Muon Veto Simulations for

GERDA Collaboration Meeting

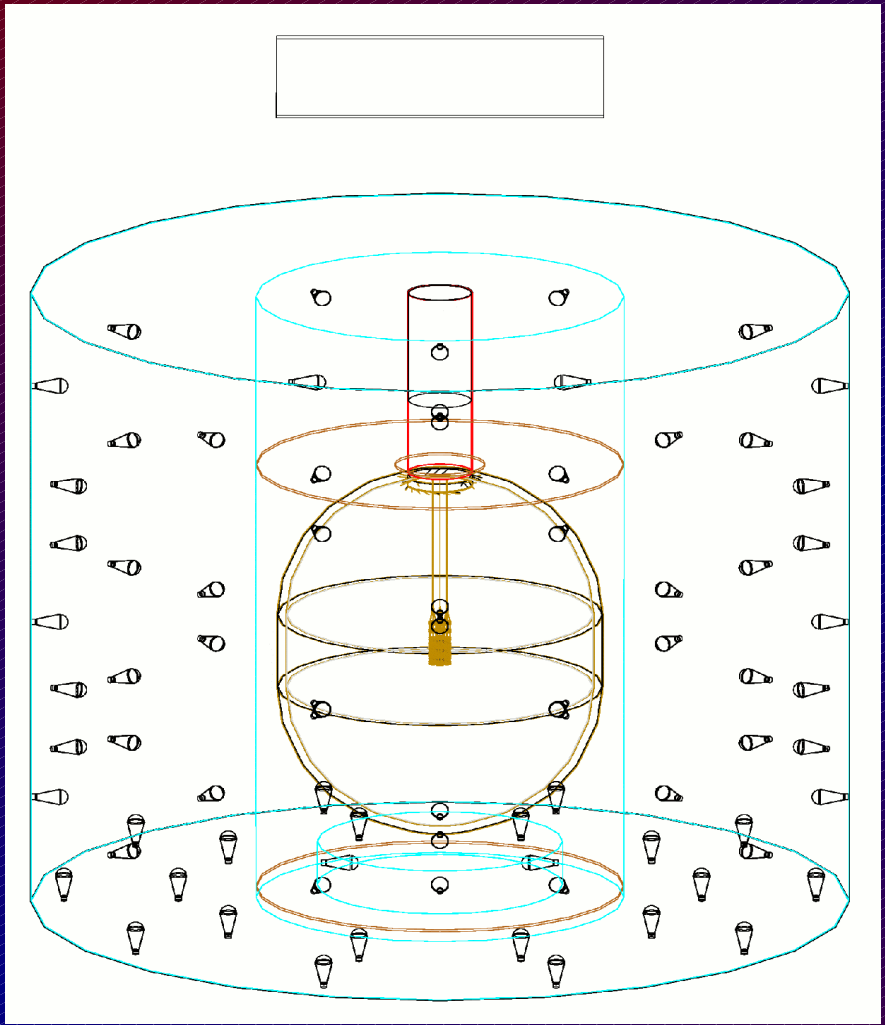
Tübingen

November 9th – 11th 2005

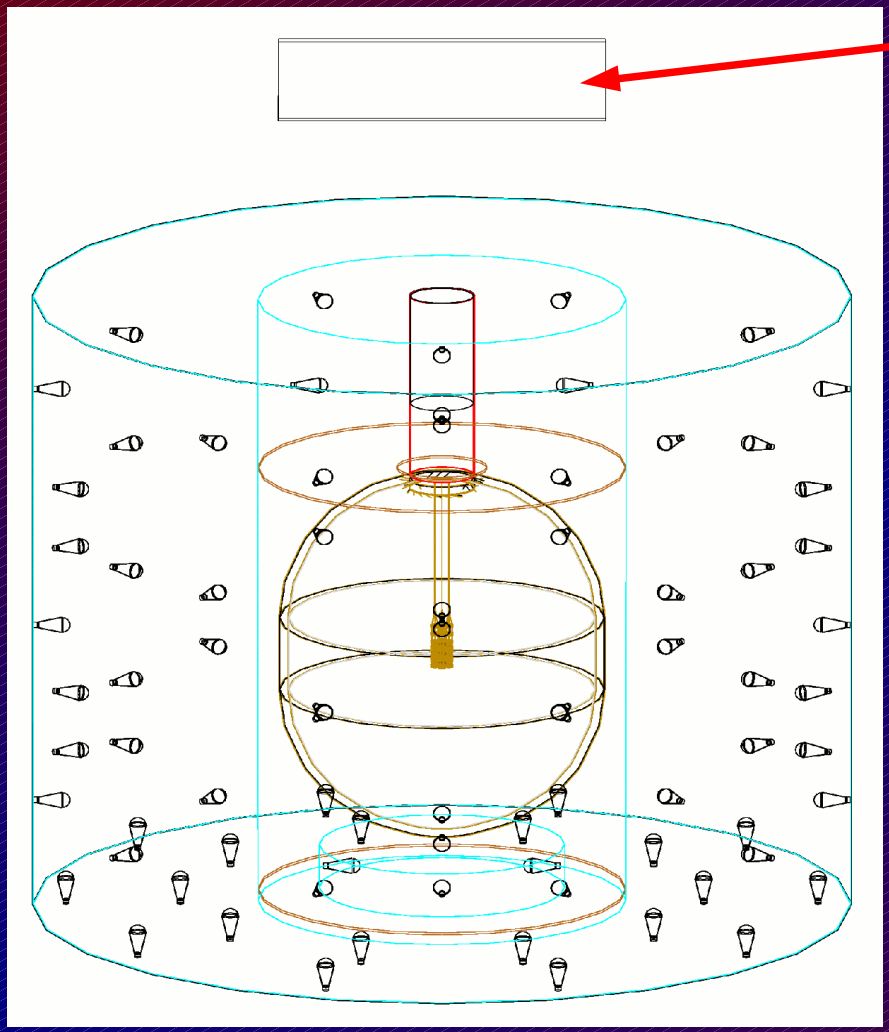
Content

- Overview: Muon-veto design
- Different photomultiplier-distributions
- Latest results
- Conclusion & Outlook

