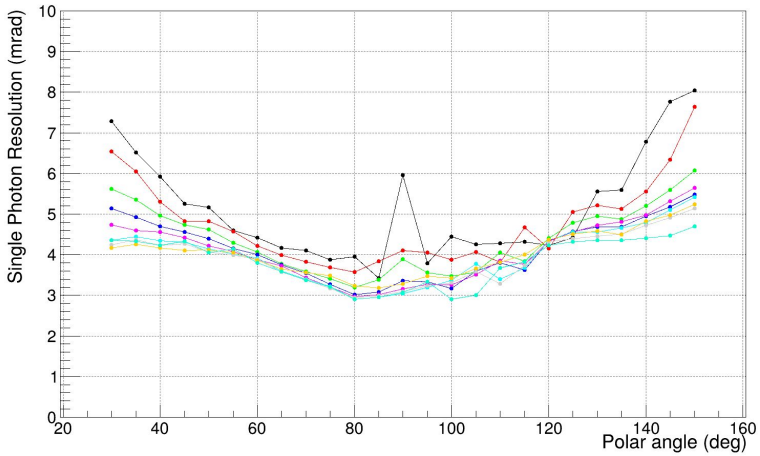
Number of bars	Bar Width(mm)	Barbox Width(mm)	Radius (mm)	Lens Thickness (mm)
5	70.15	351.35	770.5	42 (bad lens)
6	58.4333	351.35	770.5	22.8563 (bad lens)
7	50.0643	351.35	770.5	17.6295
8	43.7875	351.35	770.5	14.7688
9	38.9056	351.35	770.5	12.97
10	35	351.35	770.5	11.7488
11	31.8045	351.35	770.5	10.8761
12	29.1417	351.35	770.5	10.2284
13	26.8885	351.35	770.5	9.73336

Geometric reco performance plots (Pion-Kaon) for different number of bars in barbox

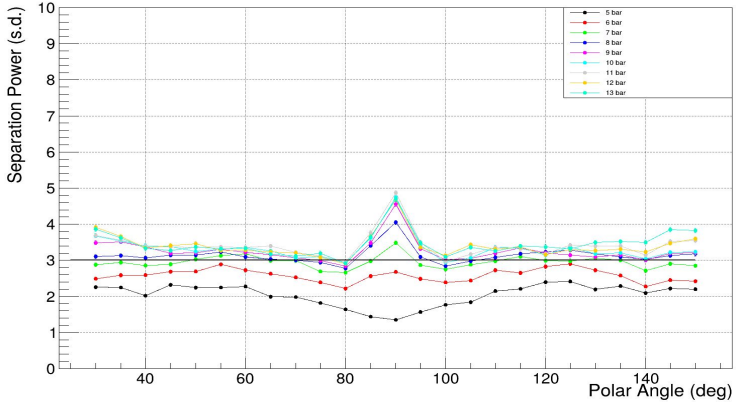
Photon yield at 6 GeV/c - geometric reco.



SPR at 6 GeV/c - geometric reco.

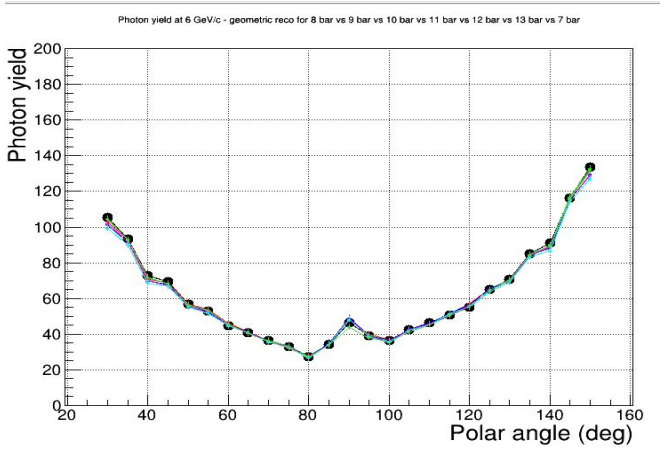


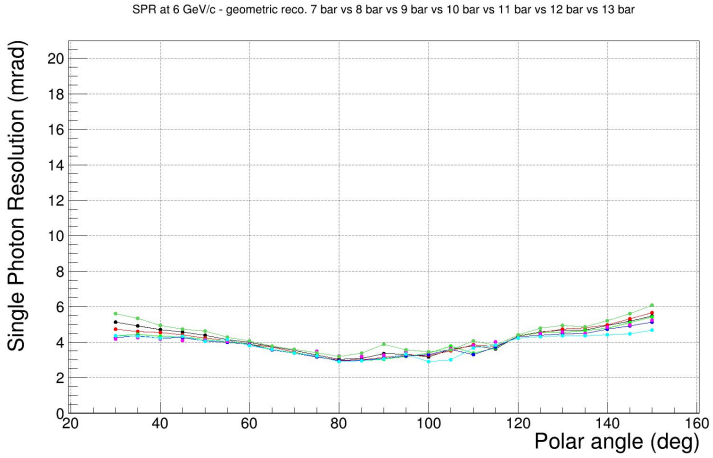
Separation Power at 6 GeV/c - Geometric Reconstruction

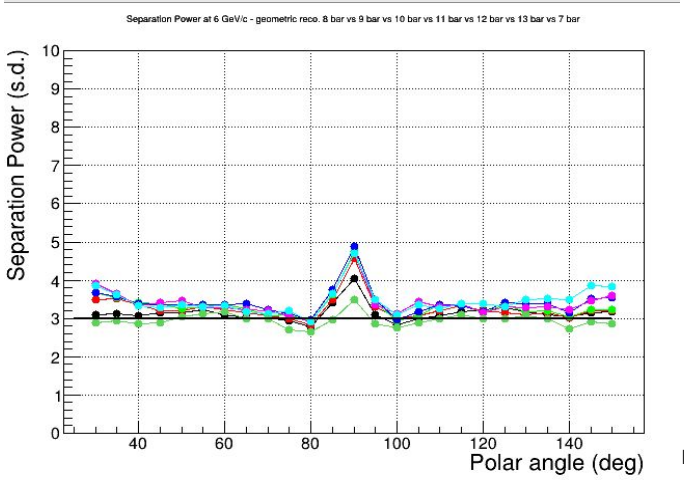


5 bars in a barbox
6 bars in a barbox
7 bars in a barbox
8 bars in a barbox
9 bars in a barbox
10 bars in a barbox
11 bars in a barbox
12 bars in a barbox
13 bars in a barbox

Geometric reco performance plots (Pion-Kaon) for different number of bars in barbox





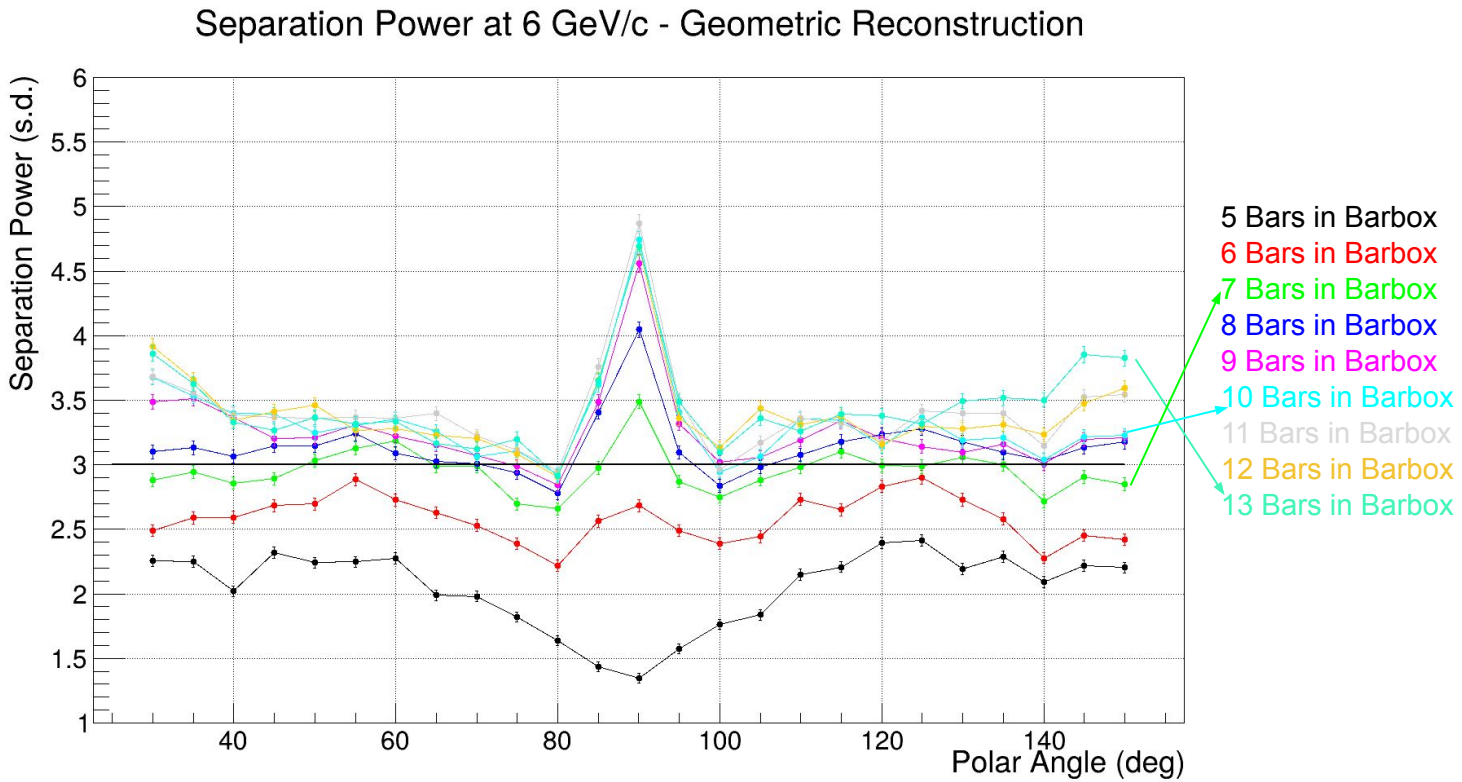


n

7 bars in a barbox
8 bars in a barbox
9 bars in a barbox
10 bars in a barbox
11 bars in a barbox
12 bars in a barbox
13 bars in a barbox

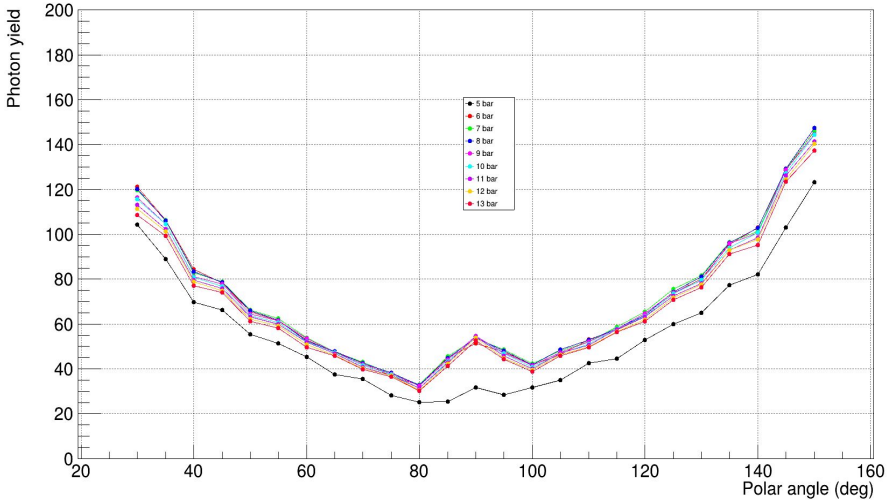
Sensor: Mcp_PMT
TimeCut: 0.5 ns
Tracking Resolution: 0.0005 rad
Without magnetic field

Geometric reco performance plots (Pion-Kaon) for different number of bars in barbox

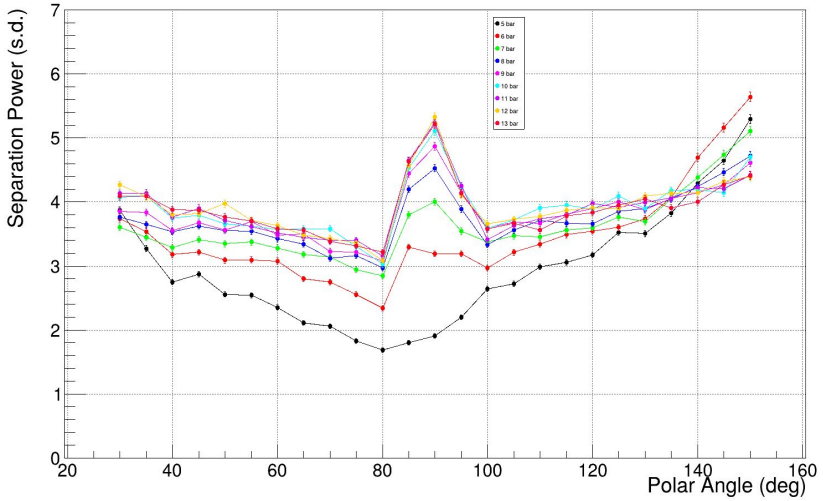


Time Imaging reco performance plots for different number of bars in barbox

Photon yield at 6 GeV/c - time imaging reco.



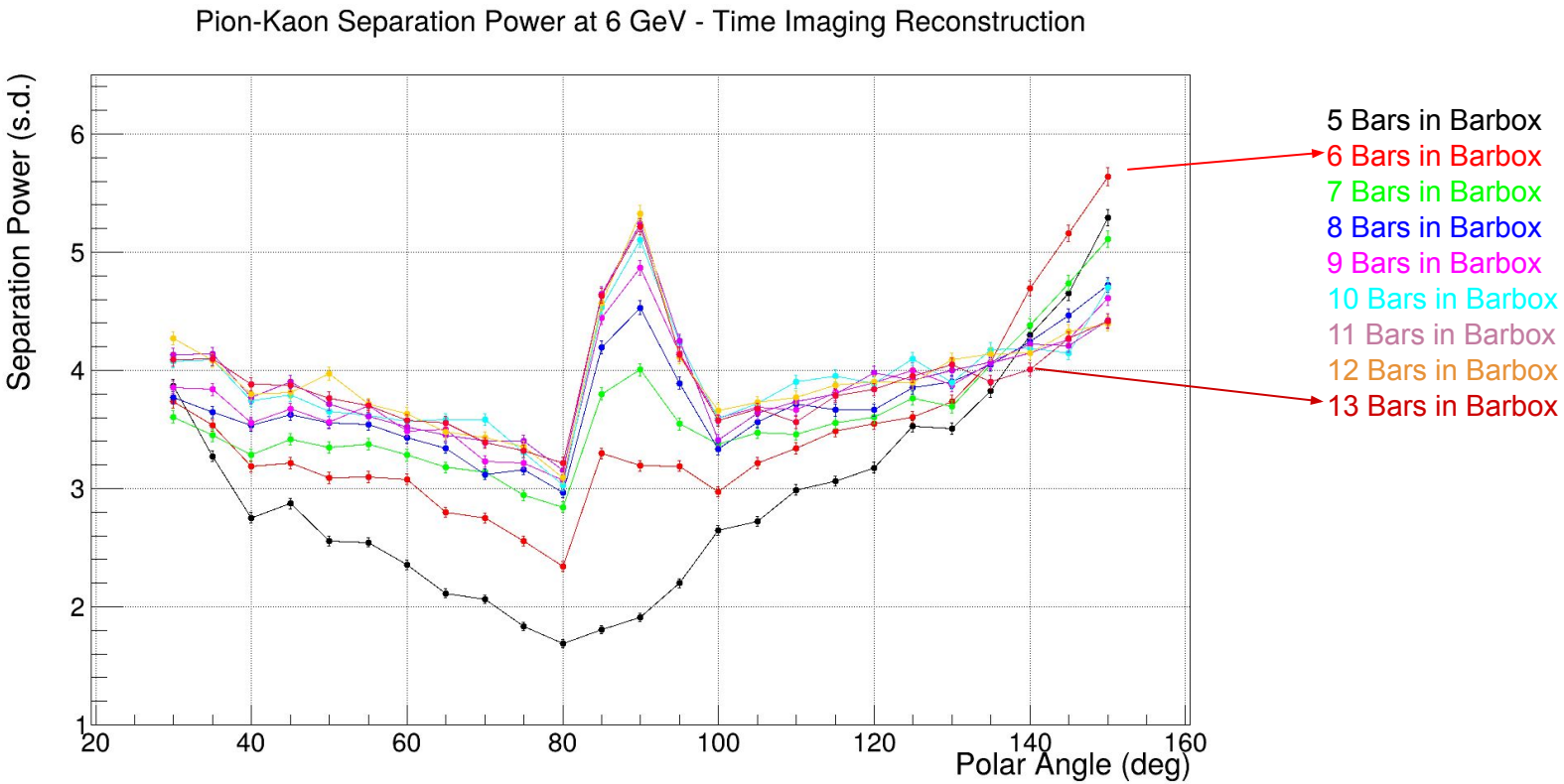
Pion-Kaon Separation Power at 6 GeV - Time Imaging Reconstruction



5 Bars in Barbox
6 Bars in Barbox
7 Bars in Barbox
8 Bars in Barbox
9 Bars in Barbox
10 Bars in Barbox
11 Bars in Barbox
12 Bars in Barbox
13 Bars in Barbox

Sensor: Mcp_PMT
Without magnetic field

Time Imaging reco. performance plots for different number of bars in barbox



Conclusion

- **Geometric Reconstruction:**
  Using 8 to 13 bars per bar box — corresponding to bar widths ranging from 43.79 mm to 26.89 mm and lens thicknesses from 14.77 mm to 9.73 mm — yields at least 3σ separation power. The study was conducted up to a maximum of 13 bars; configurations with more than 13 bars were not evaluated.

- **Time Imaging Reconstruction:**
  Using 7 to 13 bars per bar box — corresponding to bar widths ranging from 50.06 mm to 26.89 mm and lens thicknesses from 17.63 mm to 9.73 mm — also achieves separation power above 3σ.

Performance plots for various bar widths in the presence of a magnetic field

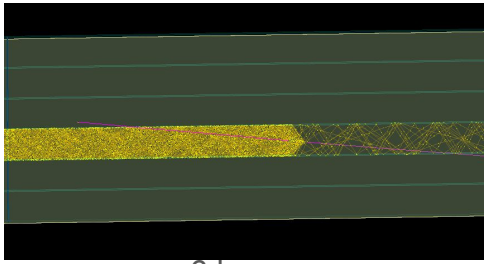
Study Approach and Objectives

Approach:

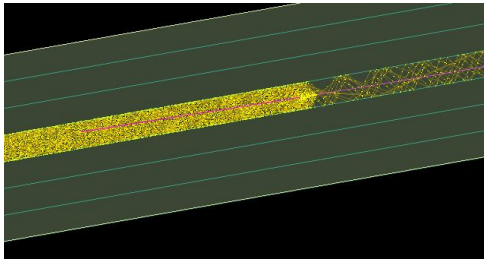
In the current configuration, the bar box contains 10 bars, each with a width of 35 mm. To study how performance varies with bar width in the presence of a magnetic field (1.7 T), we varied the number of bars per bar box from 6 to 13, while keeping the total bar box width fixed at 351.35 mm. The lens geometry was adjusted accordingly for each bar width configuration to ensure proper optical matching.

Objectives:

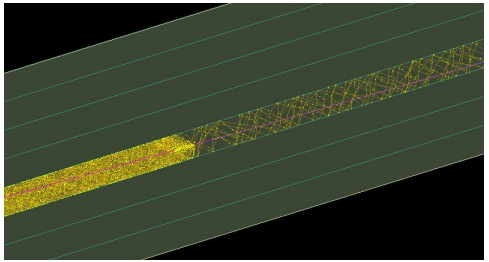
The objective is to identify the range of bar configurations that provide at least 3σ separation power for pion–kaon identification at a momentum of 6 GeV/c in the presence of a magnetic field.