GERDA – Muon veto system



GERDA – Muon veto system



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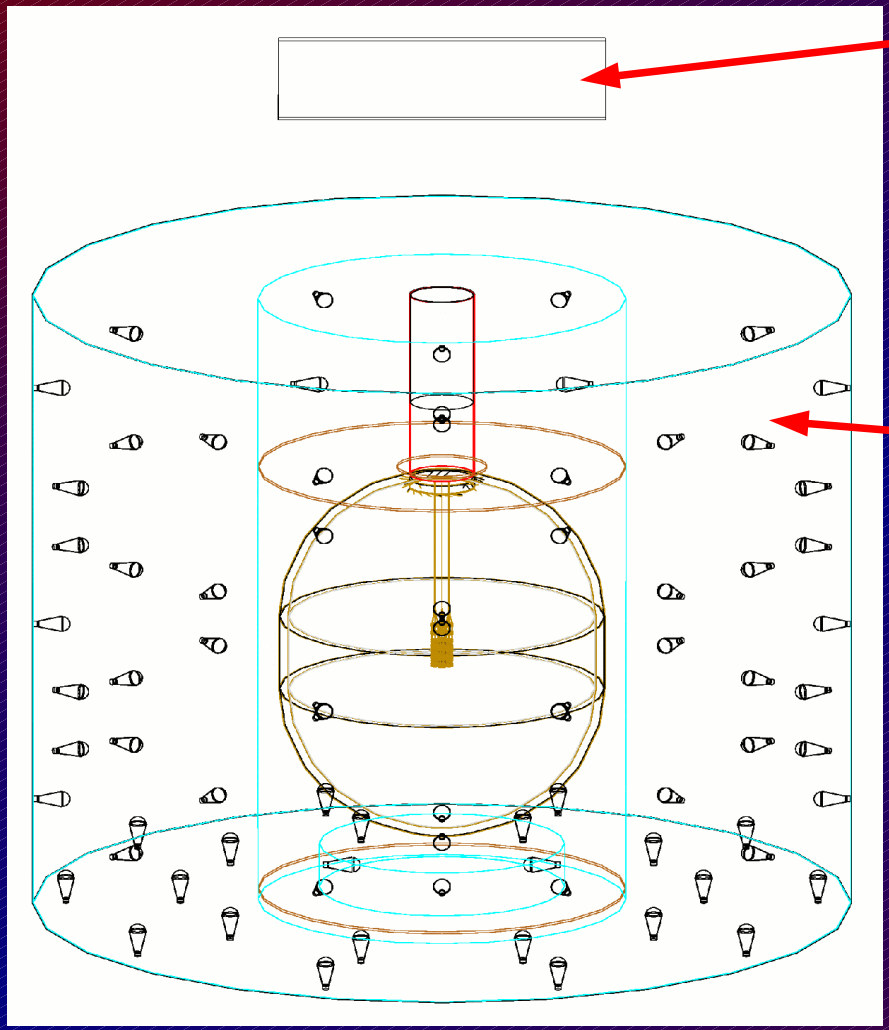
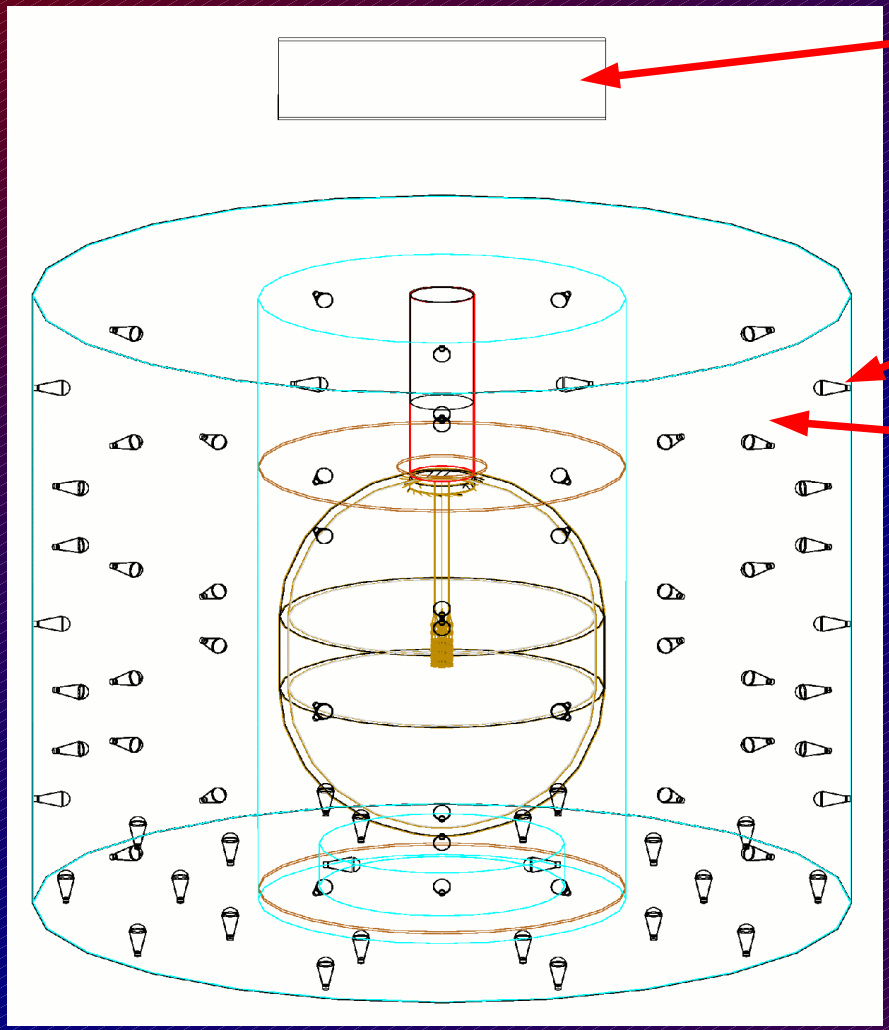