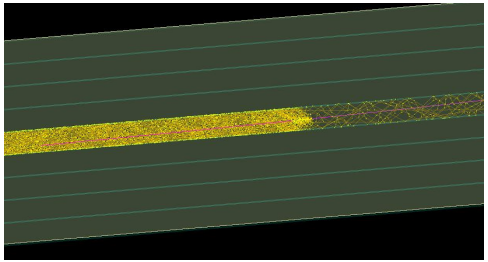
6 bars



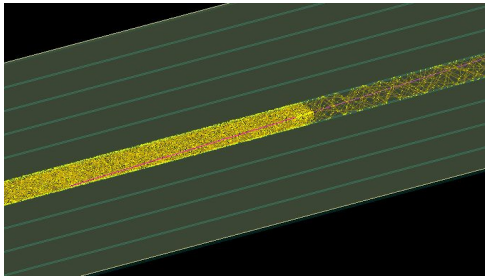
7 bars



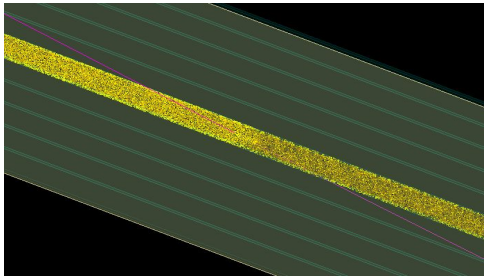
8 bars



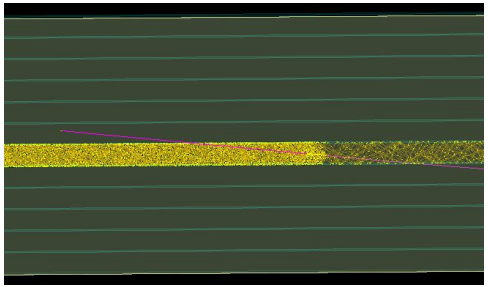
9 bars



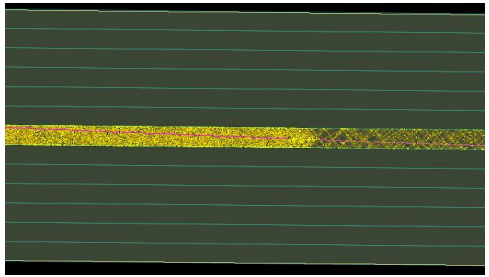
10 bars



11 bars



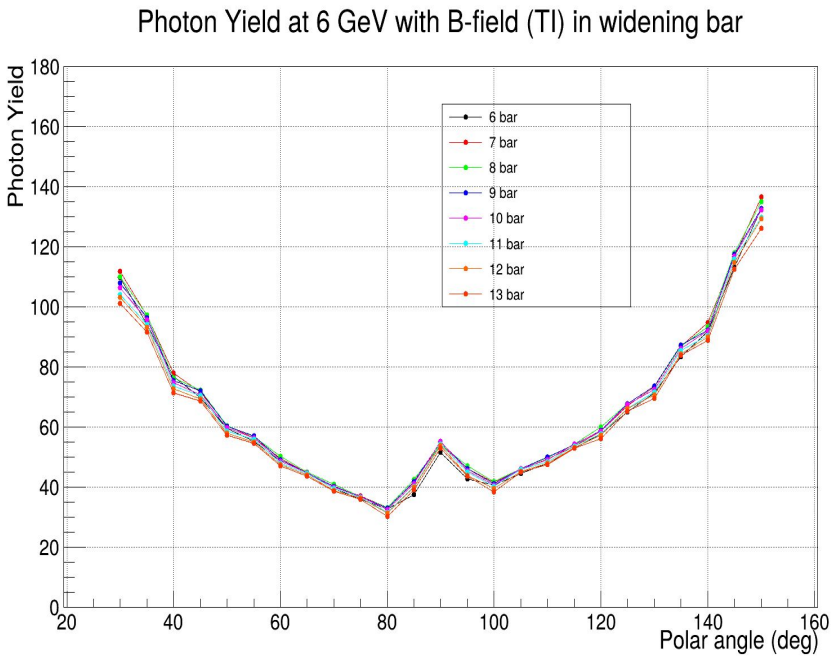
12 bars

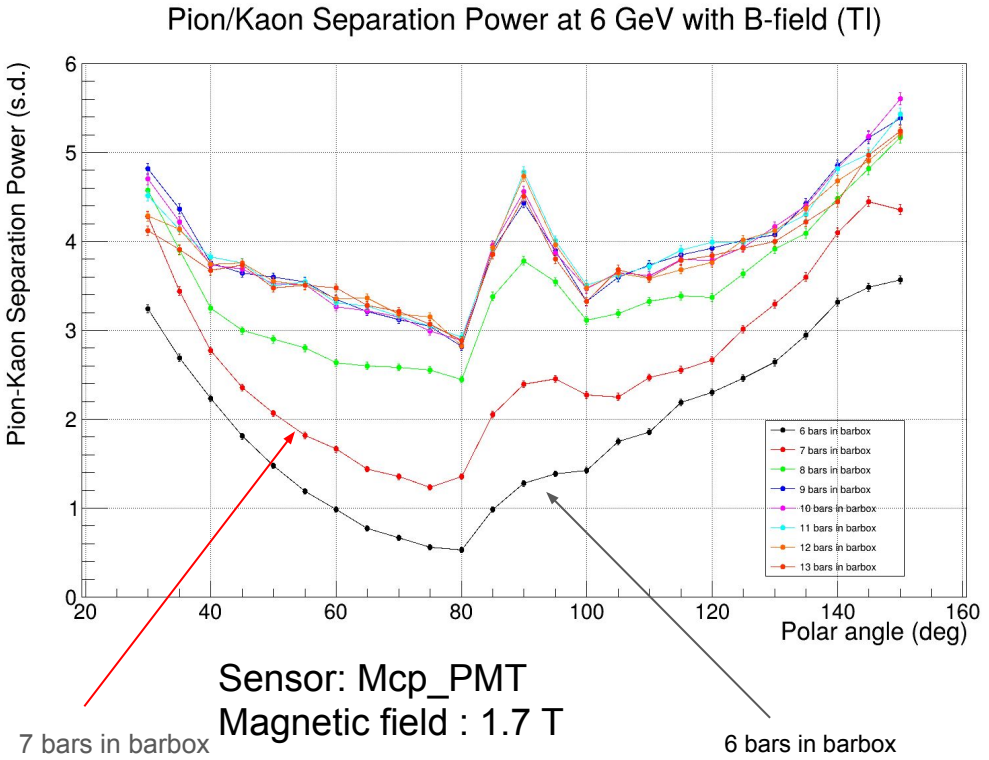


13 bars

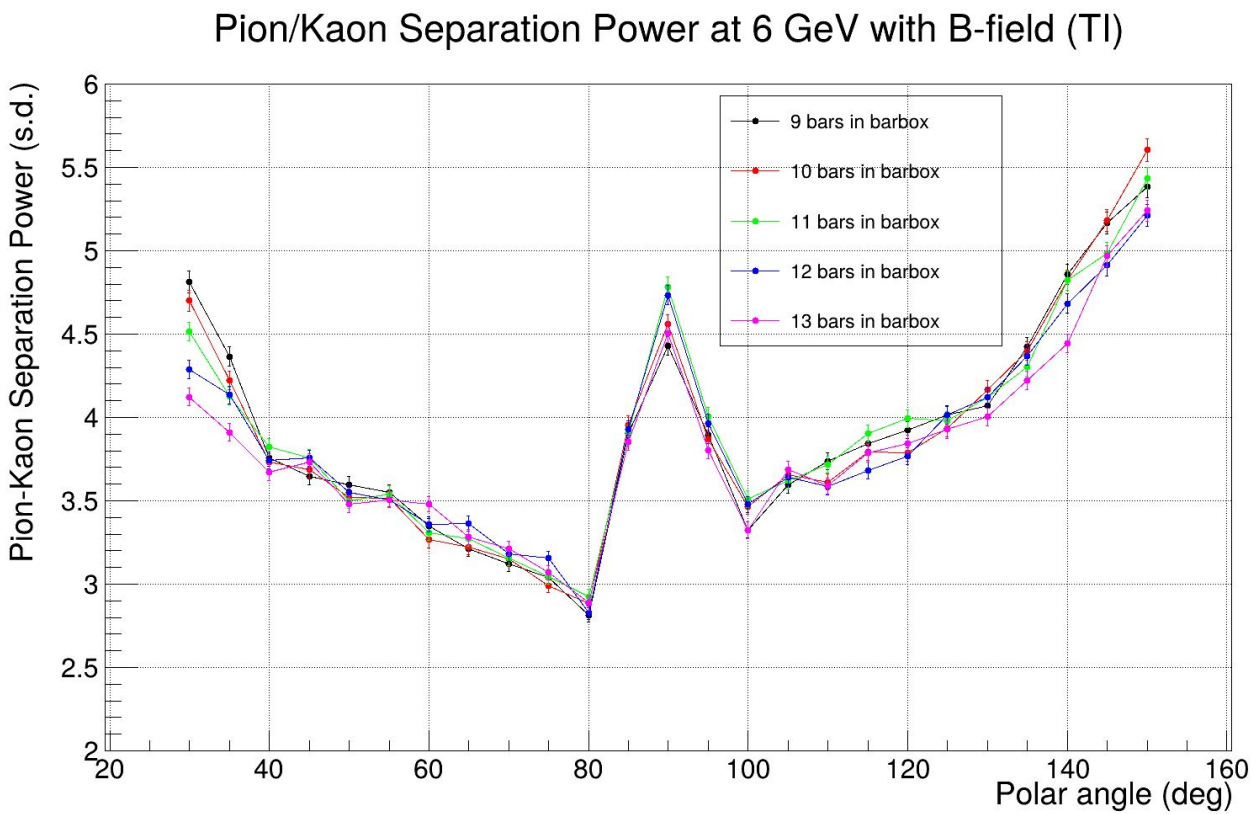
Pol. Angle 150 deg.
Bar Box: 351.35 mm

Performance Plots for different bar widths with B-field





Performance Plots for 9 bars to 13 bars in a barbox



Conclusion

- **Time Imaging Reconstruction:**
  Using 9 to 13 bars per bar box — corresponding to bar widths ranging from 38.9056 mm to 26.89 mm and lens thicknesses from 12.97 mm to 9.73 mm — achieves separation power above 3σ.

Evaluating the impact of increased dark noise in HRPPDs on hpDIRC performance.

Study Approach and Objectives

Approach:

Identification of Dark Noise:

- Dark noise hits are identified by checking the **z-component of photon momentum**:
  - `if (fabs(dirz) < 1E-6)` → classified as a **dark noise** hit.
- This condition reflects that true Cherenkov photons travel along the z-direction, while dark noise lacks a meaningful trajectory.

Smearing:

- A **1 mm Gaussian smearing** is applied to the photon path (`lenz += gRandom->Gaus(0, 1)`) to mimic physical uncertainties, including for dark noise.

Study Approach and Objectives

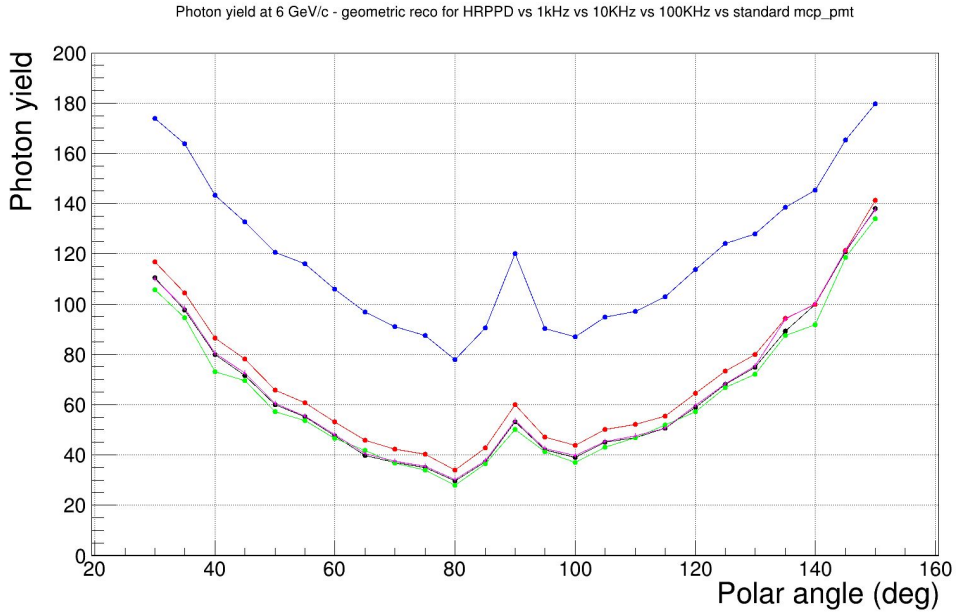
Reflection Tagging for Dark Noise:

- Since dark noise has no real trajectory, a **pseudo-reflection flag** is assigned based on angle and time:
  - If `fTheta > 99°` → marked as **direct** (`reflected = false`)
  - If `fTheta < 81°` → marked as **reflected**
  - For intermediate angles:
    - If `hitTime < 42 ns` → treated as **direct**
    - Else → **reflected**

Objectives:

- This approach ensures dark noise hits are realistically incorporated into the simulation by assigning plausible detector timing and reflection characteristics.
- Helps in evaluating detector performance for HRPPD sensor under realistic background noise conditions.

DN impact on performance (Photon Yield) with Geometric reco



HRPPD (0.01KHz per square mm && 116.64 KHz/pmt)

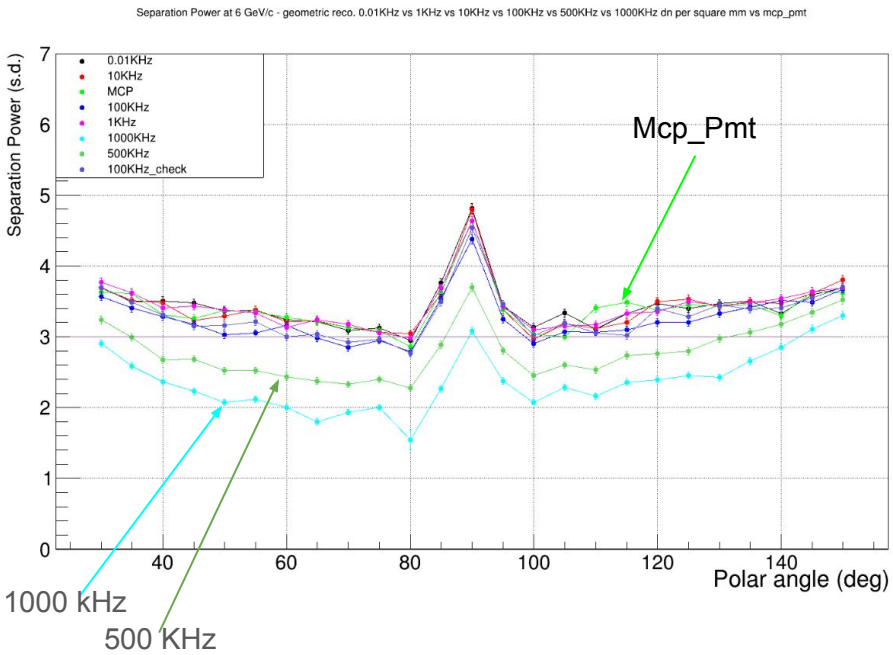
1KHz DN per square mm, **11664** KHz/Pmt

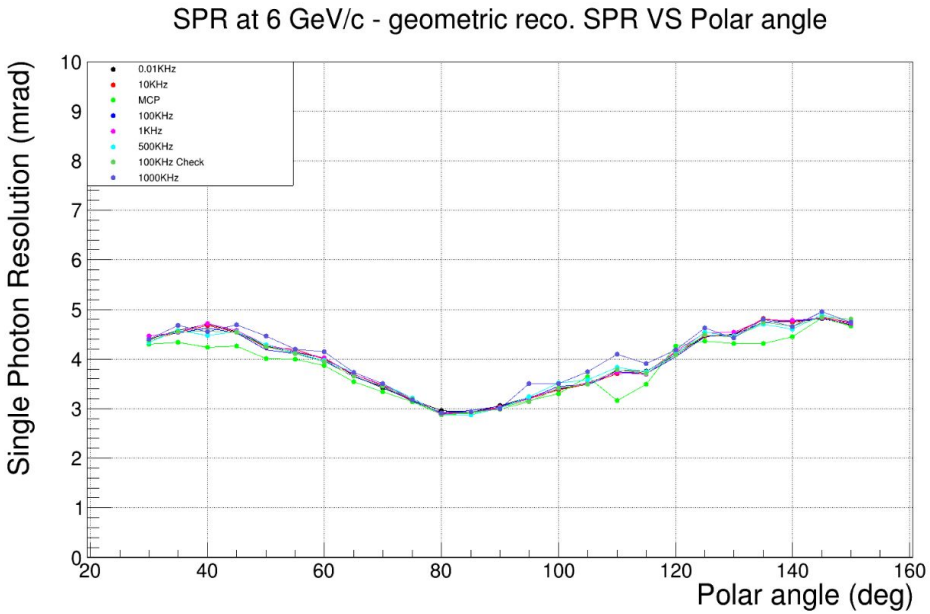
10KHz DN per square mm, **116640** KHz/Pmt

Standard mcp_pmt (0.01KHz per square mm && 28.09 KHz/pmt)

100KHz DN per square mm, **1166400** KHz/Pmt

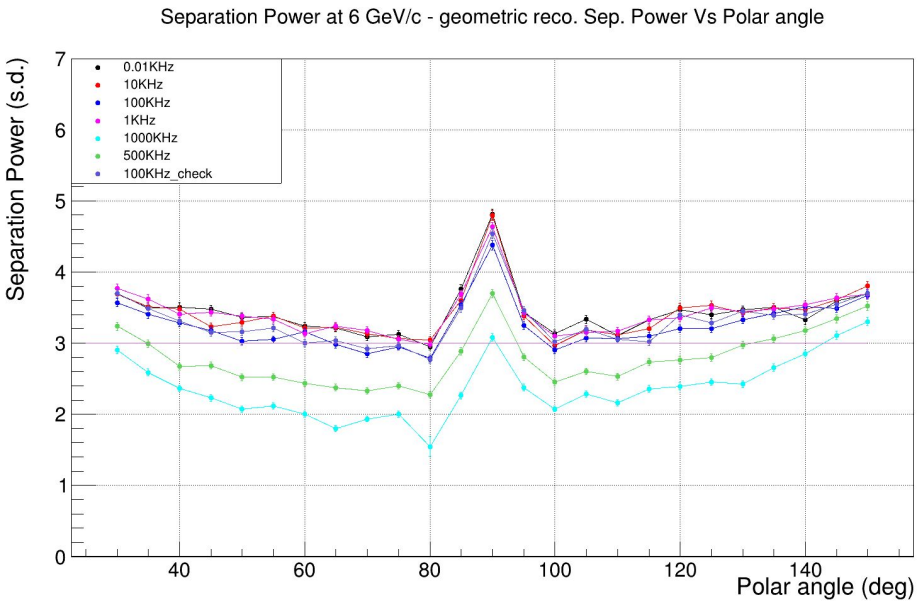
DN impact on performance with Geometric reconstruction

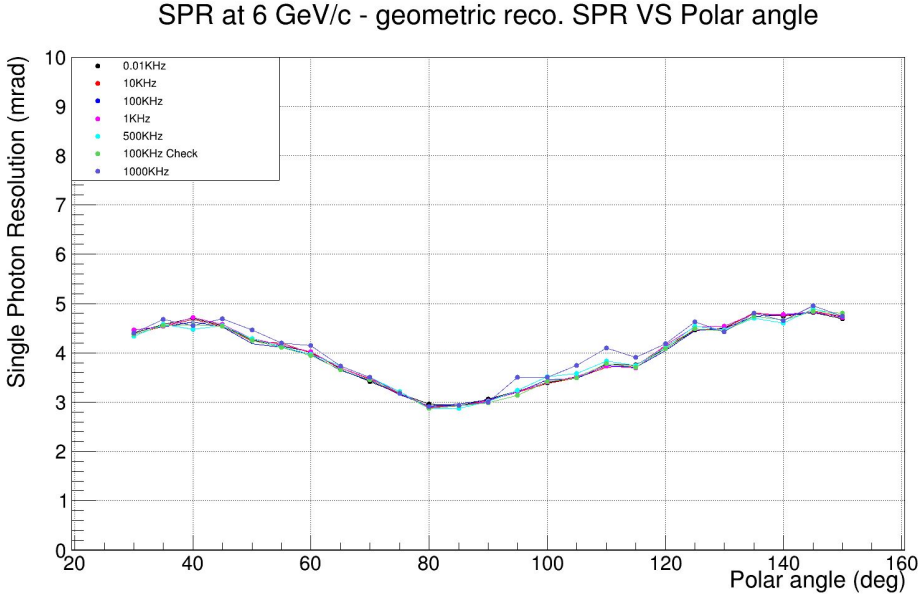




For Mcp_pmt, pixel size (16 x 16) = 3.3125 x 3.3125 mm², active area =53x53 mm² , total active area = 6 x 4 x 53 x 53 mm².
For HRPPD, pixel size (32 x 32) = 3.375 x 3.375 mm², active area = 108 x 108 mm², total active area = 2 x 3 x 108 x 108 mm².

DN impact on performance with Geometric reconstruction



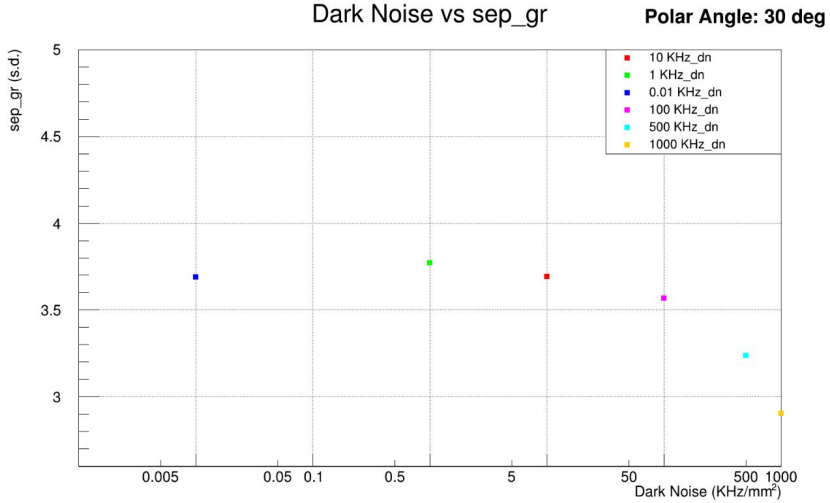


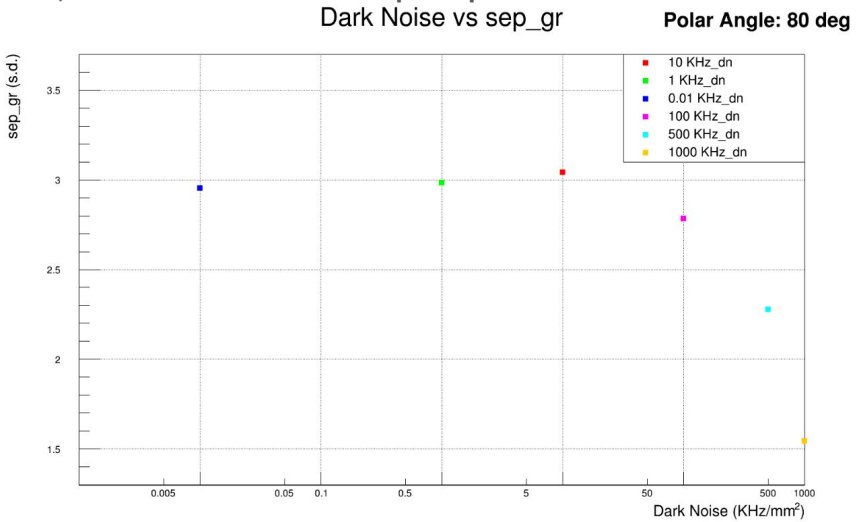
For HRPPD, pixel size (32 x 32) = 3.375 x 3.375 mm², active area = 108 x 108 mm²,

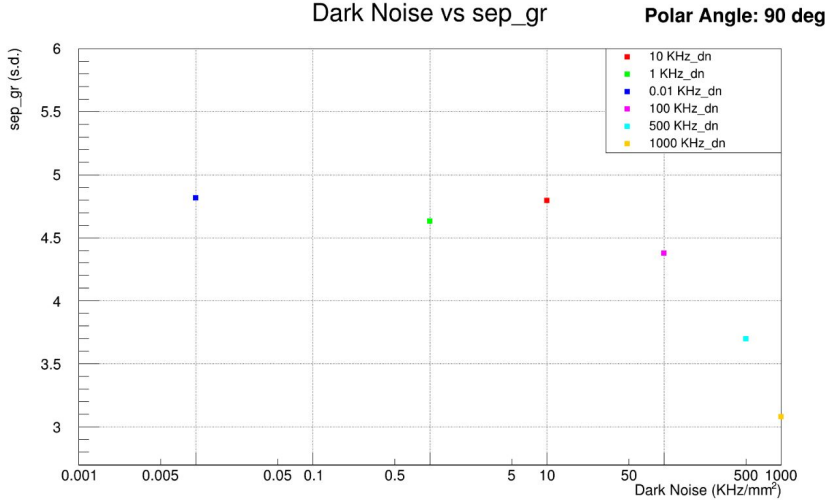
Sensor: HRPPD

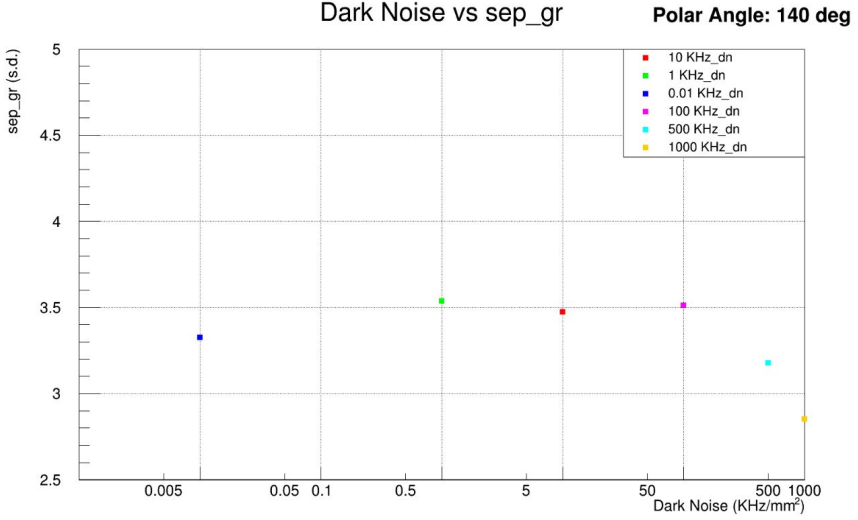
0.01 KHz per mm²
1 KHz per mm²
10 KHz per mm²
100 KHz per mm²
500 KHz per mm²
1000 KHz per mm²