Plasticscintillator

Watertank /
Cherenkov-Veto

GERDA – Muon veto system



Plasticscintillator

Photomultiplier

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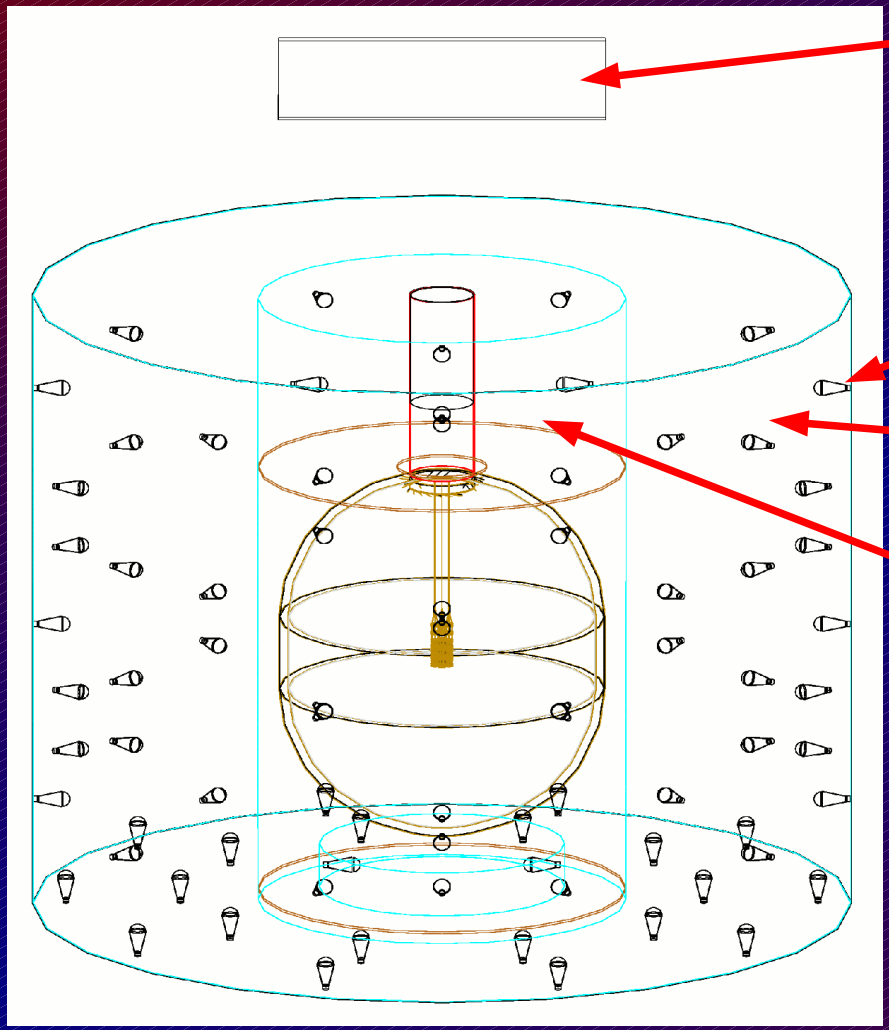
GERDA – Muon veto system



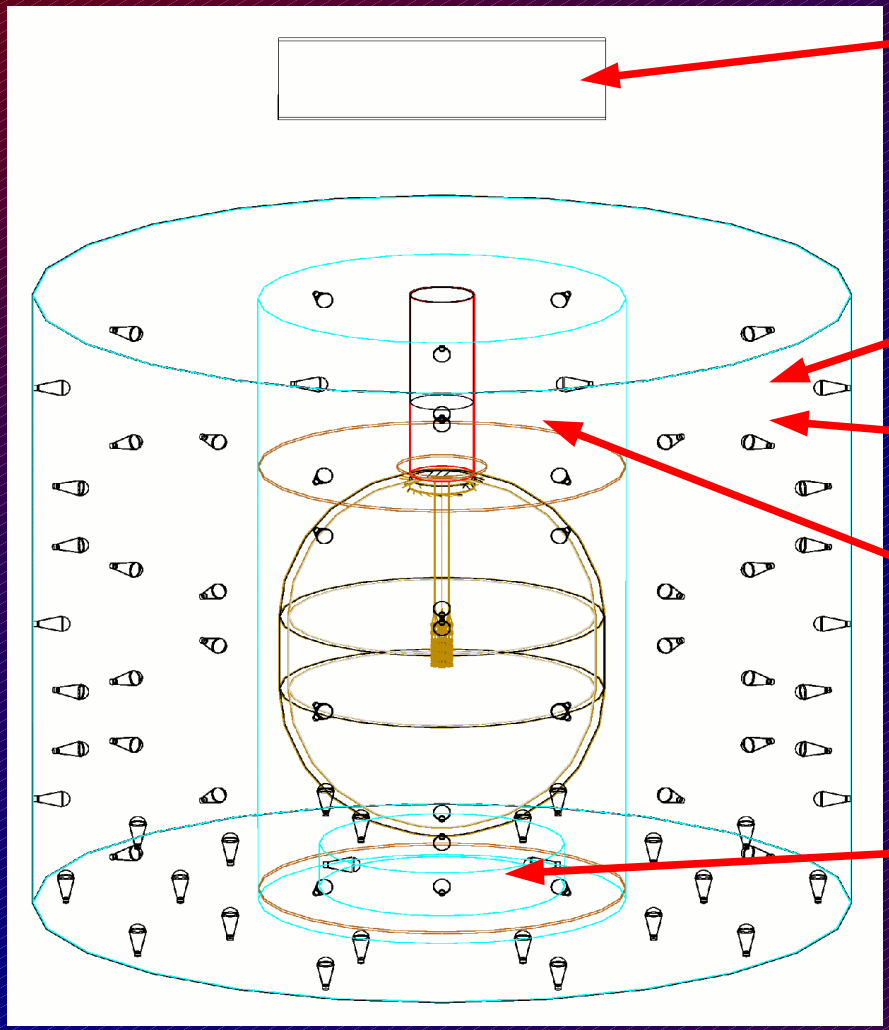
Plasticscintillator

Photomultiplier

Watertank / Cherenkov-Veto

„Upper pillbox“

GERDA – Muon veto system



Plasticscintillator

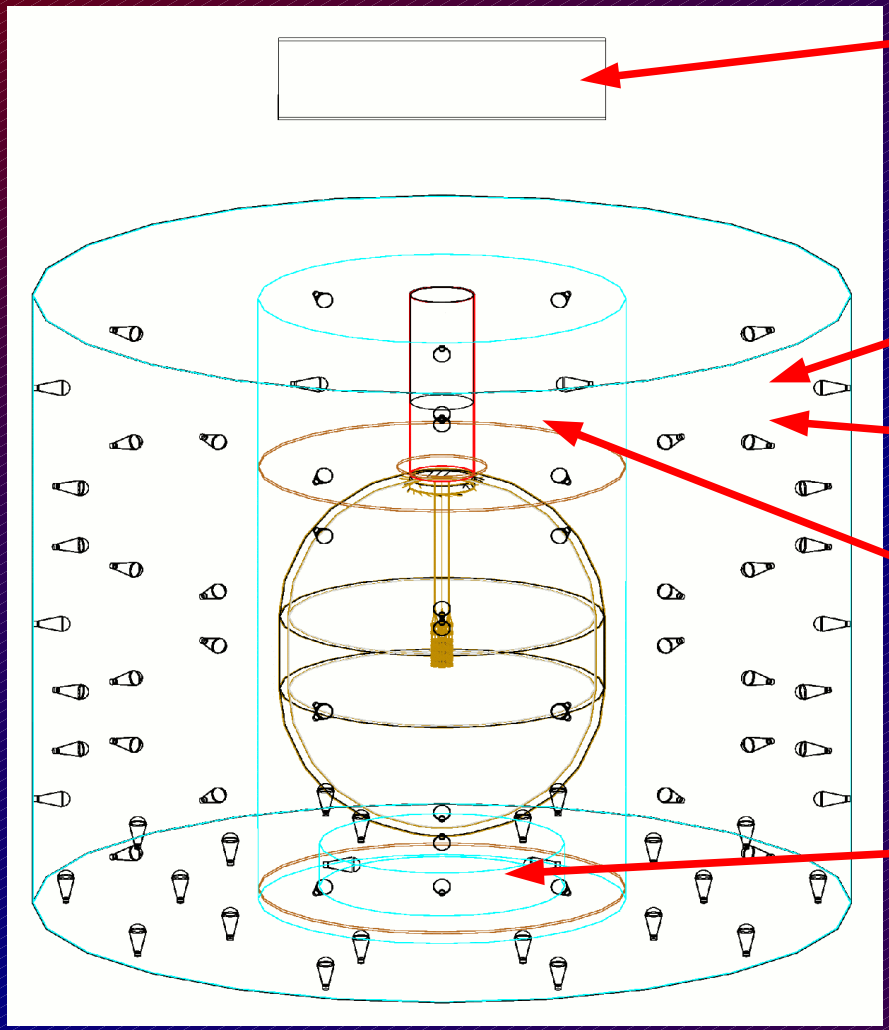
Photomultiplier

Watertank / Cherenkov-Veto

„Upper pillbox“

„Lower pillbox

GERDA – Muon veto system