DN vs sep_gr plot for 0.01KHz, 1KHz, 10KHz and 100KHz, 500KHz and 1000KHz DN per square mm

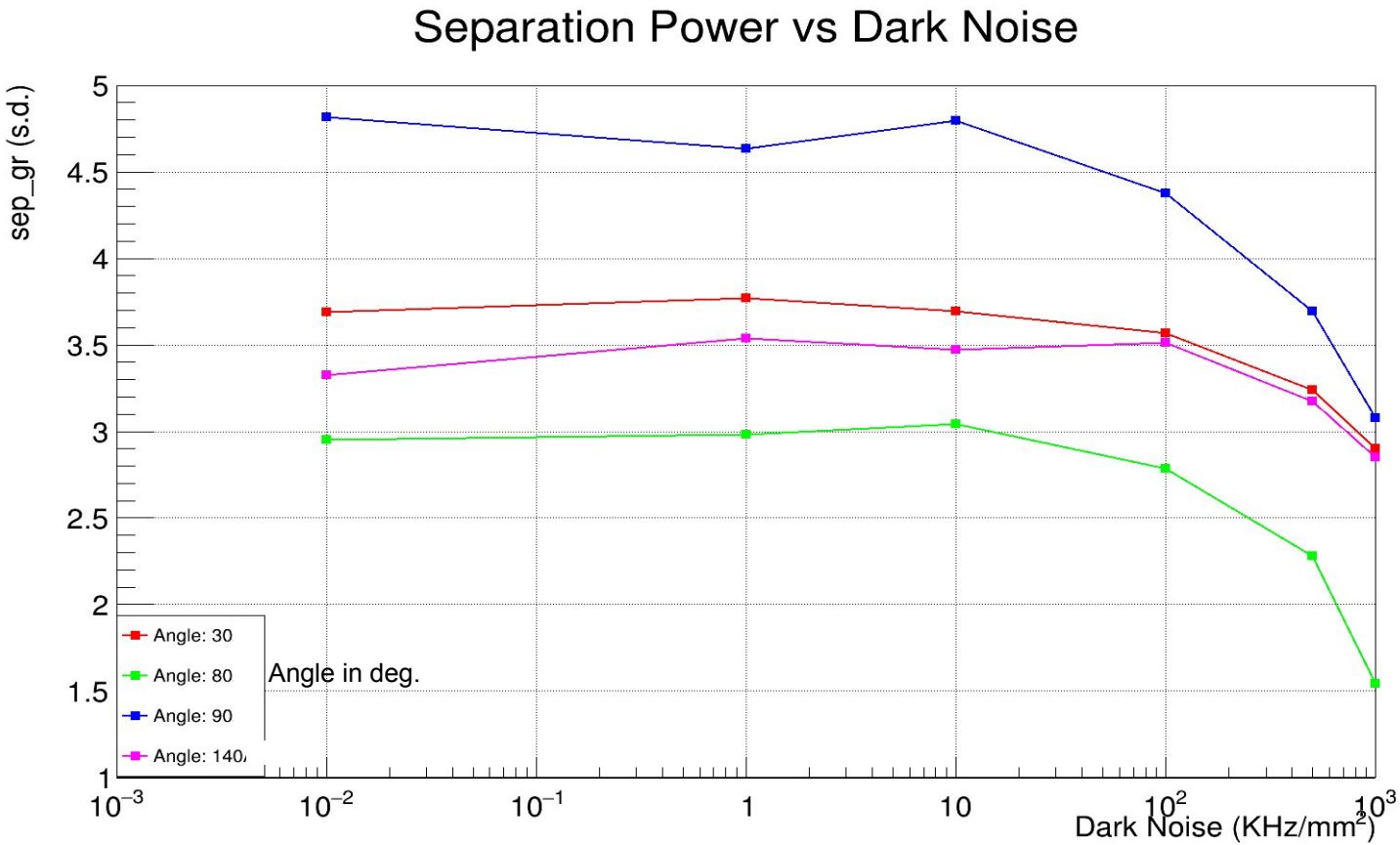




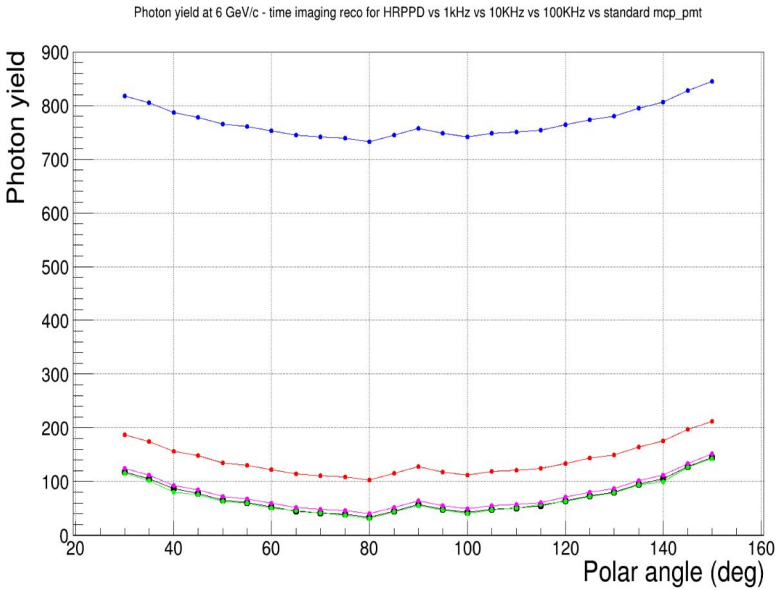


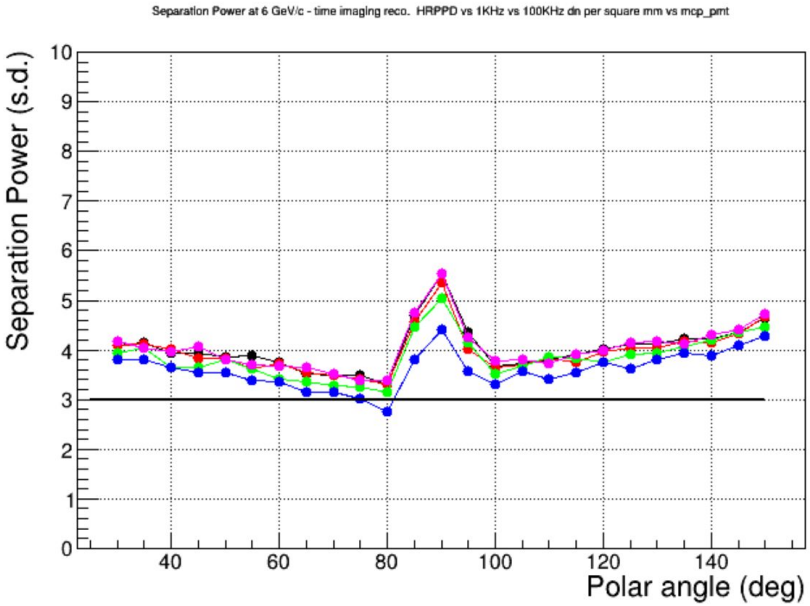


DN vs sep_gr plot for four different polar angle



DN impact on performance with time-based reco different pixel size for mcp_pmt and HRPPD





Photon Yield is visibly higher for higher DN rates because in time imaging reco there are no cuts applied..

For MCP_PMT, pixel size (16 x 16) = 3.3 x 3.3 mm² , active area = 53 x 53 mm²
For HRPPD, pixel size (40x40)= 2.7 x 2.7 mm², active area = 108 x 108 mm²

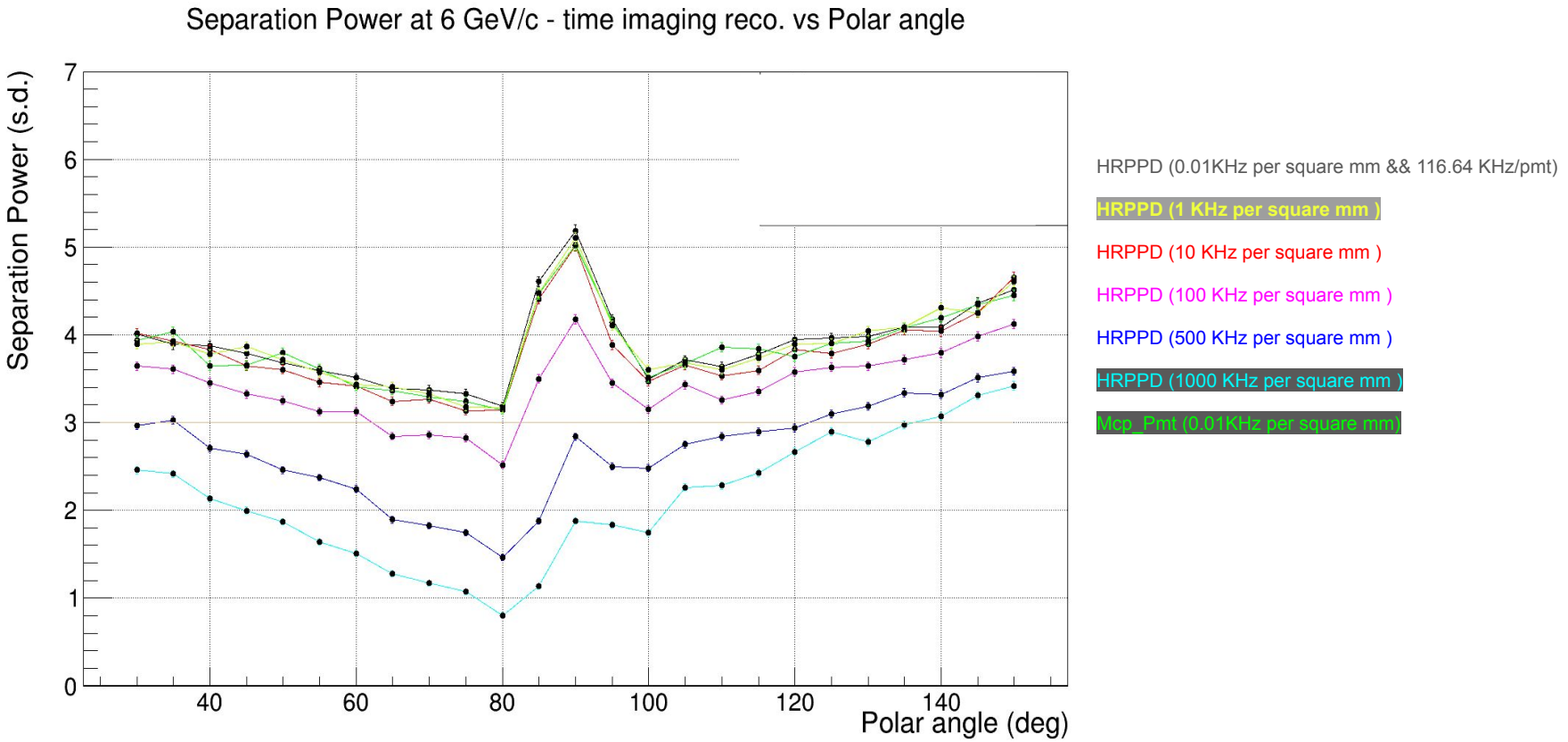
HRPPD (0.01KHz per square mm && 116.64 KHz/pmt)

1KHz DN per square mm

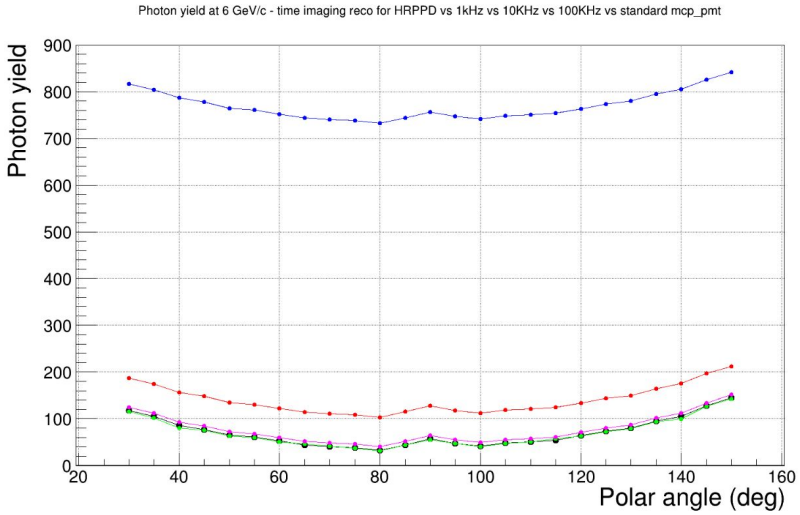
10KHz DN per square mm

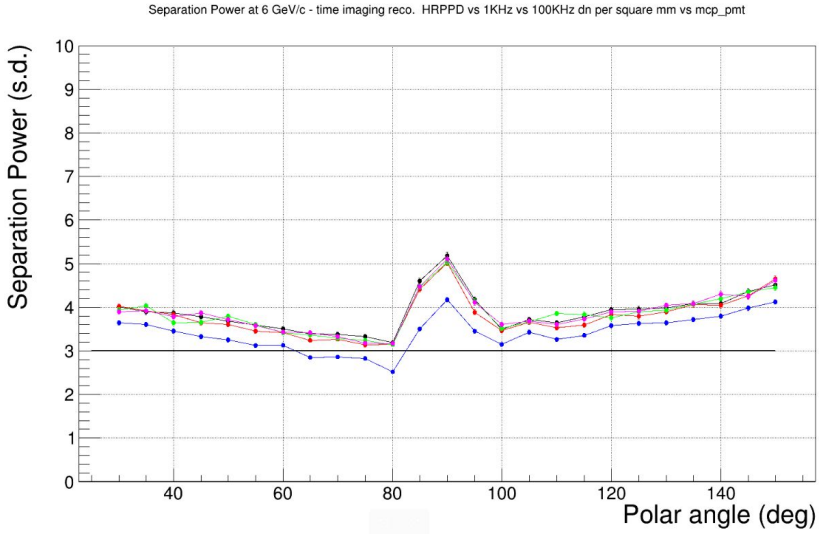
100KHz DN per square mm

Standard mcp_pmt (0.01KHz per square mm && 28.09 KHz/pmt)


Separation Power at 6 GeV/c - time imaging reco. vs Polar angle
Separation Power (s.d.)
Polar angle (deg)
0
1
2
3
4
5
6
7
40
60
80
100
120
140
HRPPD (0.01KHz per square mm && 116.64 KHz/pmt)
HRPPD (1 KHz per square mm)
HRPPD (10 KHz per square mm)
HRPPD (100 KHz per square mm)
HRPPD (500 KHz per square mm)
HRPPD (1000 KHz per square mm)
Mcp_Pmt (0.01KHz per square mm)

DN impact on performance with time-based reco almost same pixel size for mcp_pmt and HRPPD





Time Imaging Reco.

HRPPD (0.01KHz per square mm && 116.64 KHz/pmt)

1KHz DN per square mm

10KHz DN per square mm

100KHz DN per square mm

Standard mcp_pmt (0.01KHz per square mm && 28.09 KHz/pmt)

Photon Yield is more for more dark noise because we did not use any time cut here.

For MCP_PMT, pixel size (16 x 16) = 3.3 x 3.3 mm^2 , active area = 53mm
For HRPPD, pixel size (32 x 32)= 3.375 x 3.375 mm^2, active area = 108 mm

Detailed performance values for Geometric reco (HRPPD pixel 3.37 mm and Mcp_pmt pixel 3.3mm)

	Dark noise(mm^2)	80°	90°	110°	125°	145°
Geo.	1KHz	27.88/ 41	51.00 / 65	44.34 / 59	64.84 / 82	117.53/139
	10KHz	28.29 / 105	52.50 / 129	46.49 / 122	66.59 / 145	118.93/ 202
Photon yield	100KHz	32.09 / 734	70.05 / 758	65.27 / 752	86.73 / 775	134.99/ 832
reco /sim photon	HRPPD (0.01KHz)	27.65 / 34	50.55 / 59	44.53 / 52	64.94 / 75	117.76/132
	Mcp_Pmt (0.01KHz)	26.16 / 32	47.76 / 55	45.32 / 52	64.53 / 74	115.24/130
	1KHz	2.91	3.04	3.67	4.45	4.80
	10KHz	2.90	3.03	3.72	4.52	4.77
SPR	100KHz	2.91	2.98	3.72	4.46	4.80
	HRPPD default	2.89	3.05	3.73	4.47	4.74
	Mcp_Pmt (0.01KHz)	2.95	3.04	3.33	4.57	5.13

Average SPR shift from pixel size 2.7 mm to 3.3 mm= 0.0716 mrad.

Detailed performance values for Time imaging reco (HRPPD pixel 3.37 mm and Mcp_pmt pixel 3.3mm)

	Dark noise(mm^2)	80°	90°	110°	125°	145°
Time imaging	1KHz	41	66	59	82	139
(pixel size around 3.3)	10KHz	104	129	122	145	202
Photon yield	100KHz	734	758	752	775	832
	HRPPD (0.01KHz)	34	59	52	75	132
	Mcp_Pmt (0.01KHz)	32	55	52	74	130
Sep.	10KHz	3.15	5.02	3.54	3.79	4.26
Power	100KHz	2.52	4.18	3.26	3.63	3.98
	HRPPD (0.01KHz)	3.18	5.19	3.64	3.96	4.36
	Mcp_Pmt (0.01KHz)	3.14	5.03	3.86	3.90	4.35

Average Sep power shift from pixel size 2.7 mm to 3.3 mm= 0.164 s.d.

Conclusion

- Simulations tested HRPPD dark noise levels ranging from **0.01 kHz to 1000 kHz/mm².**
- Both **geometric** and **time imaging reconstruction** methods showed approximately **3 s.d** separation power for Pion Kaon Identification up to **100 kHz/mm²**.
- Performance began to degrade noticeably at **higher dark noise levels** (> 100 kHz/mm²).
- These results help define realistic operating conditions for HRPPD-based DIRC systems.
- However, this evaluation considers only dark noise. To comprehensively assess HRPPD performance, additional characteristics beyond dark noise — such as afterpulsing should be implemented

hpDIRC detector plane coverage study

Study Approach and Objectives

- In the current geometry, each MCP-PMT sensor has a total area of **59 × 59 mm²**, with an **active area of 53 × 53 mm²**.
- However, **fitting 6 × 4 MCP-PMTs** within the available detector plane is **not practical** due to space constraints.
- To address this, we explored an alternative configuration using **5 × 4 MCP-PMTs** and evaluated its impact on detector performance.

Two layout approaches were studied:

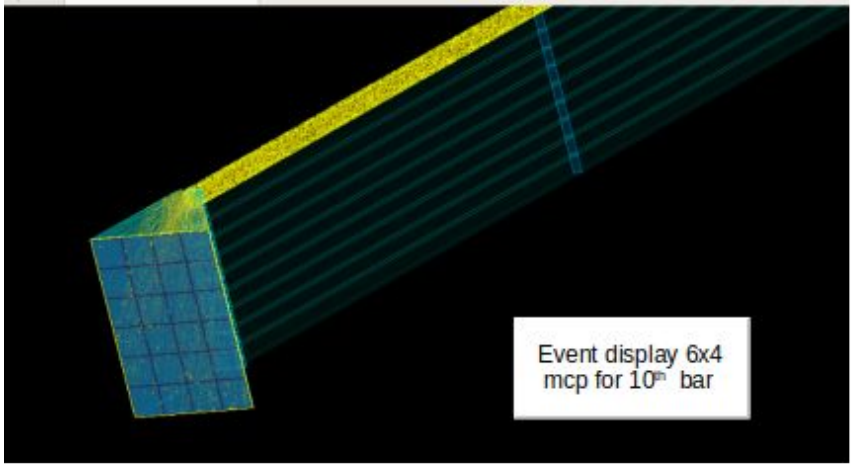
1. **Compact Layout (Centered Block):**
    - All **5 × 4 MCP-PMTs** are placed **tightly together**, without any space between adjacent PMTs.
    - The entire block is centered on the detector plane by leaving **symmetrical gaps of 28.25 mm** on both sides along the x-axis.

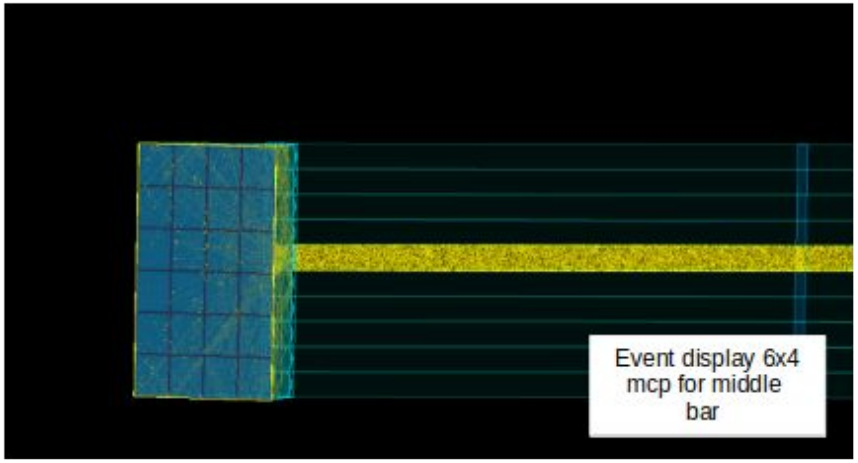
Study Approach and Objectives

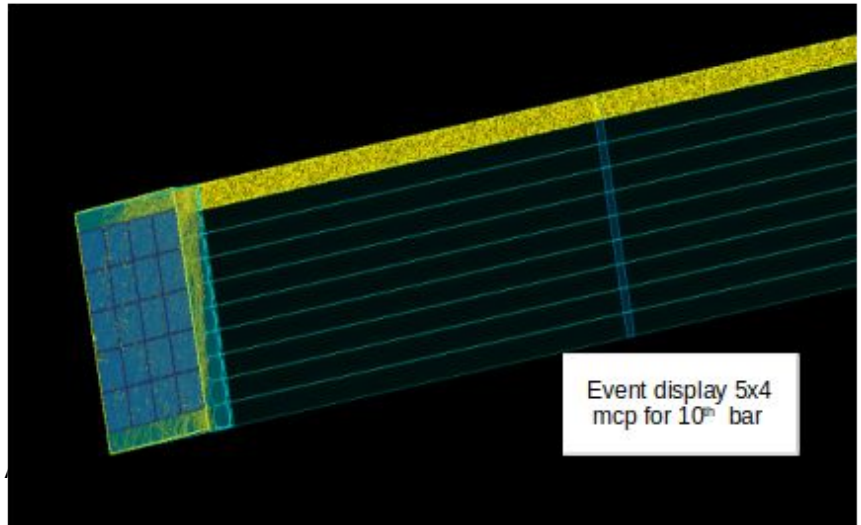
2. Symmetrical Spread Layout:

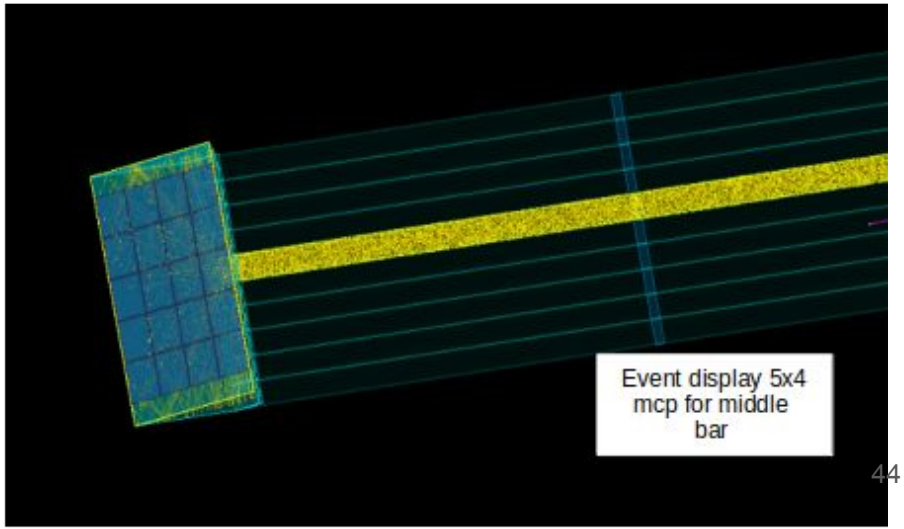
- The **5 × 4 MCP-PMTs** are **evenly distributed across the detector plane**.
- **Symmetrical gaps (9.42 mm)** are introduced **between PMTs along the x-direction** to spread them uniformly.

❖ The goal is to assess whether reducing the number of PMTs while adjusting the layout still preserves the desired performance, particularly in terms of photon yield and separation power.


Event display 6x4
mcp for 10th bar


Event display 6x4
mcp for middle
bar


Event display 5x4
mcp for 10th bar


Event display 5x4
mcp for middle
bar

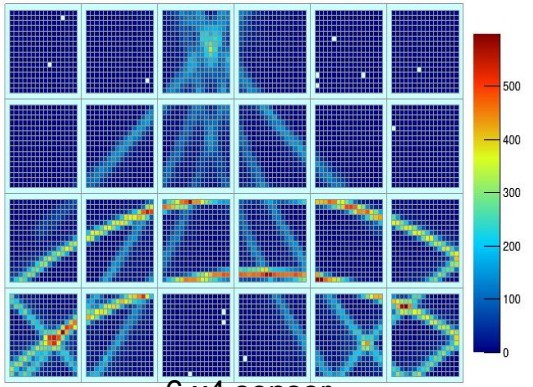
Compact Layout of Mcp_Pmt

6x4 Sensor arrangement

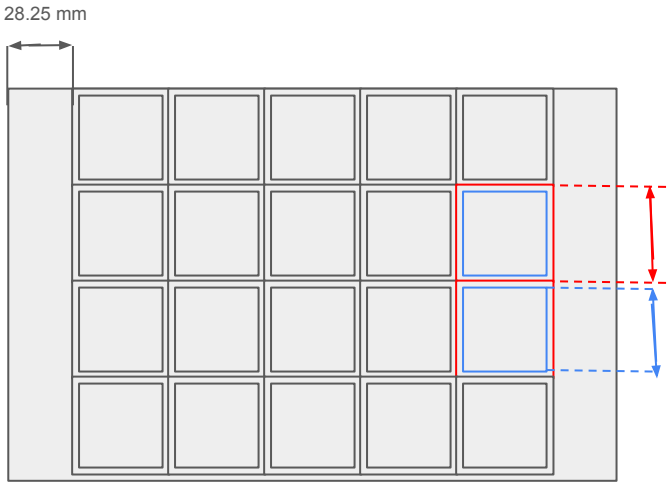
- Total area = 6x4x59x59 mm²
  = 83544 mm²
- Active area = 6x4x53x53 mm²
  = 67416 mm²

5x4 Sensor arrangement

- Total area = 5x4x59x59 mm²
  = 69620 mm²
- Active area = 5x4x53x53 mm²
  = 56180 mm²

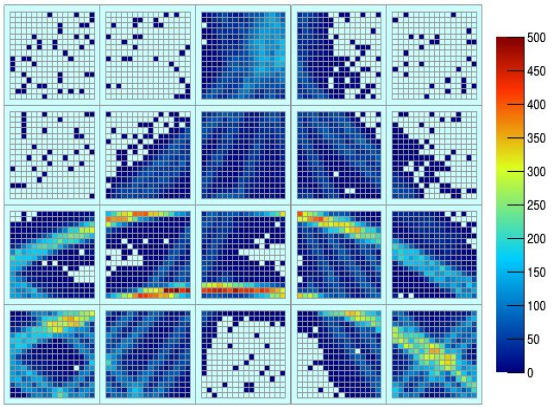


6 x4 sensor



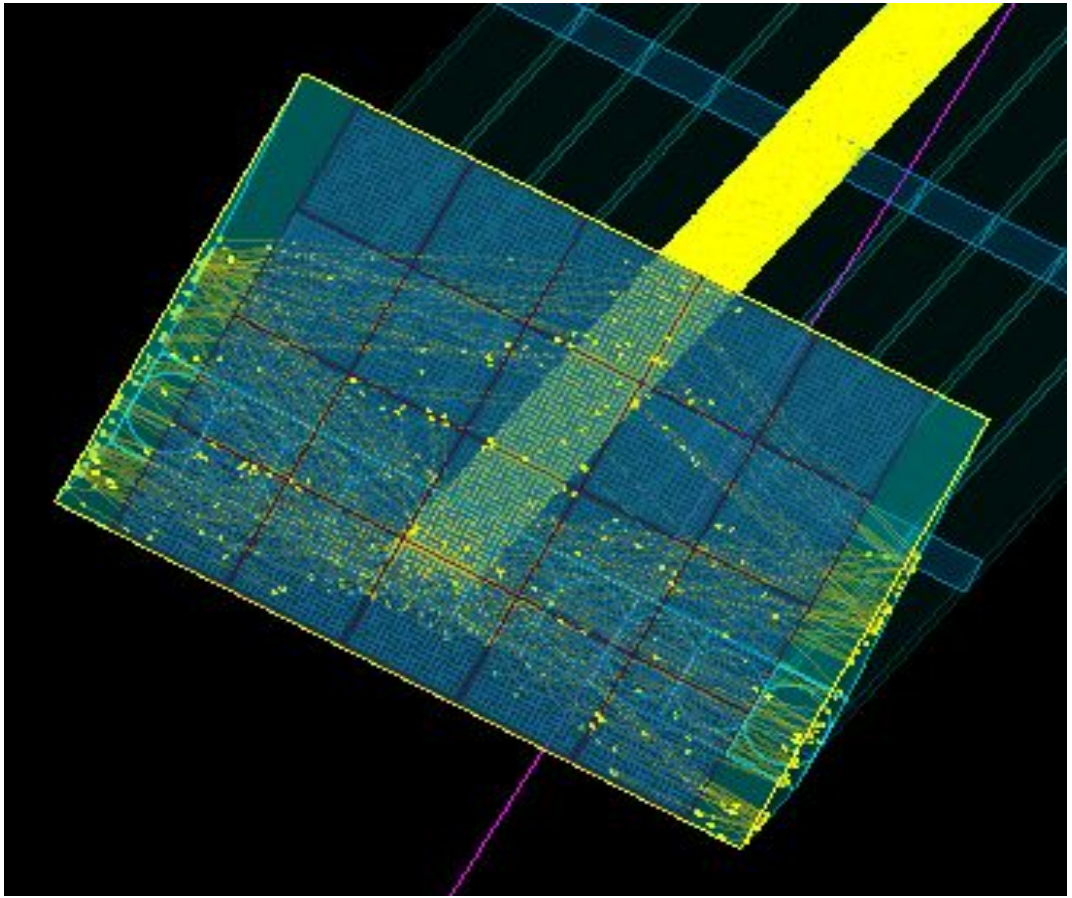
59 x 59 mm²

53 x 53 mm²



5 x4 sensor

Event display (compact layout) of Mcp_Pmt



6x4 Sensor arrangement

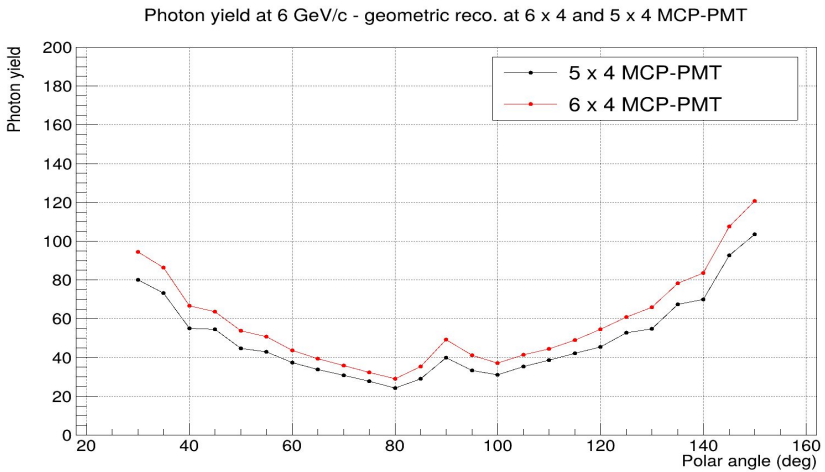
- Total area = 6x4x59x59 mm²
  = 83544 mm²
- Active area = 6x4x53x53 mm²
  = 67416 mm²

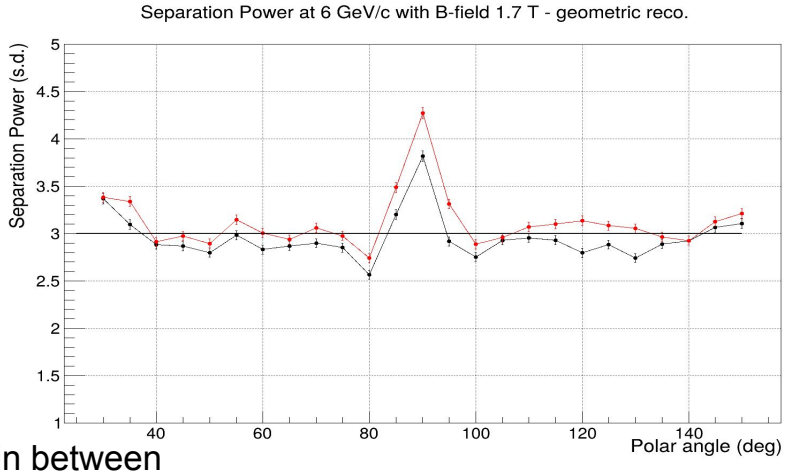
5x4 Sensor arrangement

- Total area = 5x4x59x59 mm²
  = 69620 mm²
- Active area = 5x4x53x53 mm²
  = 56180 mm²

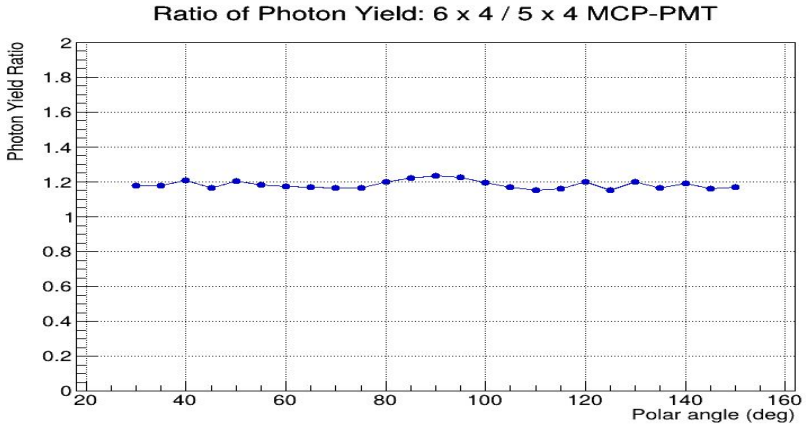
Space uncovered in both sides = 28.25 mm

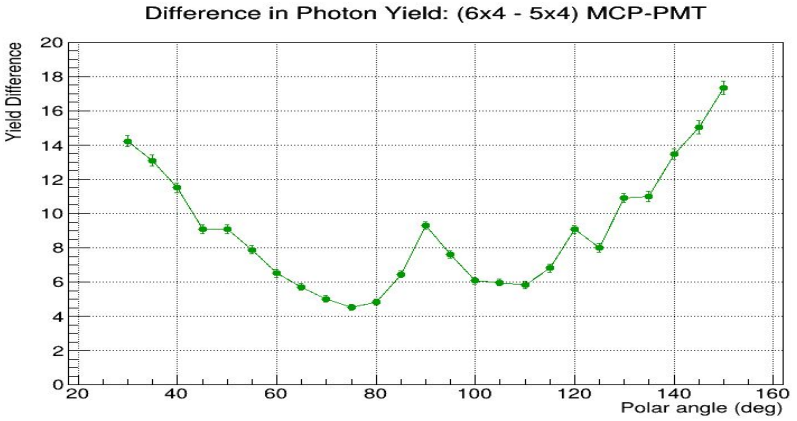
Performance plots (compact layout) at 6 Gev/c - Geometric reco with b-field



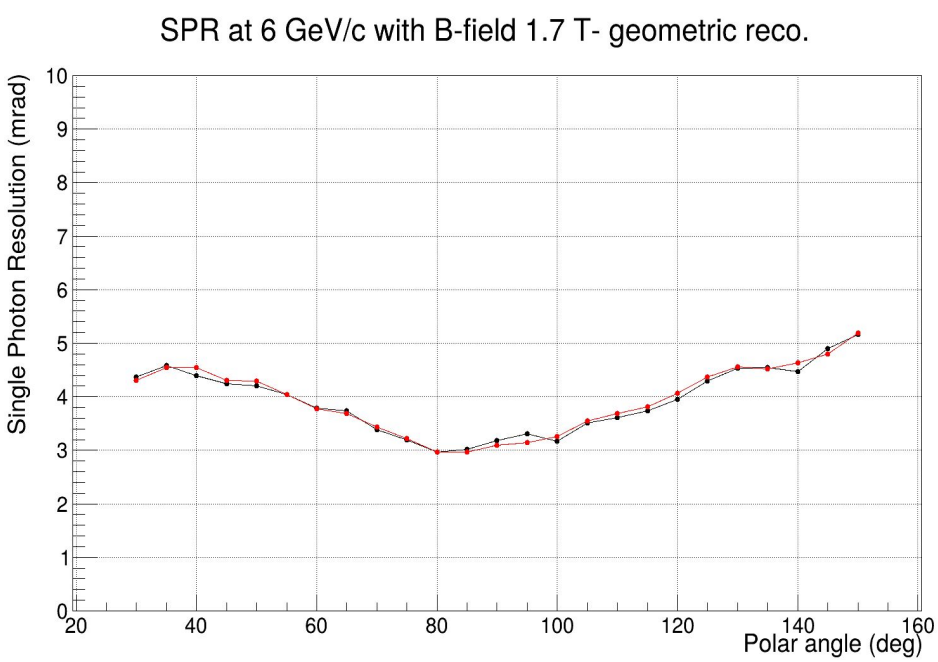


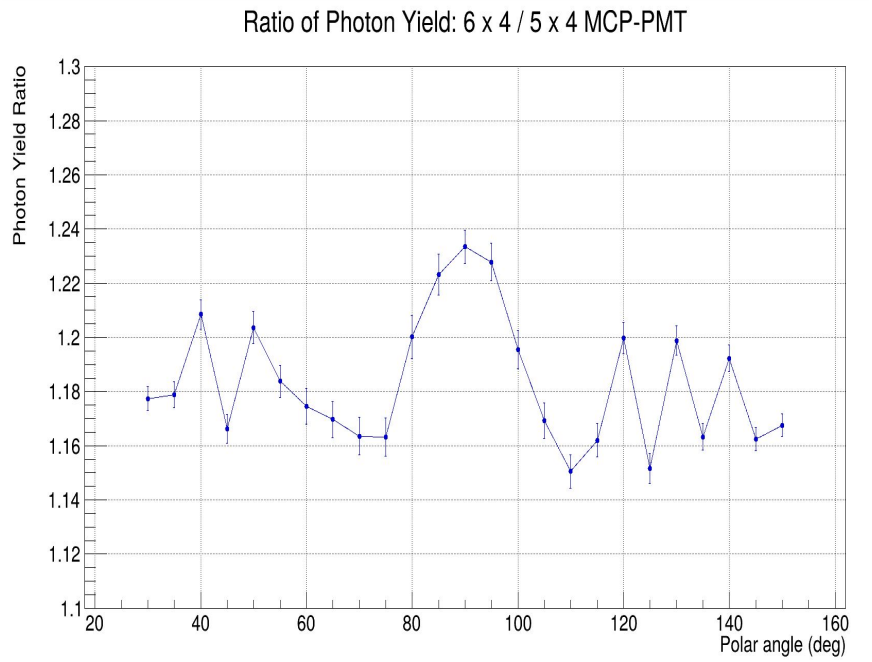
No Gaps in between pmts





Performance plots (compact layout) at 6 Gev/c - Geometric reco with b-field



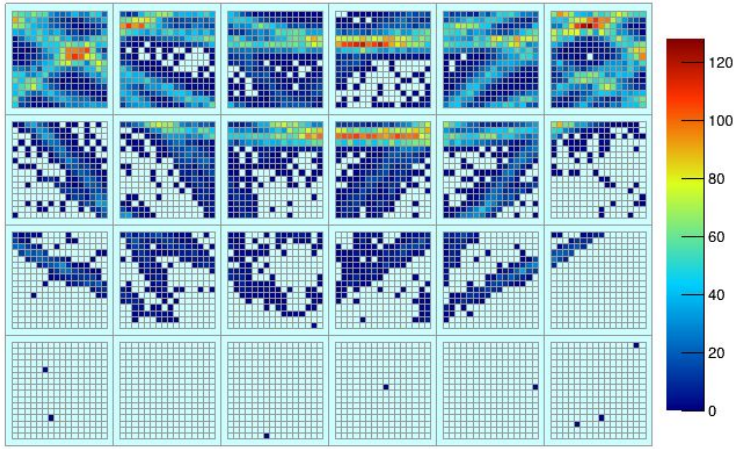


No Gaps in between pmts

6 x 4 pmts

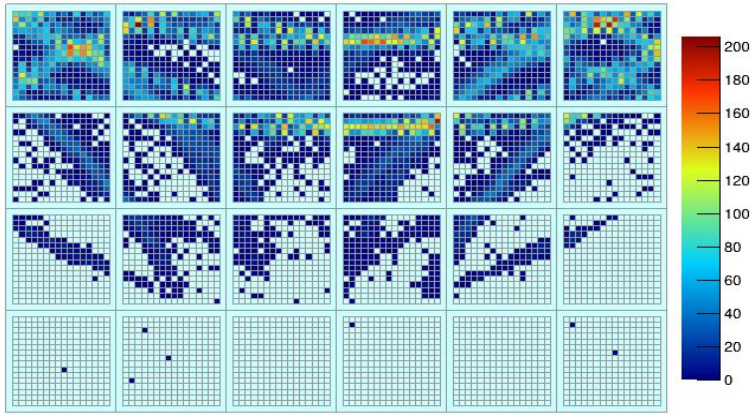
5 x 4 pmts

Hit pattern for 6 x 4 pmts vs 5 x 4 pmts (compact layout)

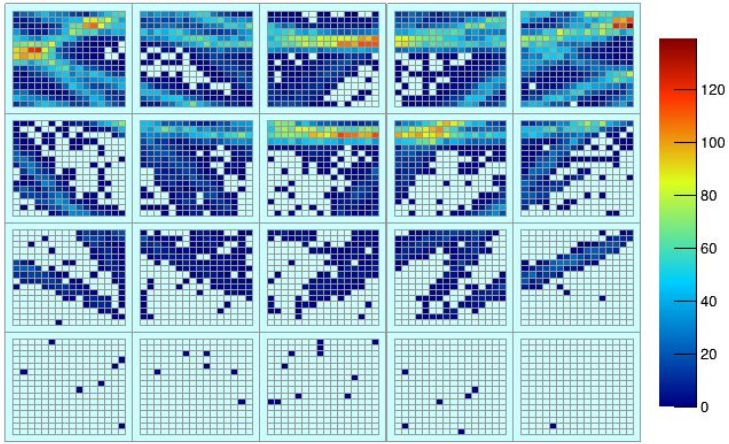


80 deg.

6 x 4 = 24 pmt

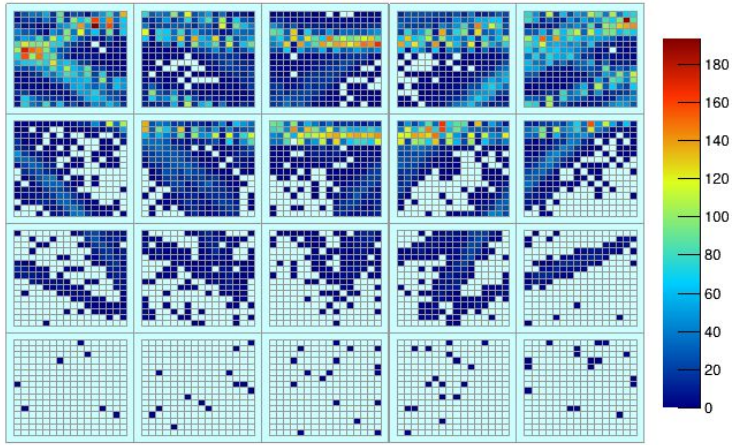


100 deg.