Photomultiplier

Watertank / Cherenkov-Veto

„Upper pillbox“

„Lower pillbox

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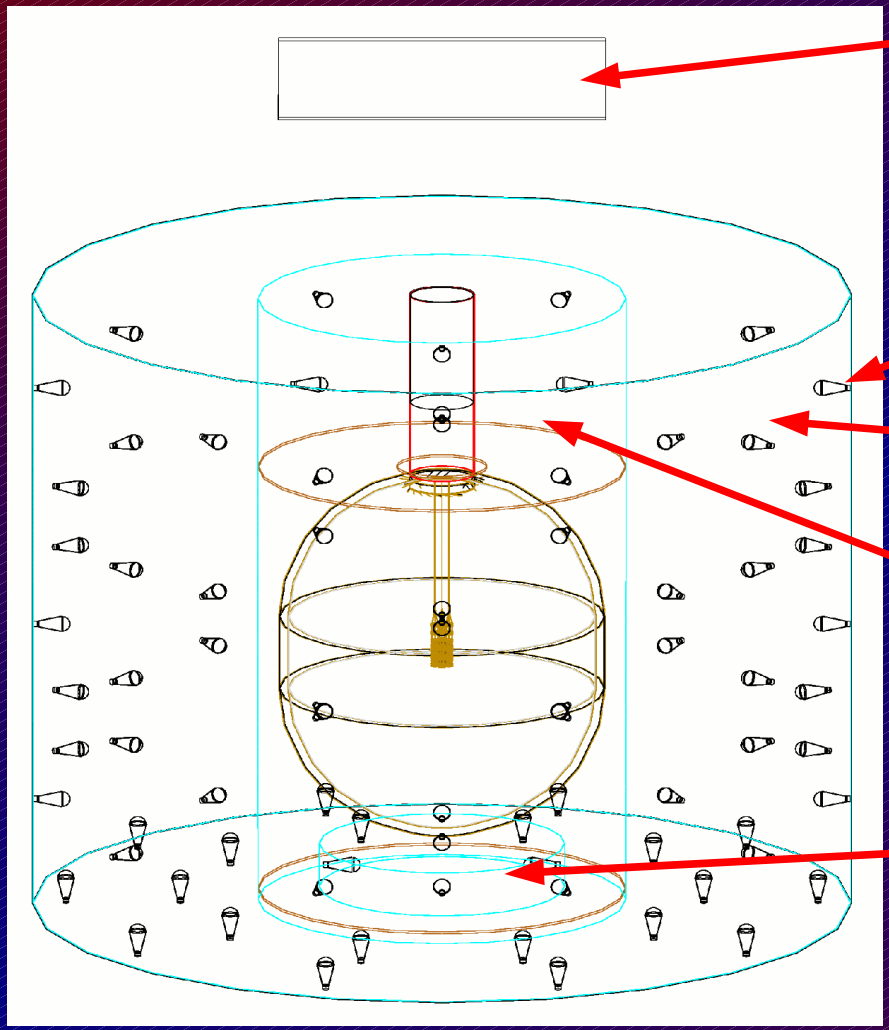

Plasticscintillator

Photomultiplier

Watertank /
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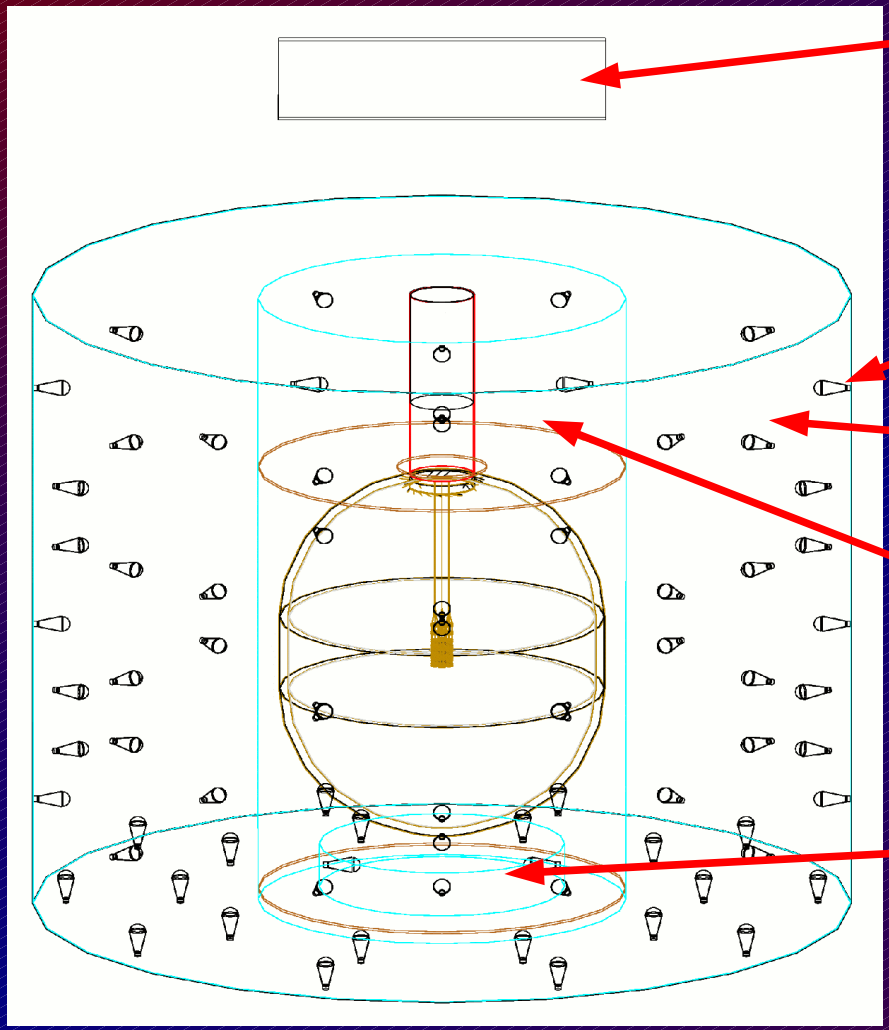