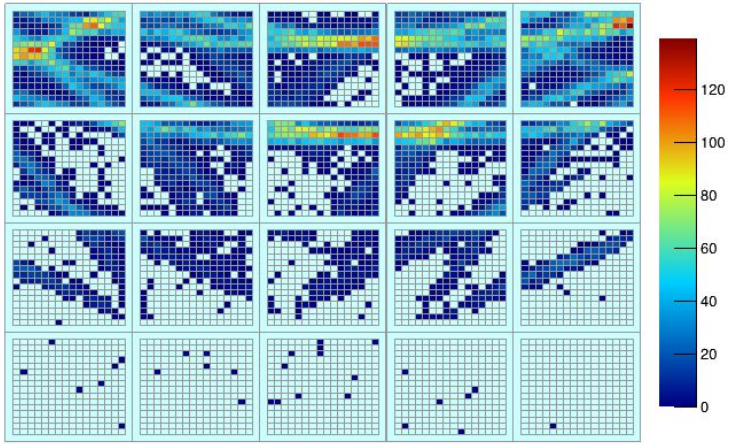


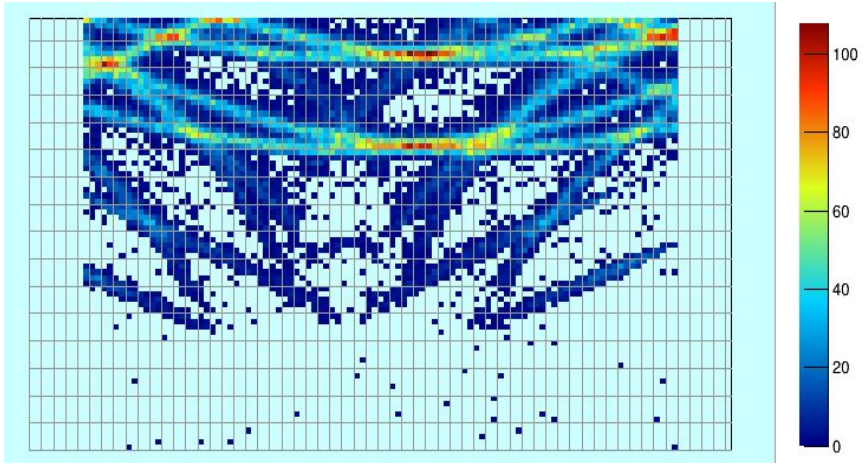
No Gaps in between pmts

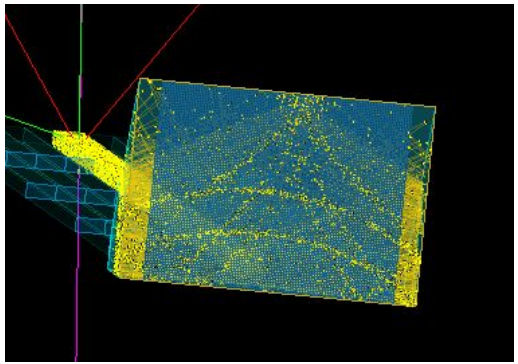
5 x 4 = 20 pmt



Hit pattern 5 x 4 pmts at 80 deg. Pol. angle (compact layout)

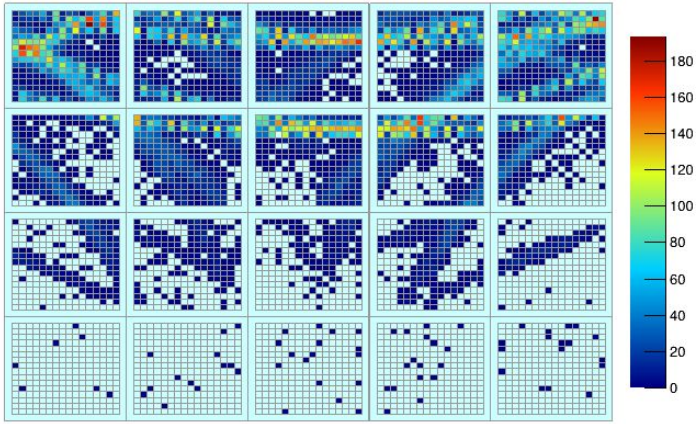


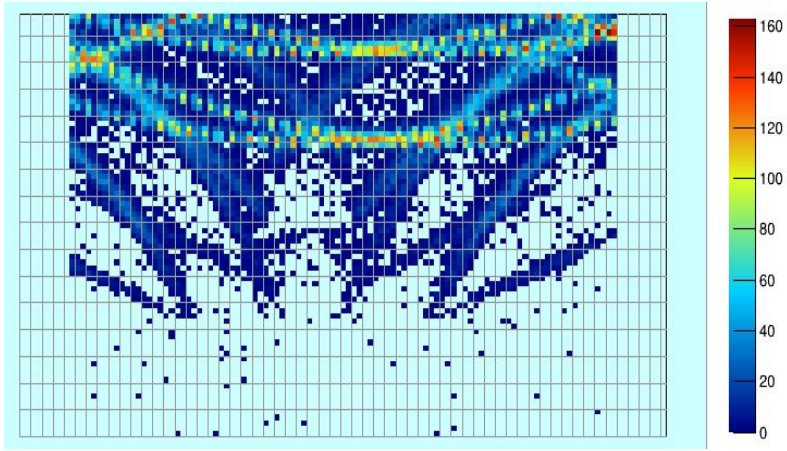


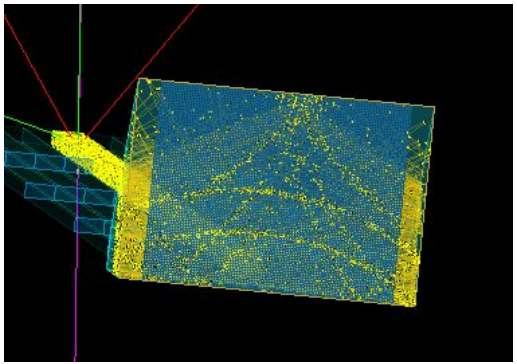


Used lens thickness = 12 optimal = 11.7532
Number of pixels =9243 pixel's size = 3
Total detector plane size: 237 mm × 351 mm
Pixel layout (geometry):
  Along X (columns) = 79
  Along Y (rows)   = 117
  Total pixels   = 9243
Deactivated edge pixels along Y: ±28.25 mm
  Active pixels: 7821
  Inactive pixels: 1422

Hit pattern 5 x 4 pmts at 100 deg. Pol. angle (compact layout)

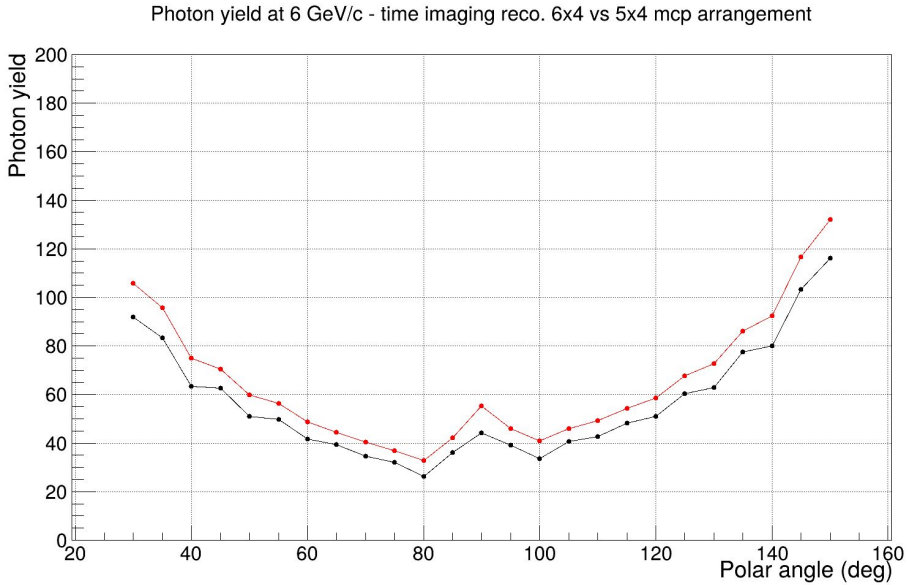


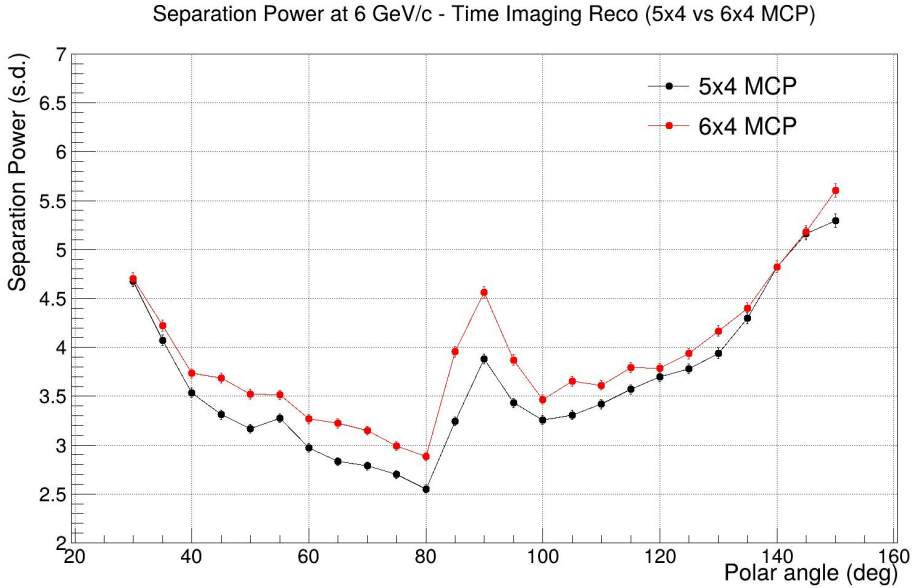




Used lens thickness = 12 optimal = 11.7532
Number of pixels =9243 pixel's size = 3
Total detector plane size: 237 mm × 351 mm
Pixel layout (geometry):
  Along X (columns) = 79
  Along Y (rows)   = 117
  Total pixels   = 9243
Deactivated edge pixels along Y: ±28.25 mm
  Active pixels: 7821
  Inactive pixels: 1422

Performance plots (compact layout) at 6 Gev/c - Time Imaging reco with b-field





Sensor: Mcp_Pmt

6 x 4 = 24 pmt

5 x 4 = 20 pmt

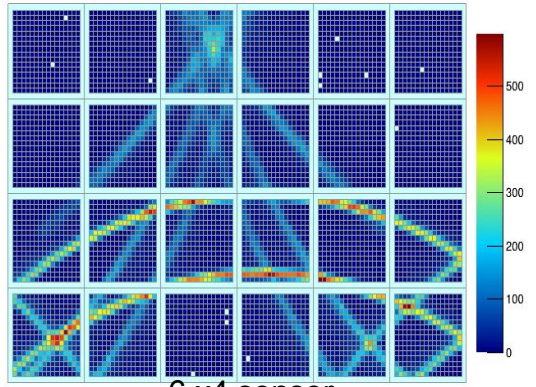
Symmetrical Spread Layout of Mcp_Pmt

6x4 Sensor arrangement

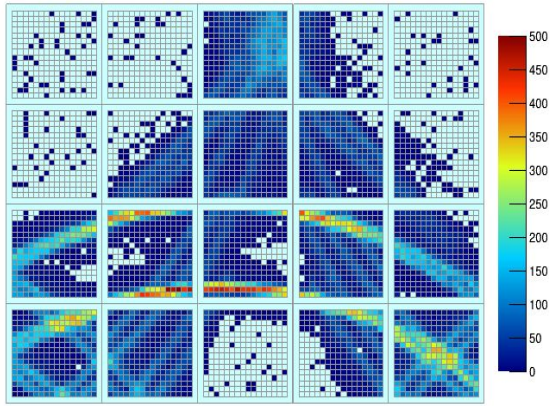
- Total area = 6x4x59x59 mm²
  = 83544 mm²
- Active area = 6x4x53x53 mm²
  = 67416 mm²

5x4 Sensor arrangement

- Total area = 5x4x59x59 mm²
  = 69620 mm²
- Active area = 5x4x53x53 mm²
  = 56180 mm²

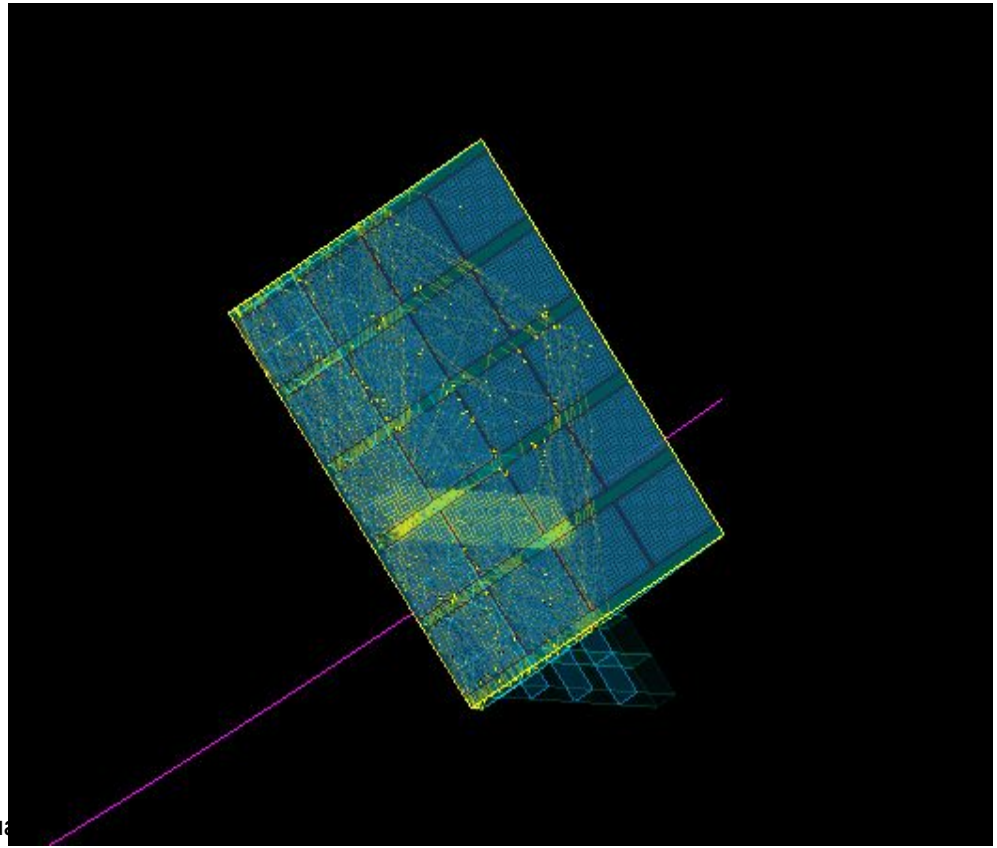


6 x4 sensor



5 x4 sensor

Event display (symmetrical spread layout) of Mcp_Pmt



6x4 Sensor arrangement

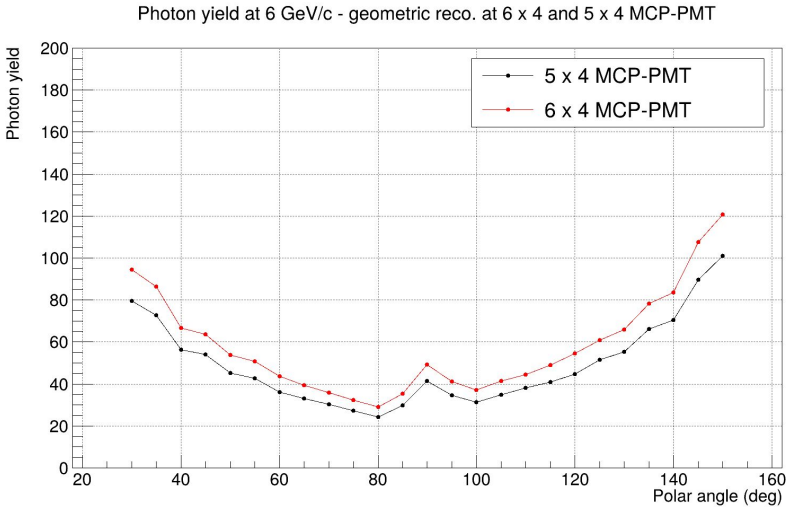
- Total area = 6x4x59x59 mm²
  = 83544 mm²
- Active area = 6x4x53x53 mm²
  = 67416 mm²

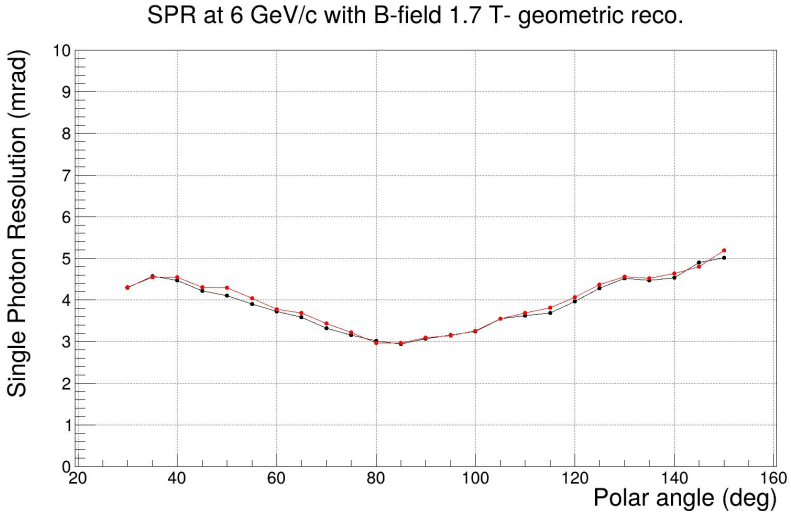
5x4 Sensor arrangement

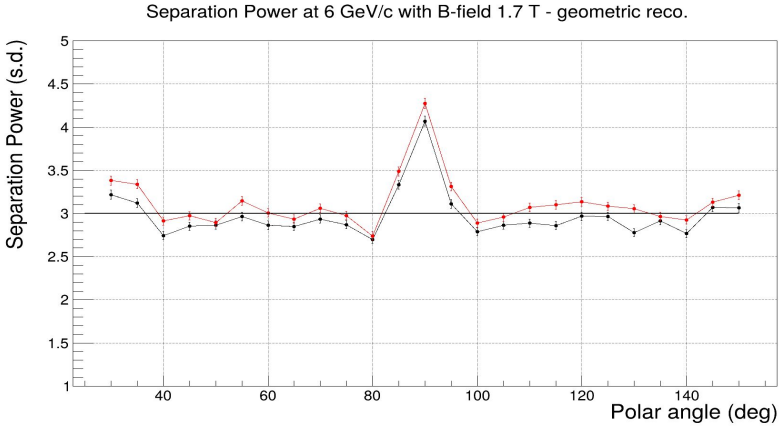
- Total area = 5x4x59x59 mm²
  = 69620 mm²
- Active area = 5x4x53x53 mm²
  = 56180 mm²

Gaps between the Pmts = 9.42 mm

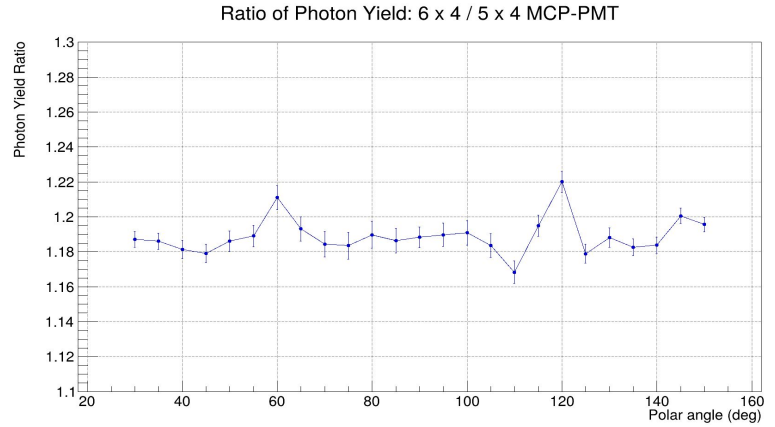
Performance plots (symmetrical spread layout) at 6 Gev/c - Geometric reco with b-field

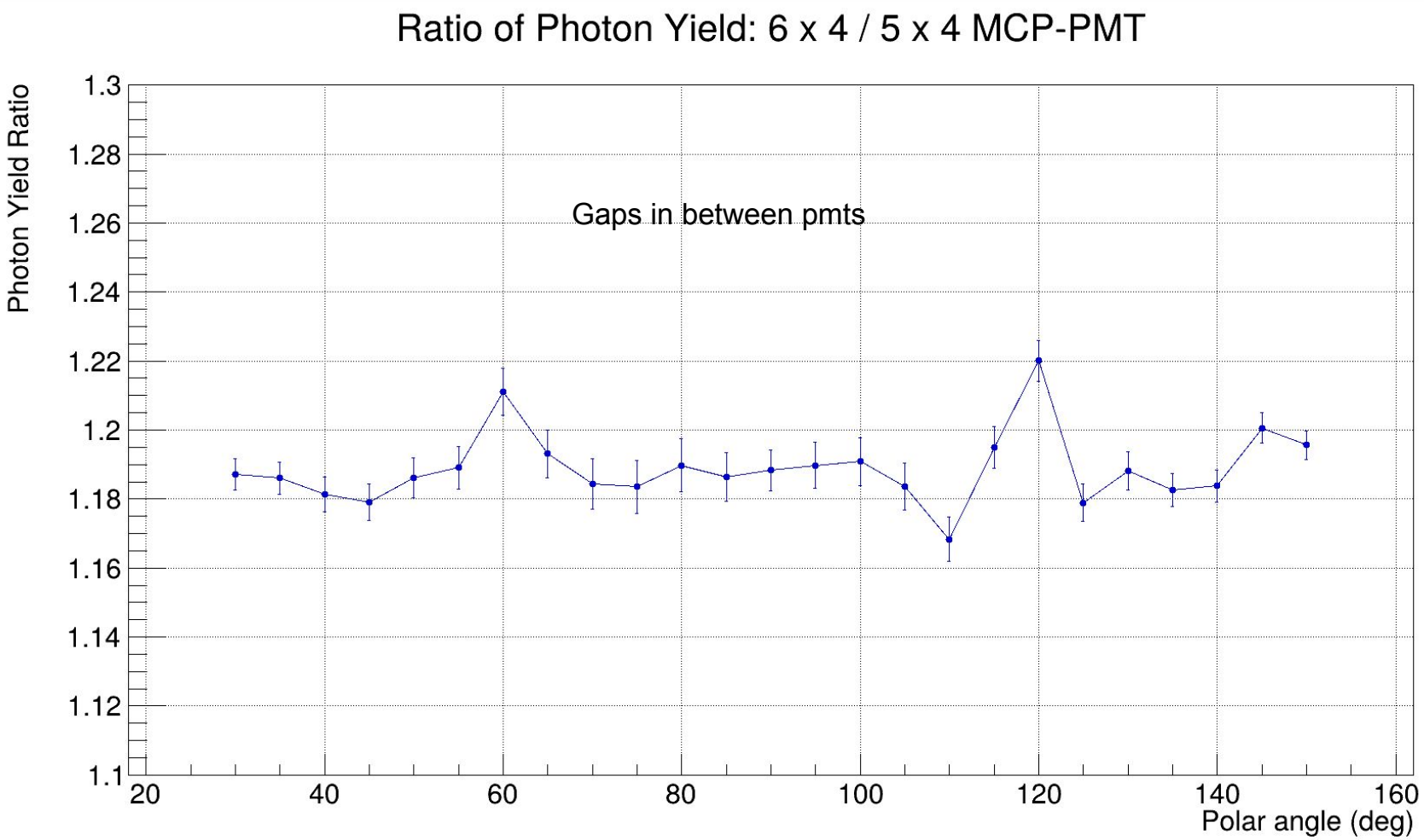




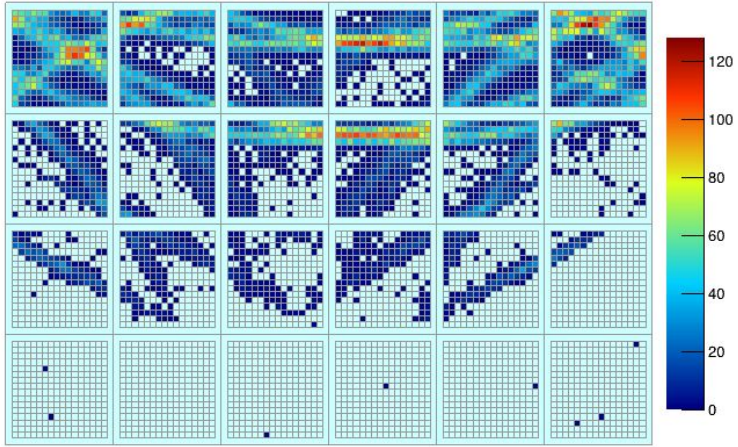


Gaps in between pmts




Ratio of Photon Yield: 6 x 4 / 5 x 4 MCP-PMT
Photon Yield Ratio
Gaps in between pmts
Polar angle (deg)
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
20
40
60
80
100
120
140
160