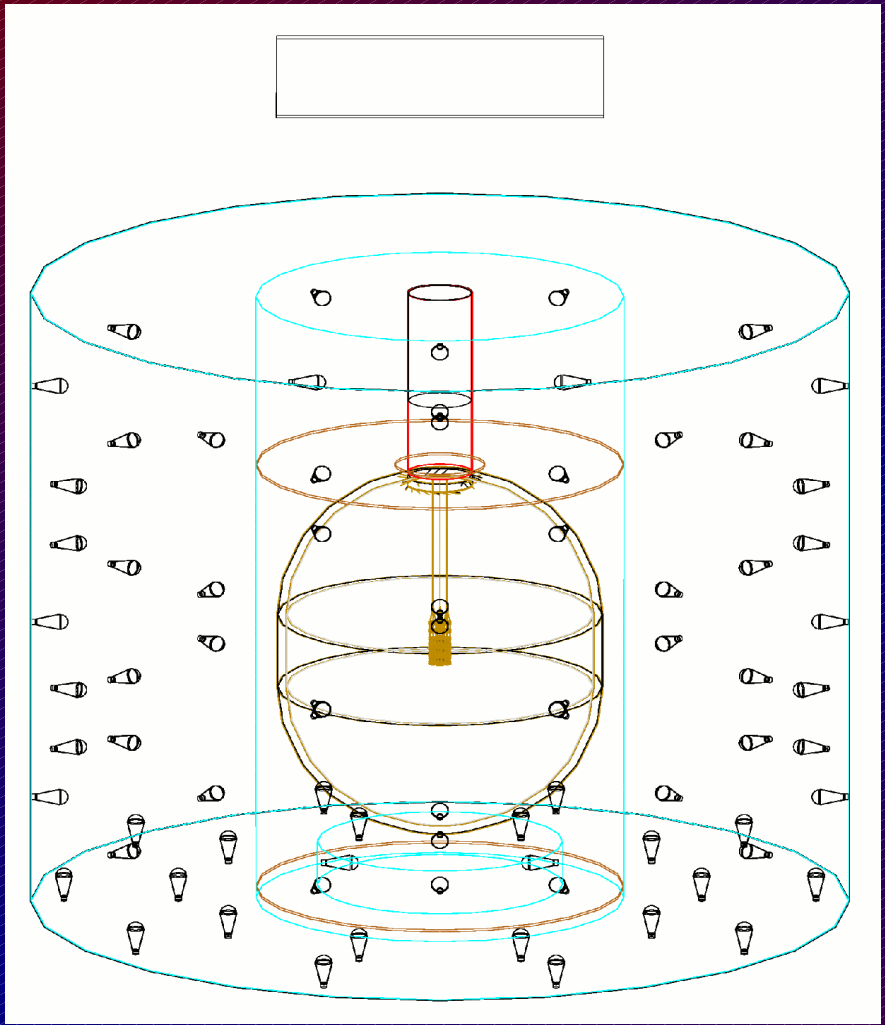
Plasticscintillator

Photomultiplier

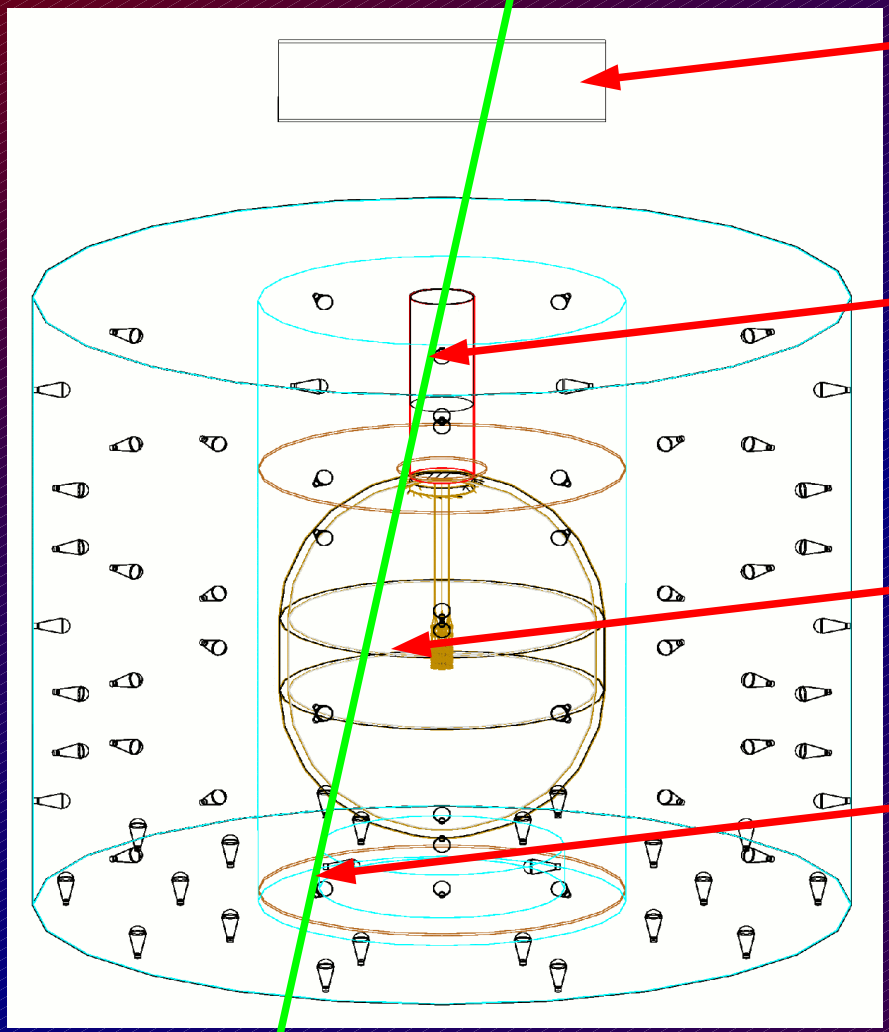
„Upper pillbox“

„Lower pillbox

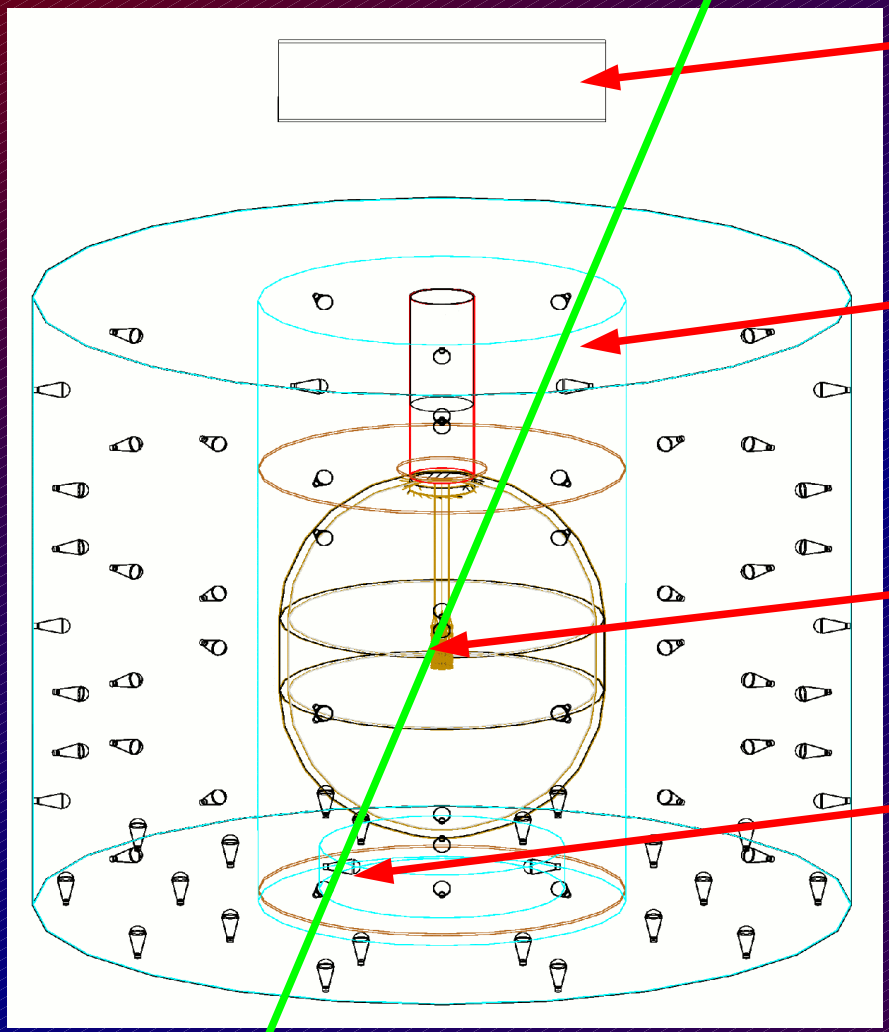
Importance of the three vetos



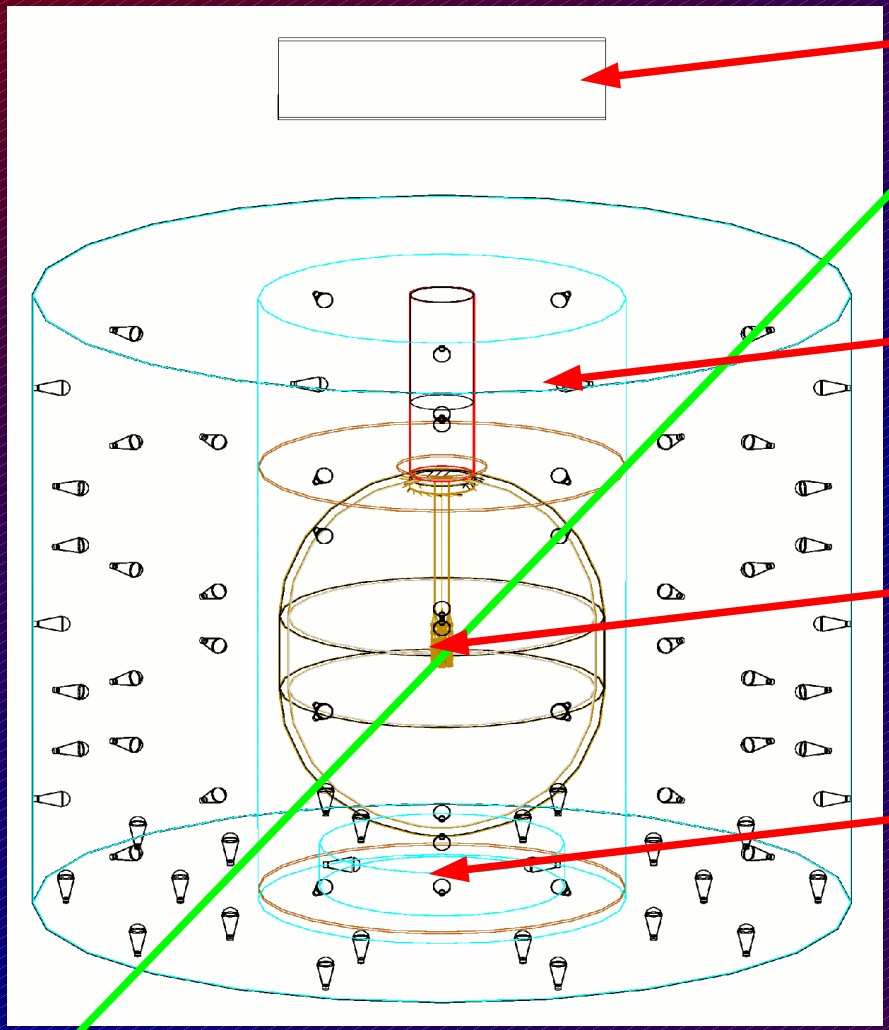
Importance of plasticscintillator



Importance of inner veto



Importance of outer veto



Muon

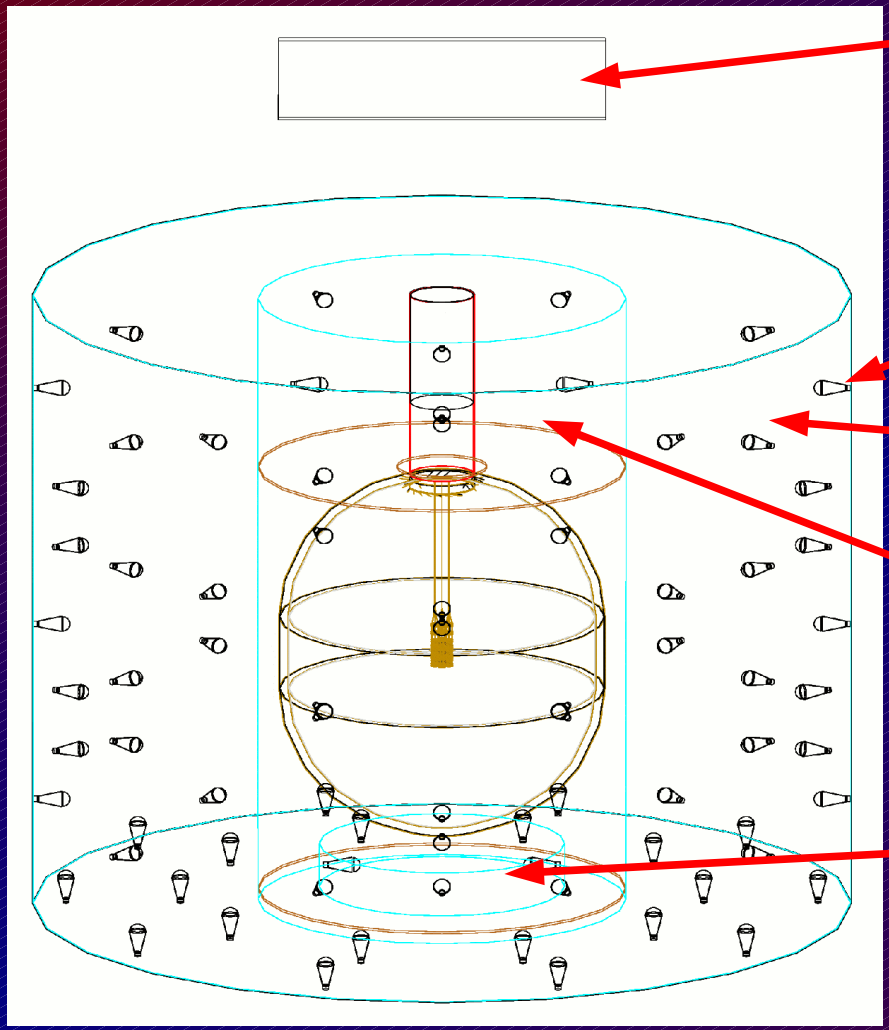
Missing the Plasticscintillator

Missing the upper pillbox

Passing through Germanium