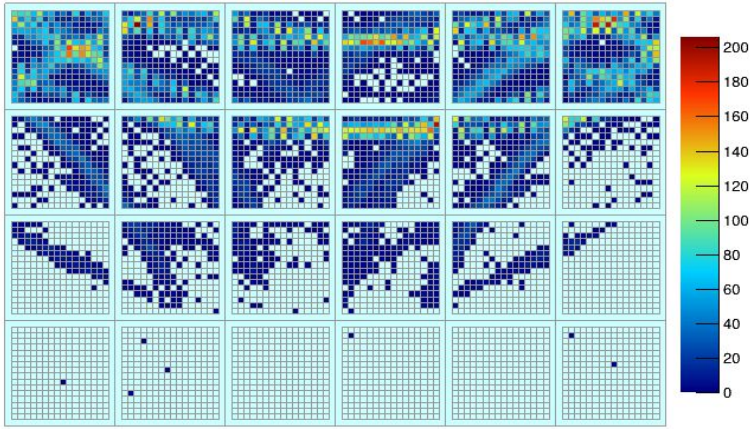
Hit pattern(symmetrical spread layout) for 6 x 4 pmts vs 5 x 4 pmts



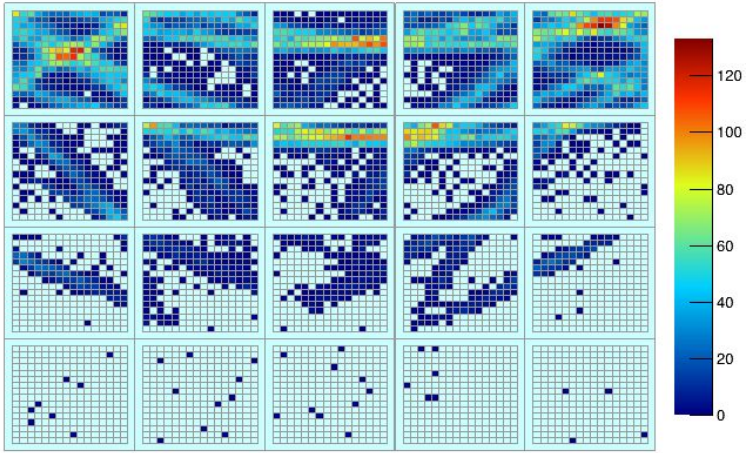
80 deg. Polar angle

6 x 4 = 24 pmt

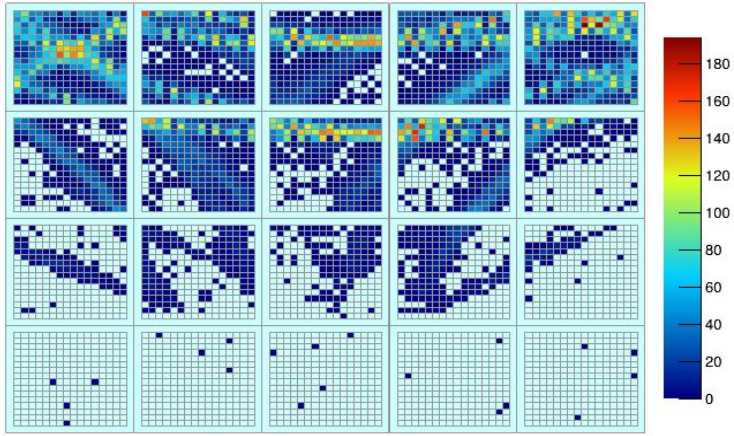
Gaps in between pmts



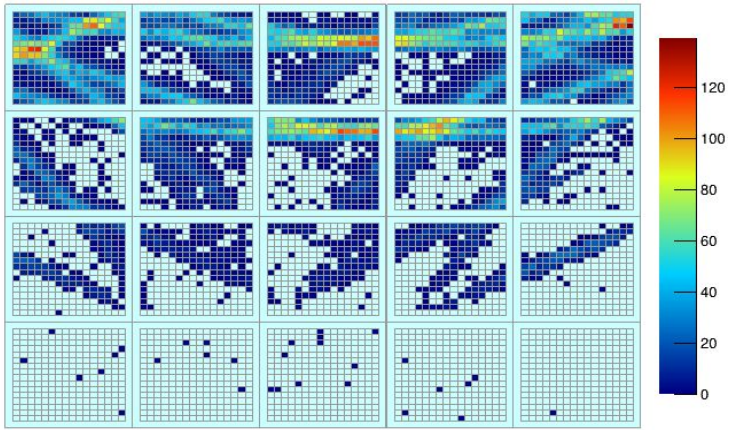
100 deg. Polar angle



5 x 4 = 20 pmt



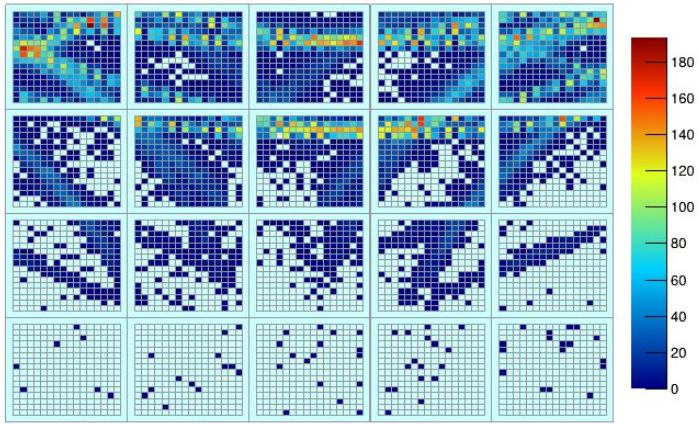
Hit pattern for the 5 × 4 configuration compact layout and symmetrical spread layout



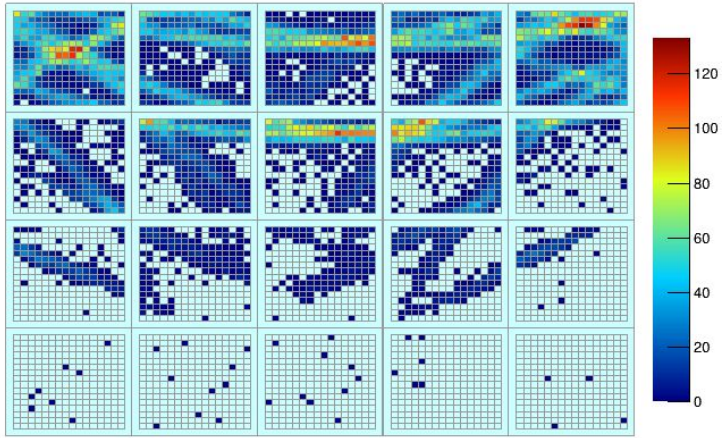
80 deg.

Gaps in both sides, no gaps between pmts

Compact layout

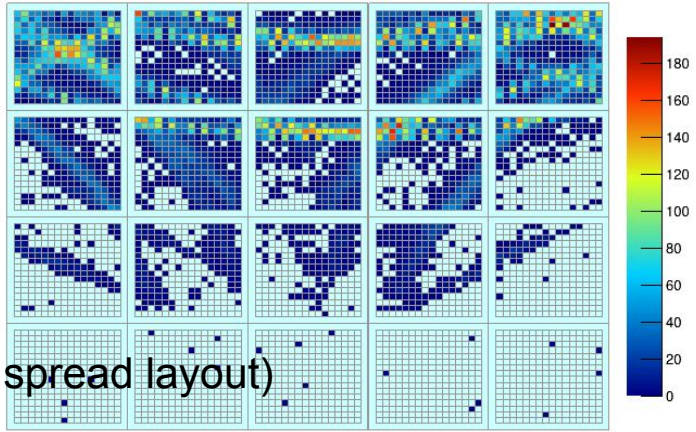


100 deg.

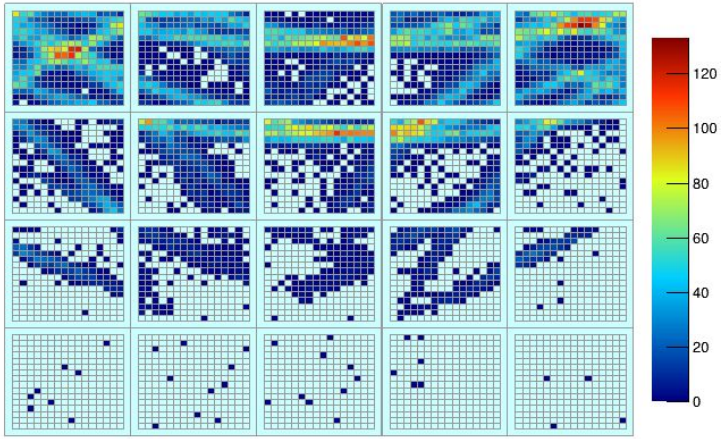


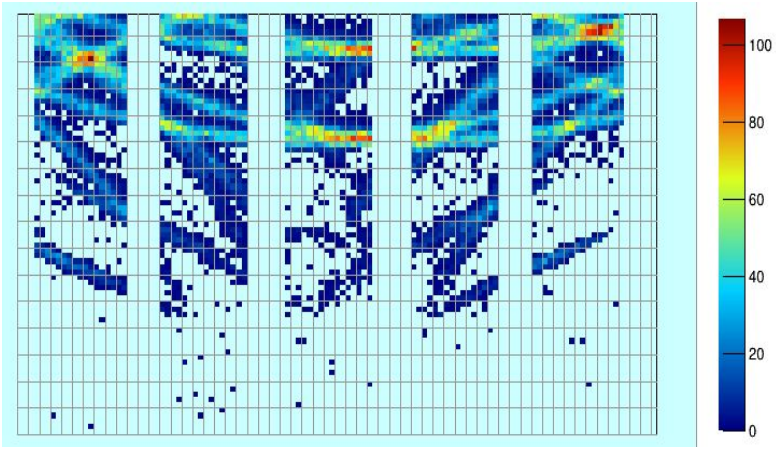
Gaps in between pmts

(symmetrical spread layout)



Hit pattern(symmetrical spread layout) 5 x 4 pmts at 80 deg. Pol. angle

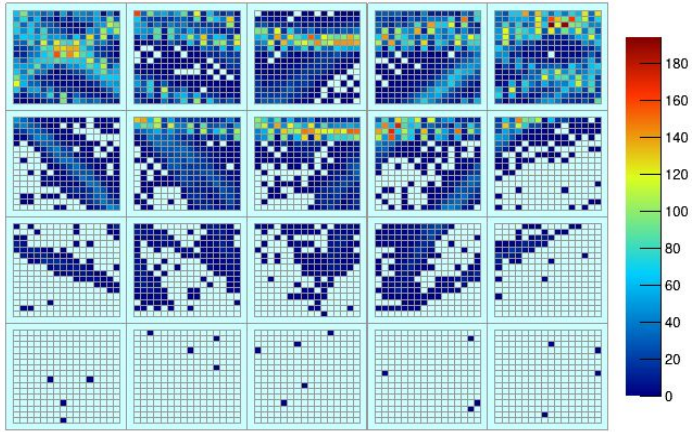


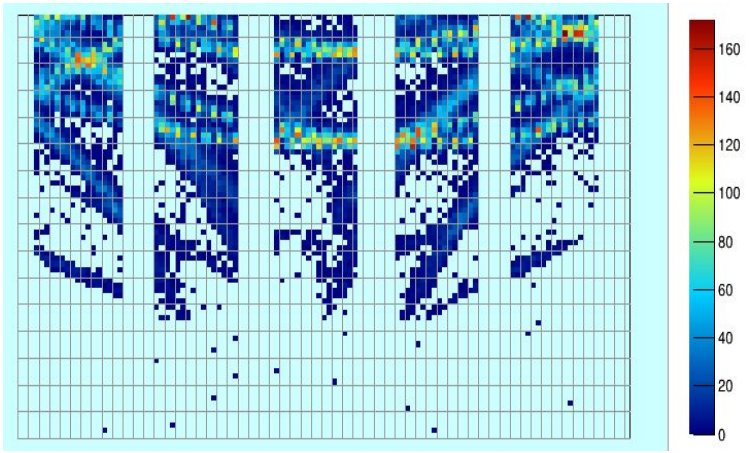


== MCP Region Boundaries (bottom to top) ==
Defined 5 PMT regions separated by 6 gaps of 9.41667 mm each.
  Gap 1: 237 pixels
  Gap 2: 237 pixels
  Gap 3: 237 pixels
  Gap 4: 316 pixels
  Gap 5: 237 pixels
  Gap 6: 237 pixels
Active pixels: 7742
Inactive pixels: 1501

Gap 0: from 0 to 9.41667 mm
 PMT 1: from 9.41667 to 68.3867 mm
 Gap 2: from 68.3867 to 77.8033 mm
 PMT 3: from 77.8033 to 136.773 mm
 Gap 4: from 136.773 to 146.19 mm
 PMT 5: from 146.19 to 205.16 mm
 Gap 6: from 205.16 to 214.577 mm
 PMT 7: from 214.577 to 273.547 mm
 Gap 8: from 273.547 to 282.963 mm
 PMT 9: from 282.963 to 341.933 mm
 Gap 10: from 341.933 to 351.35 mm

Hit pattern(symmetrical spread layout) 5 x 4 pmts at 100 deg. Pol. angle





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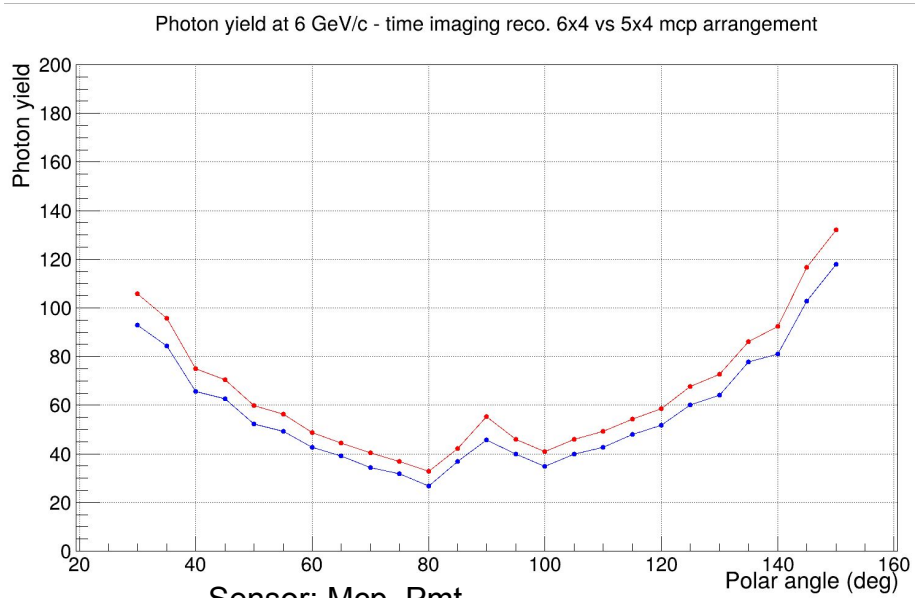
 PMT 9: from 282.963 to 341.933 mm
 Gap 10: from 341.933 to 351.35 mm

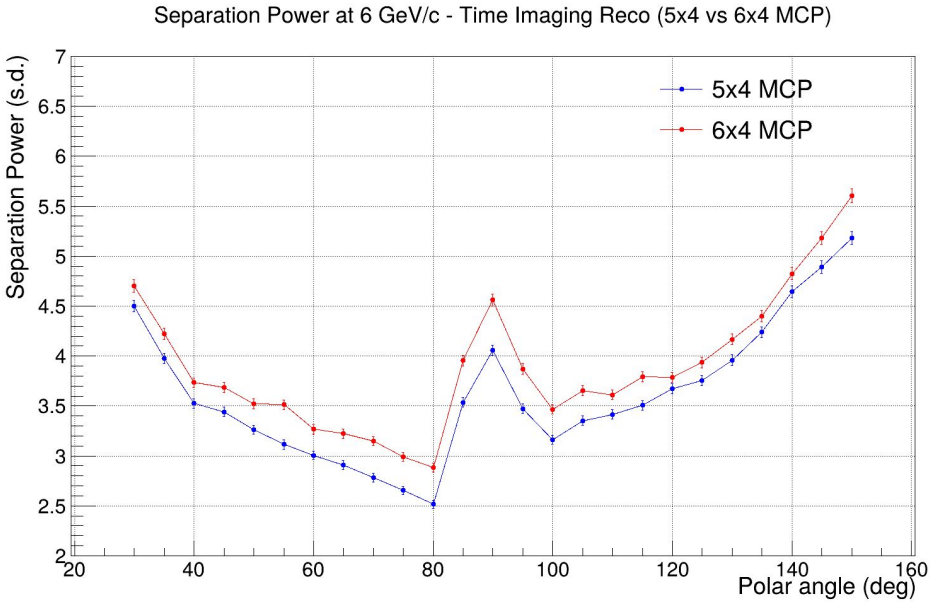
Performance plots (symmetrical spread layout) at 6 Gev/c - Time Imaging reco with b-field



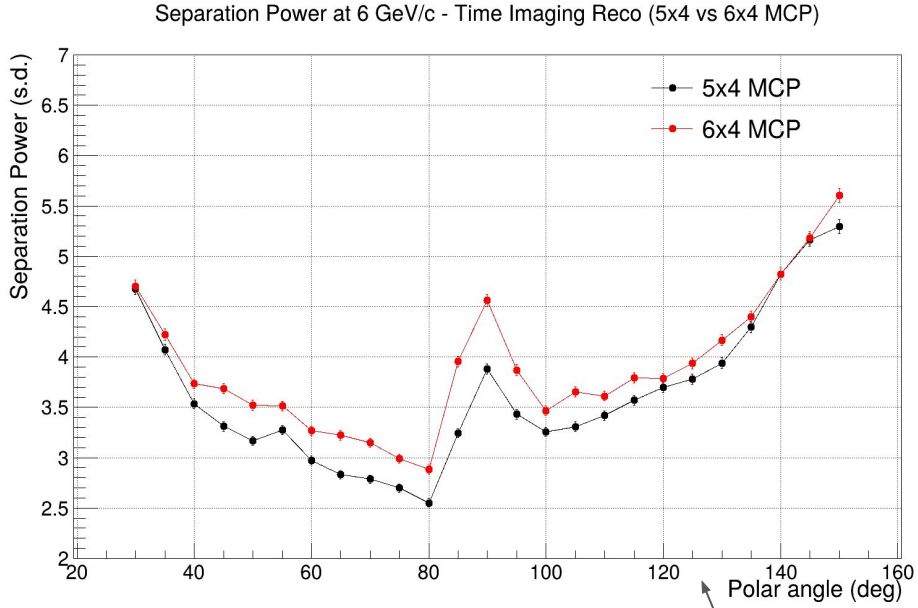
Sensor: Mcp_Pmt

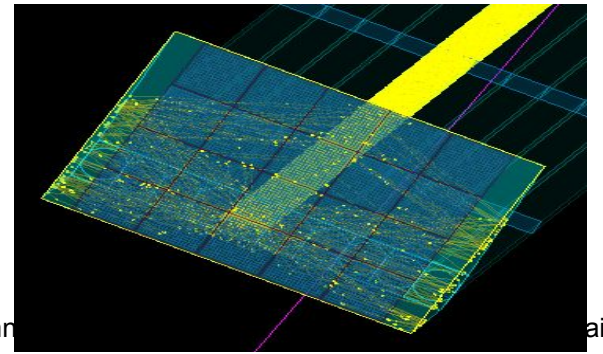
6 x 4 = 24 pmt

5 x 4 = 20 pmt

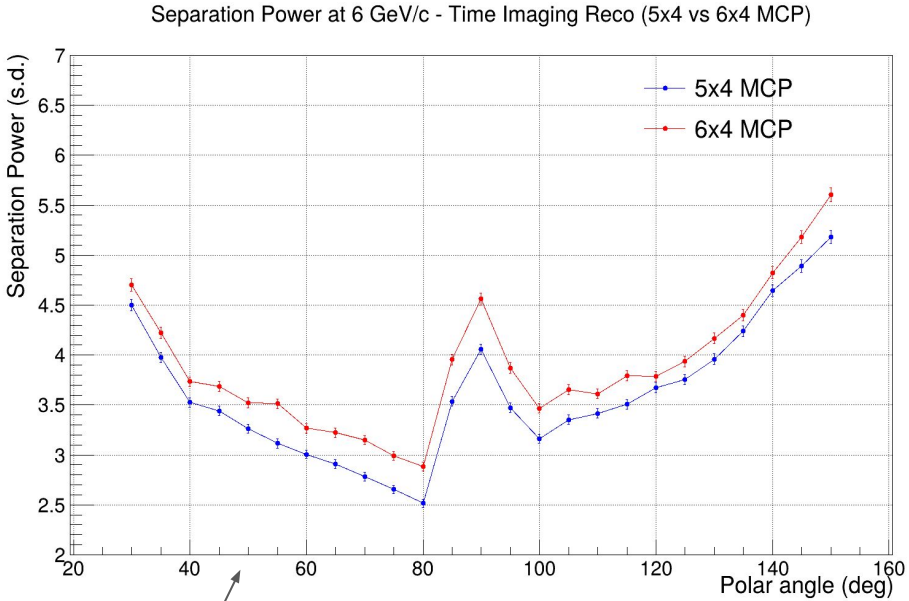


Separation Power (TI Reconstruction) with and without gaps between PMTs

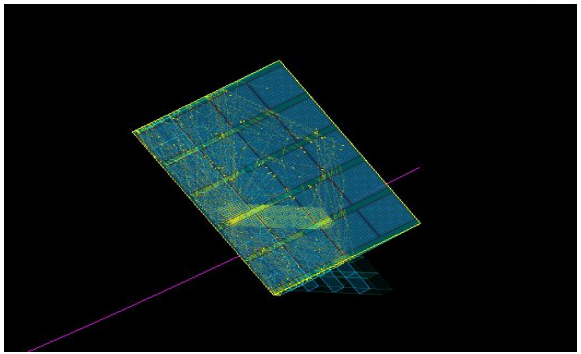




Without gap



With gap



Conclusion

- So far, the results mainly reflect the performance of the **middle bar**, which is not sufficient to make a conclusive decision.
- We need to **extend the study to all bars**, not just the center one
- Further optimization might include **adjusting PMT positions**.

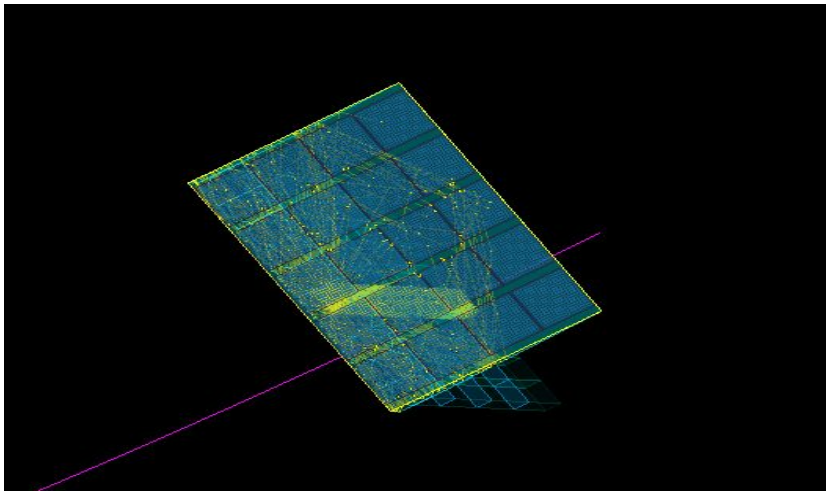
Thank you all!

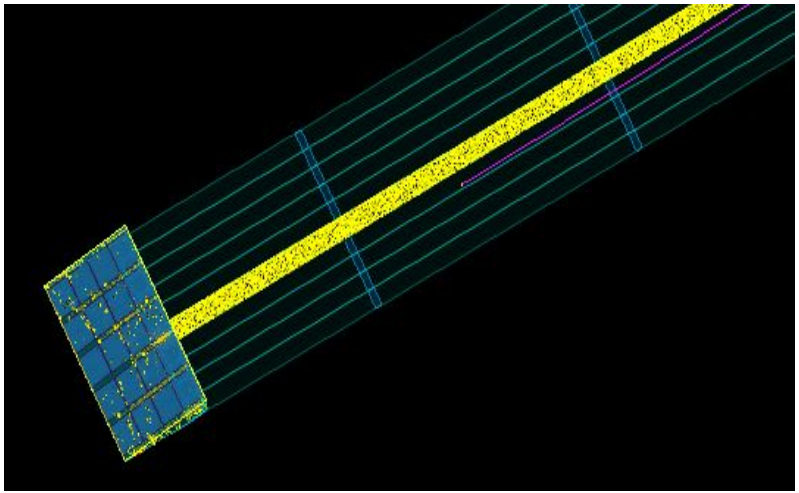
BackUp

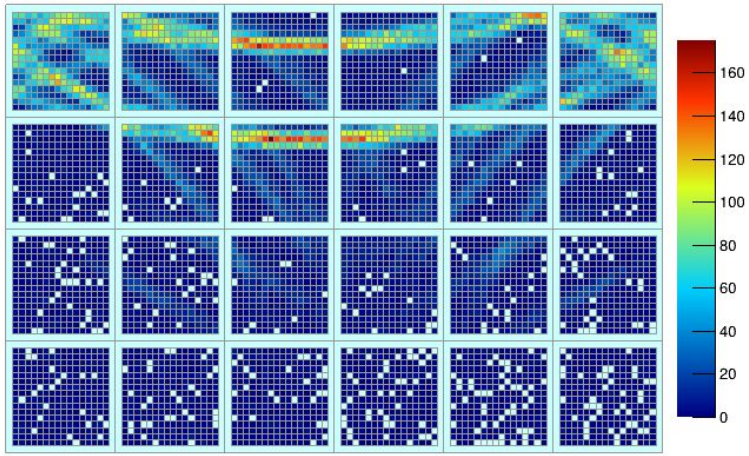
Polar Angle	Phi angle
30	-0.0623604 rad (-3.57299 deg)
35	-0.0547776 rad (-3.13853 deg.)
40	-0.0492537 rad (-2.82203 deg)
45	-0.045115 rad (-2.5849 deg)
50	-0.0419599 rad (-2.40413 deg)
55	-0.0395355 rad (-2.26522 deg)
60	-0.037676 rad (-2.15867 deg)
65	-0.0362694 rad (-2.07809 deg)
70	-0.0352396 rad (-2.01908 deg)
75	-0.0345343 rad (-1.97867 deg)
80	-0.0341192 rad (-1.95489 deg)
85	-0.0339736 rad (-1.94654 deg)

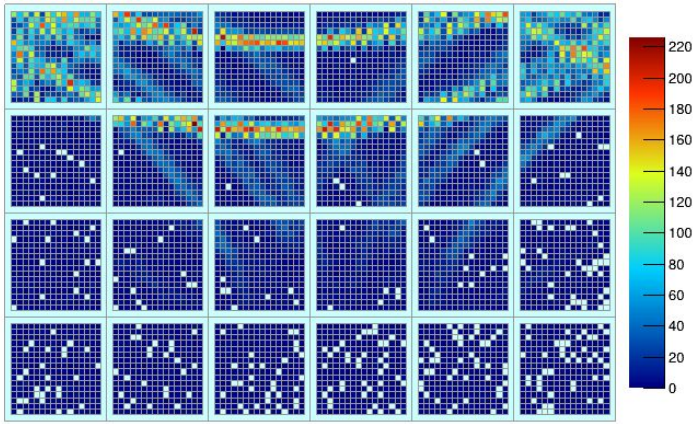
Polar angle	Phi Value
90	-0.0340879 rad (-1.95309 deg)
95	-0.0339736 rad (-1.94654 deg)
100	-0.0341192 rad (-1.95489 deg)
105	-0.0345343 rad (-1.97867 deg)
110	-0.0352396 rad (-2.01908 deg)
115	-0.0362694 rad (-2.07809 deg)
120	-0.037676 rad (-2.15867 deg)
125	-0.0395355 rad (-2.26522 deg)
130	-0.0419599 rad (-2.40413 deg)
135	-0.045115 rad (-2.5849 deg)
140	-0.0492537 rad (-2.82203 deg)
145	-0.0547776 rad (-3.13853 deg)
150	-0.0623604 rad (-3.57299 deg)

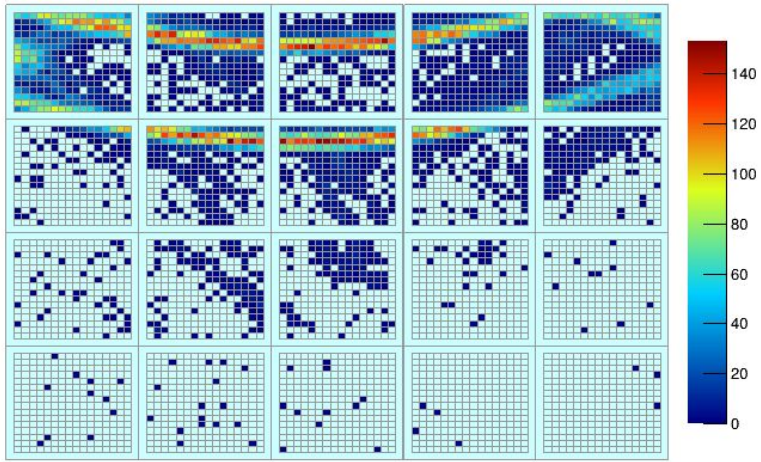
Event display of a 5 × 4 MCP-PMT configuration featuring uniform spacing between the PMTs

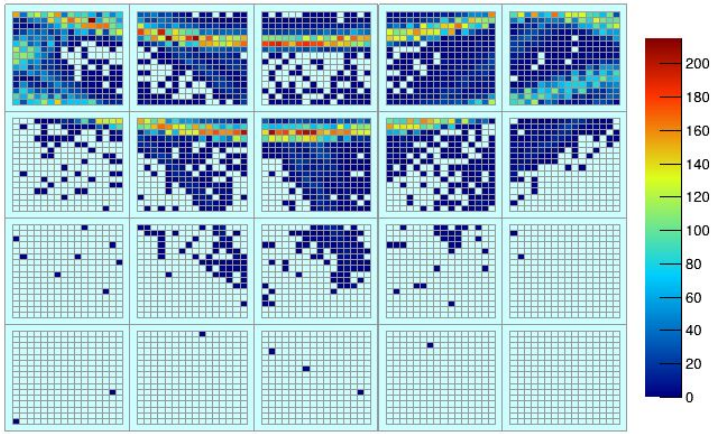


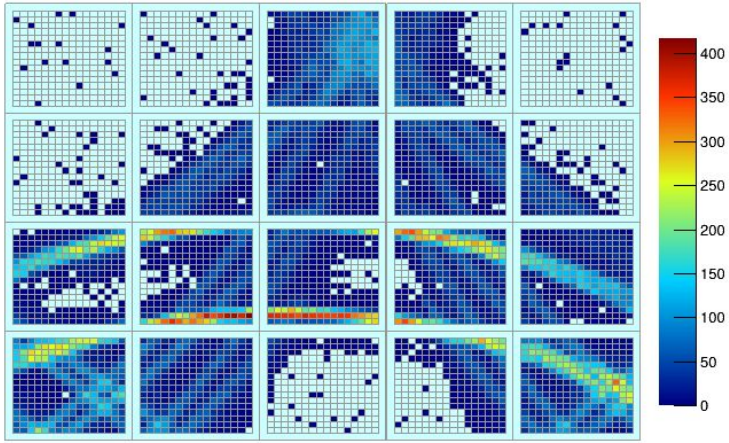



160
140
120
100
80
60
40
20
0

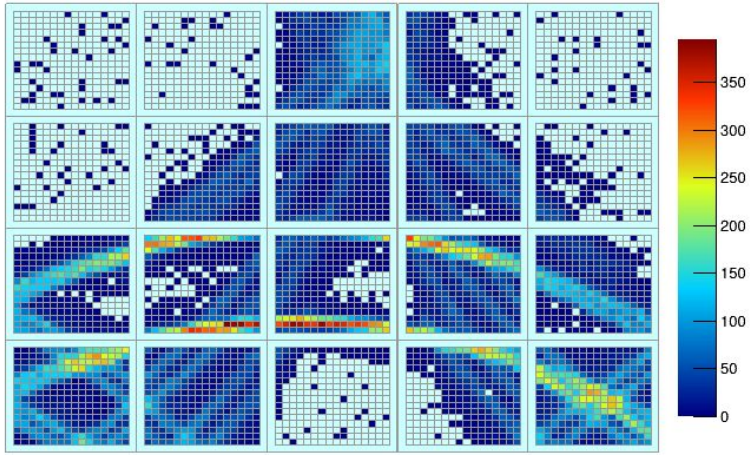

220
200
180
160
140
120
100
80
60
40
20
0


140
120
100
80
60
40
20
0

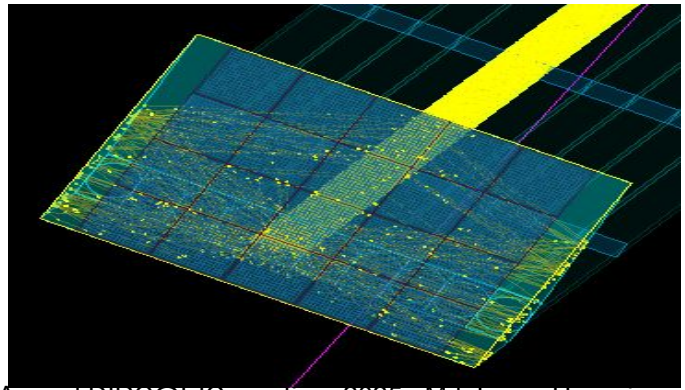

200
180
160
140
120
100
80
60
40
20
0

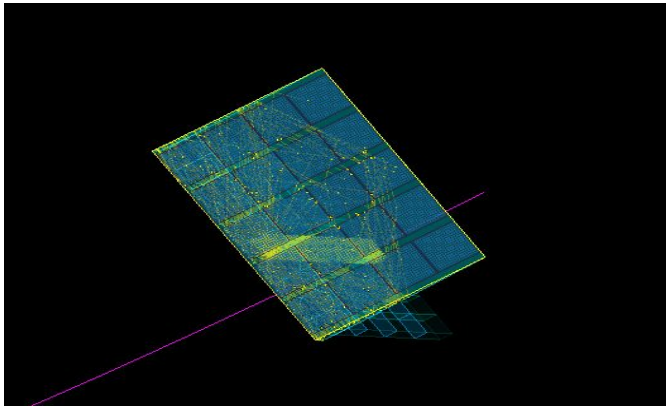


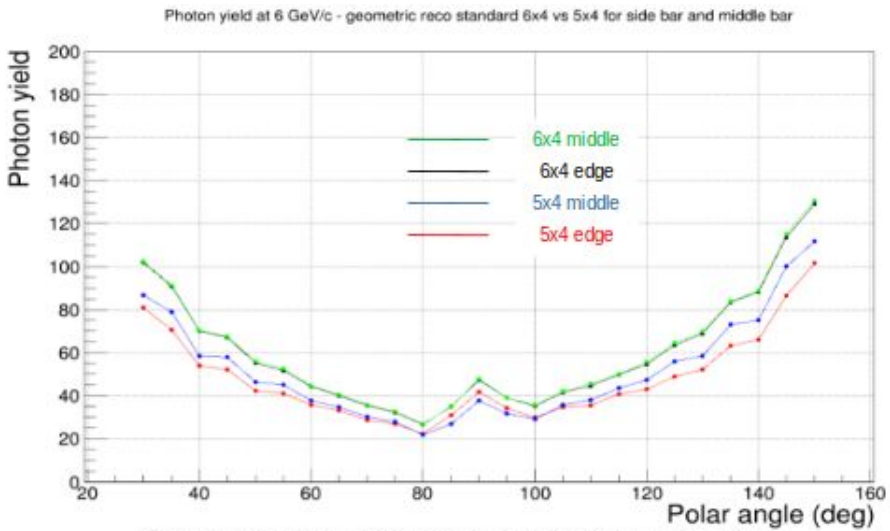
Without gap

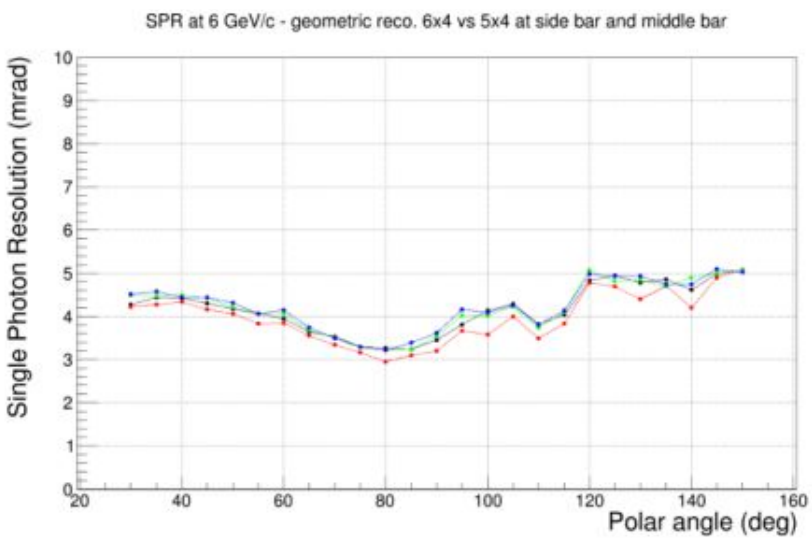


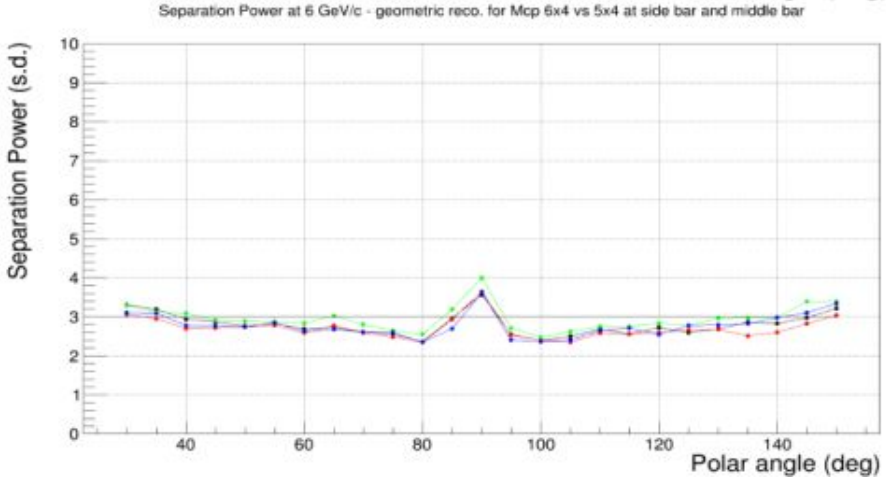
With gap



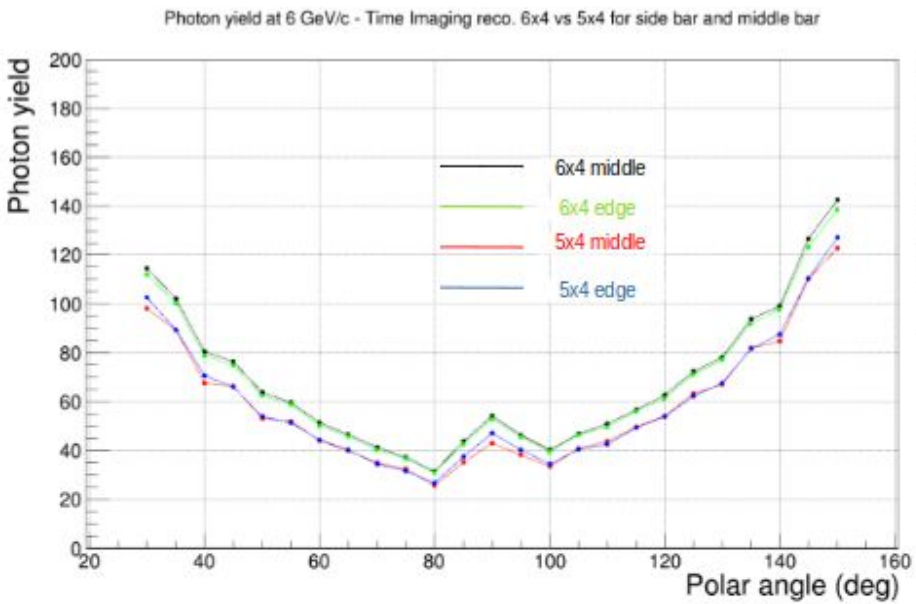


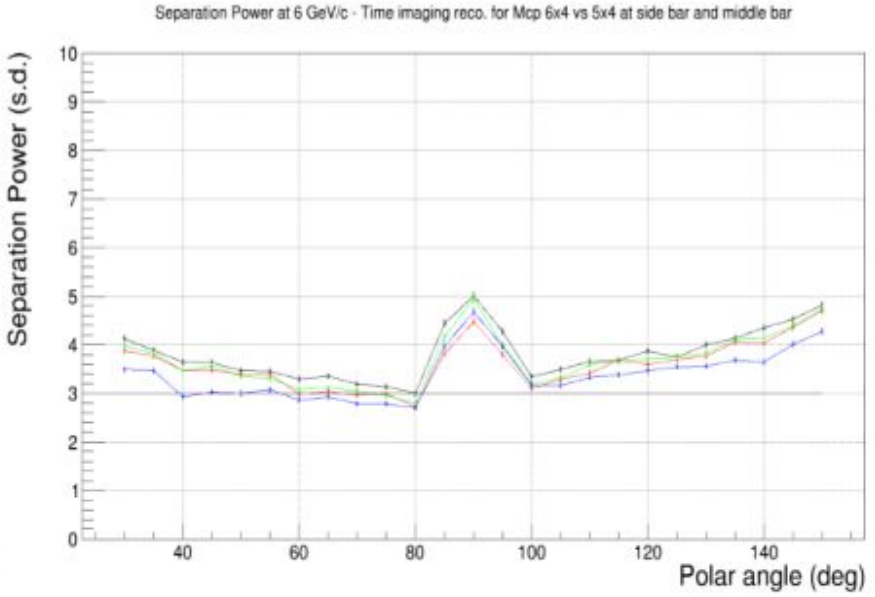






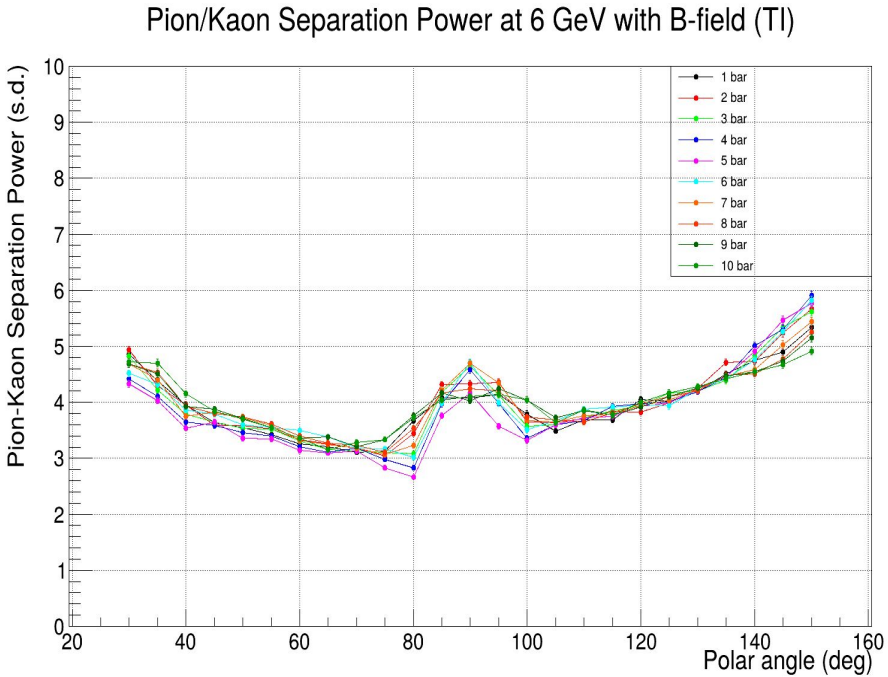
Without magnetic field

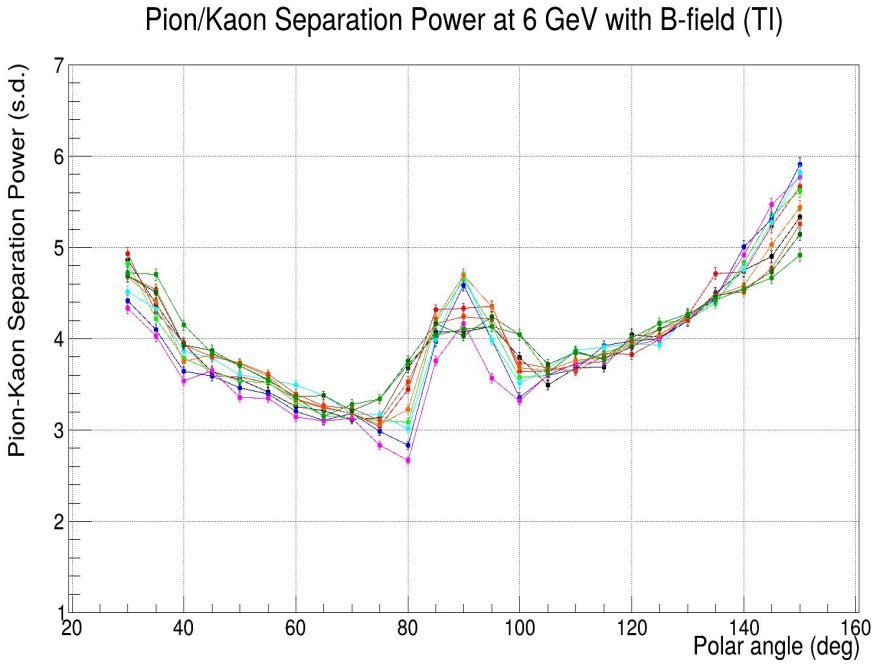




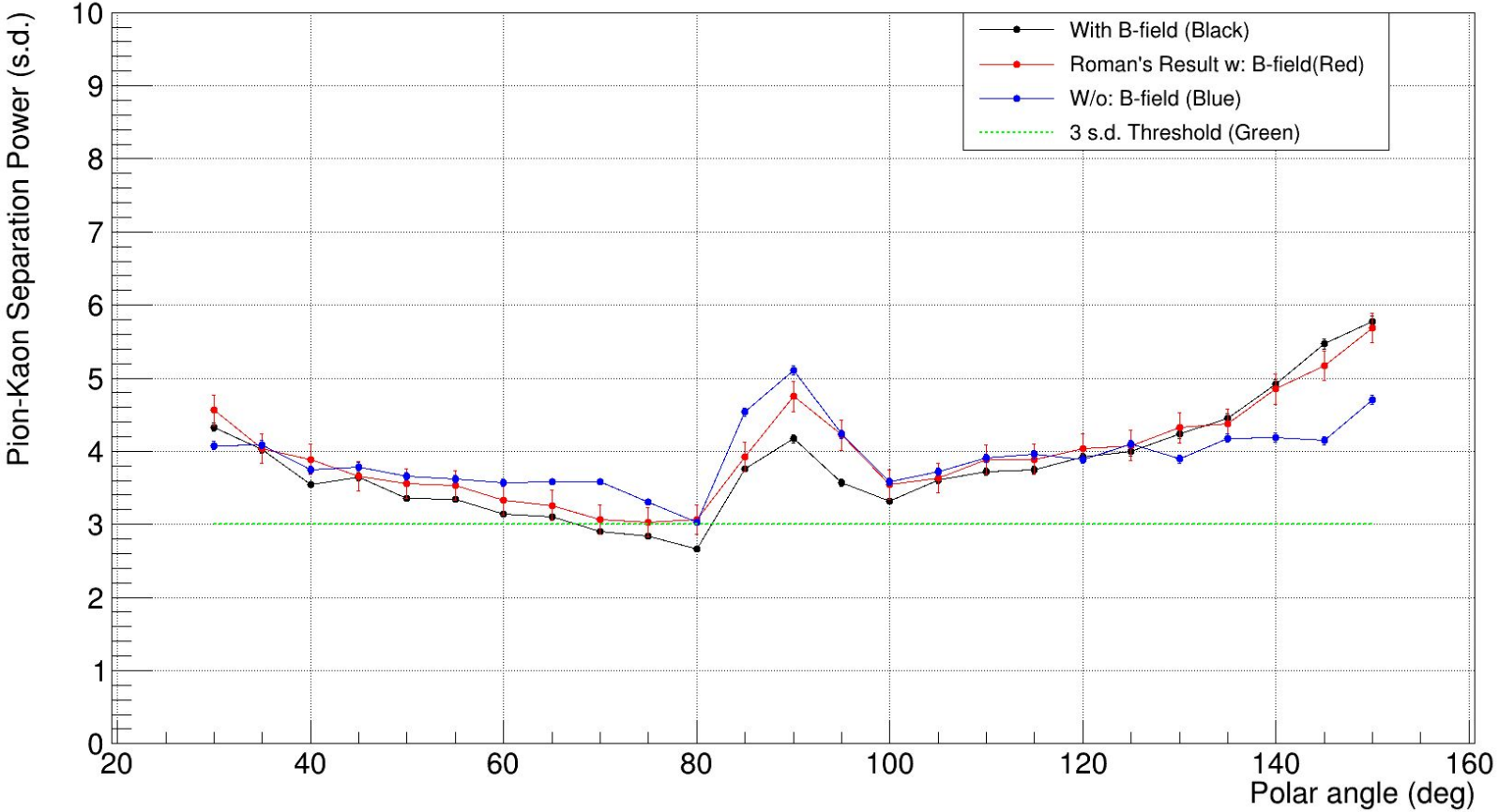
Without magnetic field

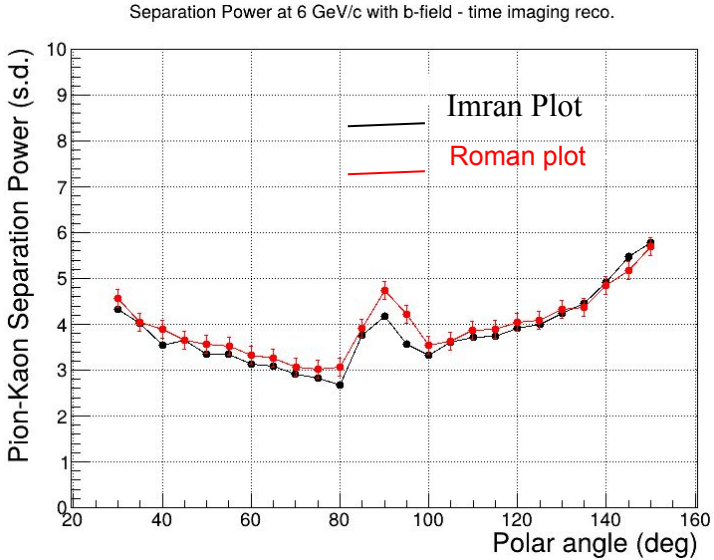
Pion/Kaon Separation Power at 1.7 T (TI) from 1st bar to 10th bar

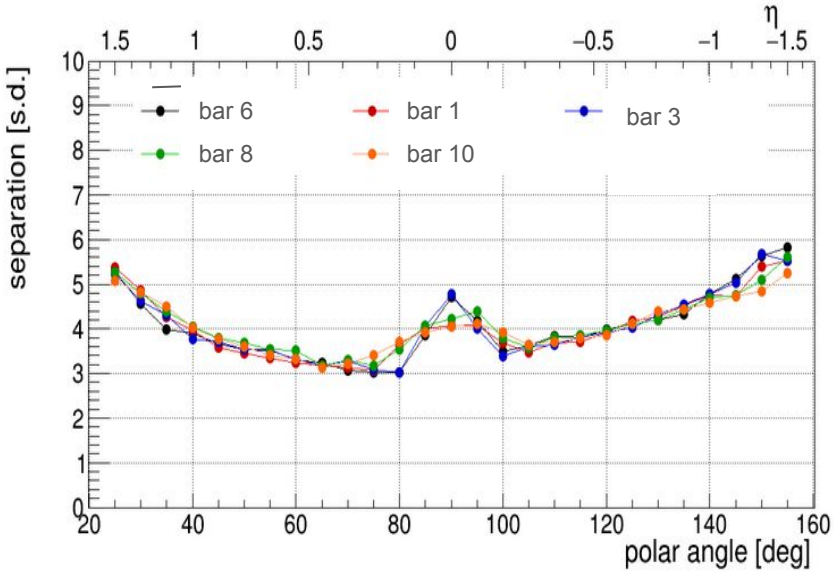




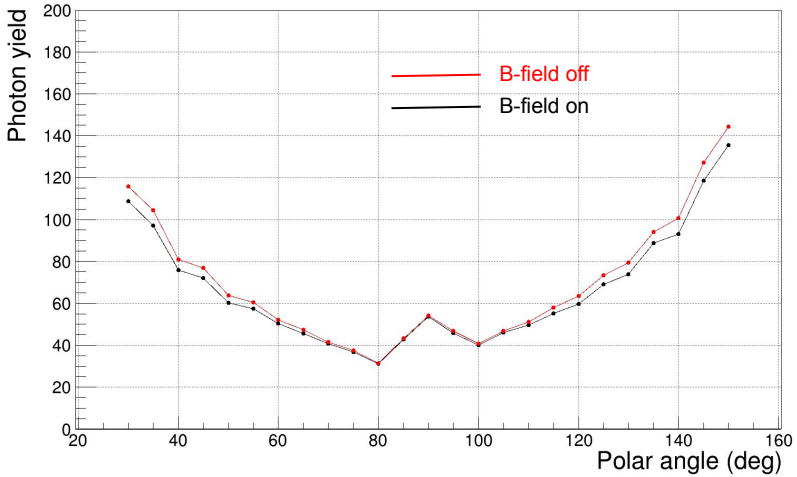
Separation Power at 6 GeV/c with B-Field



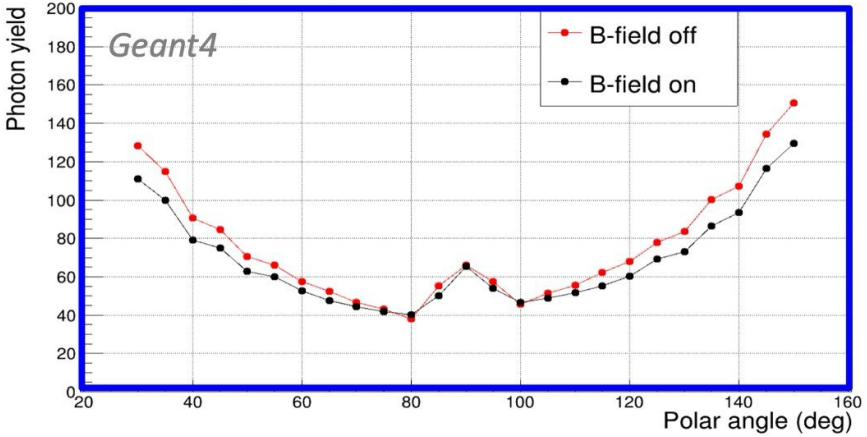

Separation Power at 6 GeV/c with b-field - time imaging reco.
Pion-Kaon Separation Power (s.d.)
Polar angle (deg)
Imran Plot
Roman plot


η
separation [s.d.]
polar angle [deg]
bar 6
bar 1
bar 3
bar 8
bar 10

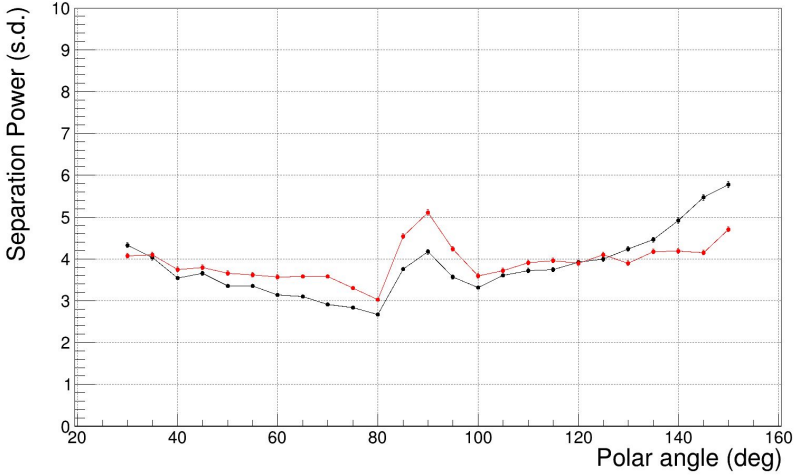
Photon yield at 6 GeV/c with and without B-field - time imaging reco.



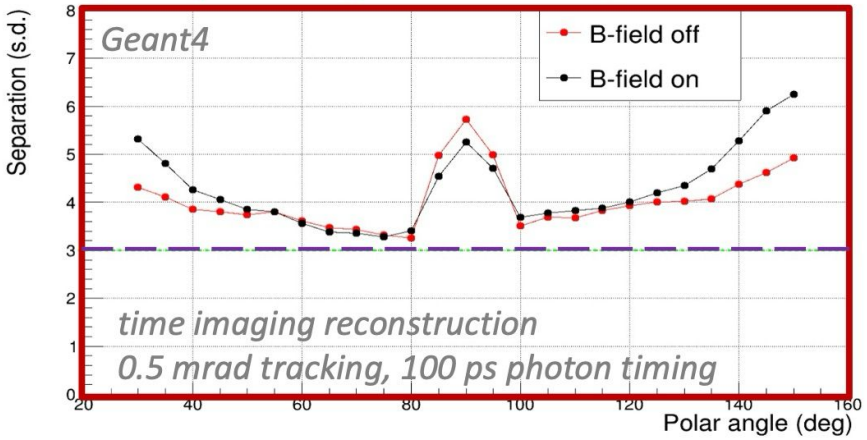
Photon yield per particle

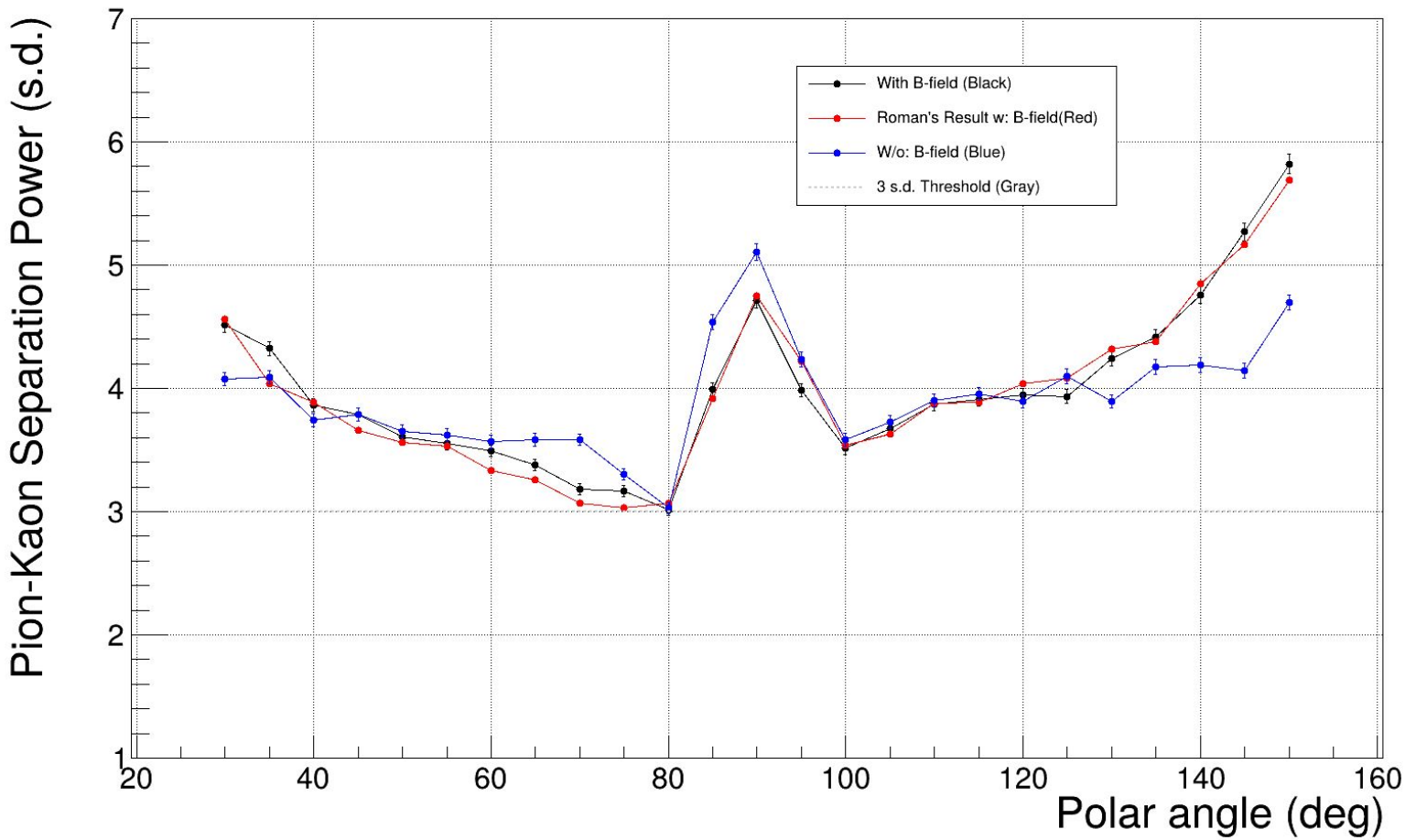


Separation Power at 6 GeV/c with and without b-field - time imaging reco.

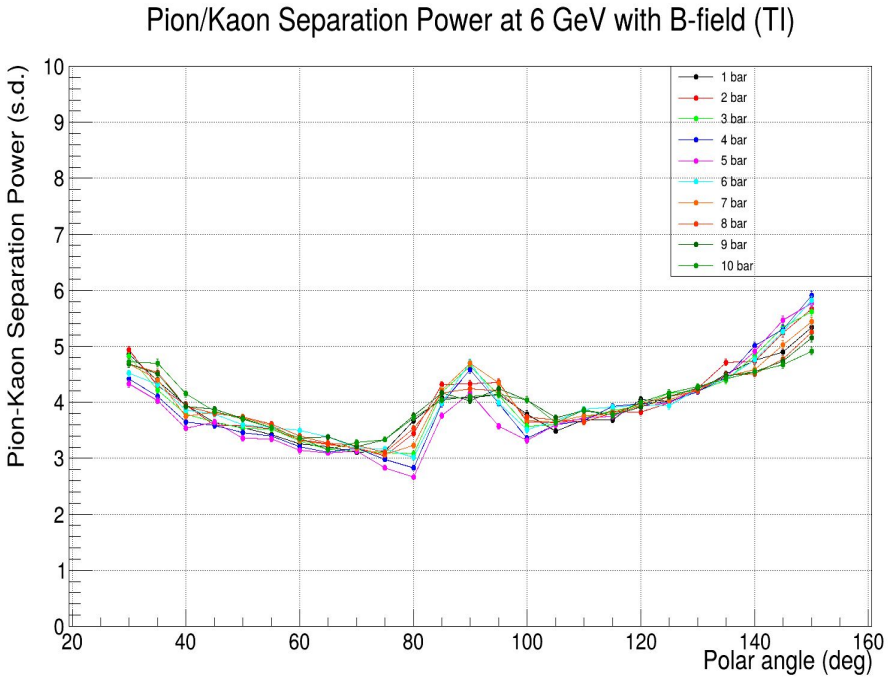


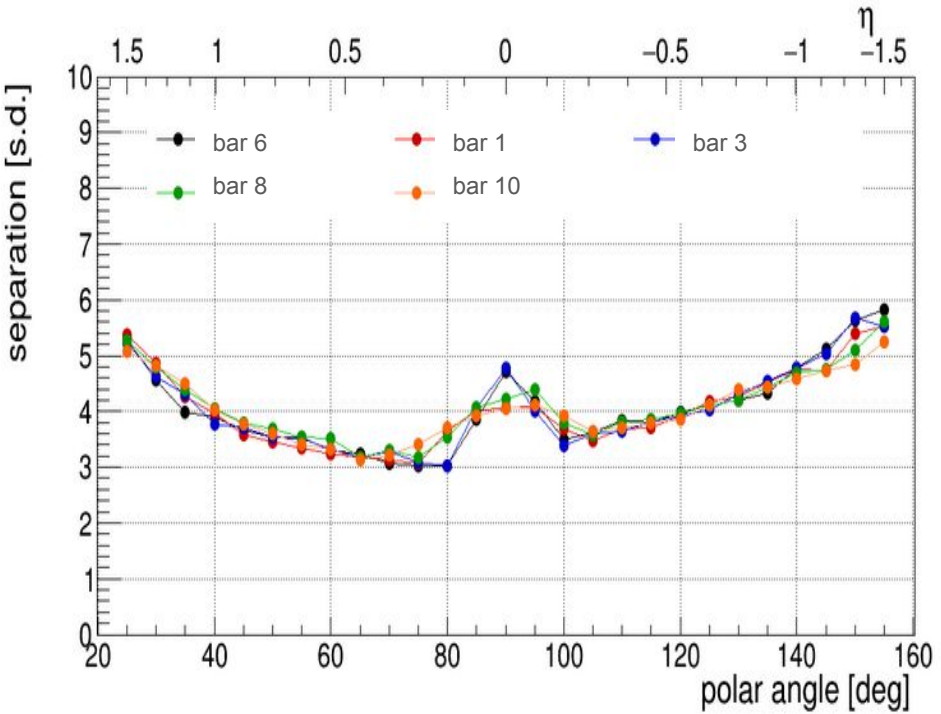
π/K separation power at 6 GeV/c

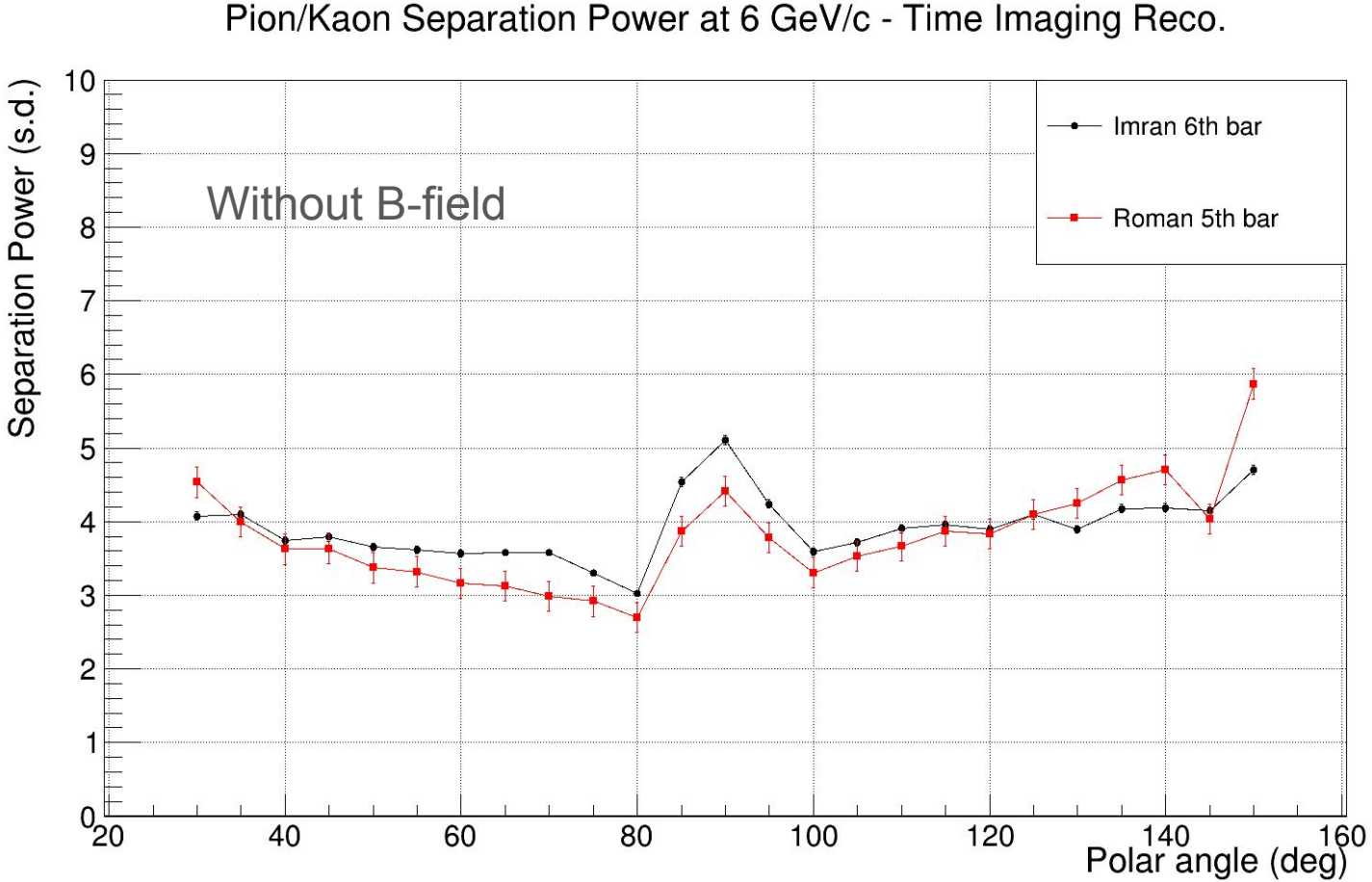




-phi 995
Bar no: 5
-field 2- 1.7 T


Pion/Kaon Separation Power at 6 GeV with B-field (TI)
Pion-Kaon Separation Power (s.d.)
Polar angle (deg)
1 bar
2 bar
3 bar
4 bar
5 bar
6 bar
7 bar
8 bar
9 bar
10 bar


η
separation [s.d.]
polar angle [deg]
bar 6
bar 1
bar 3
bar 8
bar 10


Pion/Kaon Separation Power at 6 GeV/c - Time Imaging Reco.
Without B-field
Imran 6th bar
Roman 5th bar
Separation Power (s.d.)
Polar angle (deg)
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
120
140
160