Misssing the lower pillbox

GERDA – Muon veto system



Plasticscintillator

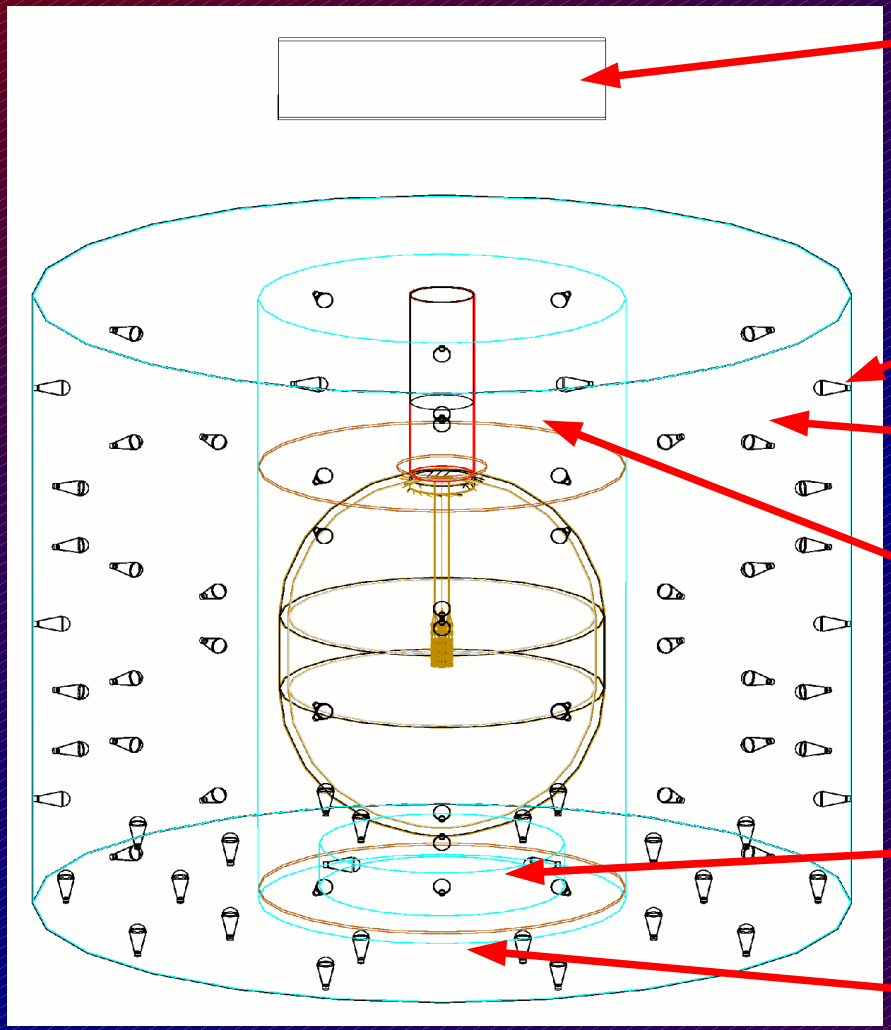
Photomultiplier

Watertank / Cherenkov-Veto

„Upper pillbox“

„Lower pillbox“

GERDA – Muon veto system



Plasticscintillator

Photomultiplier

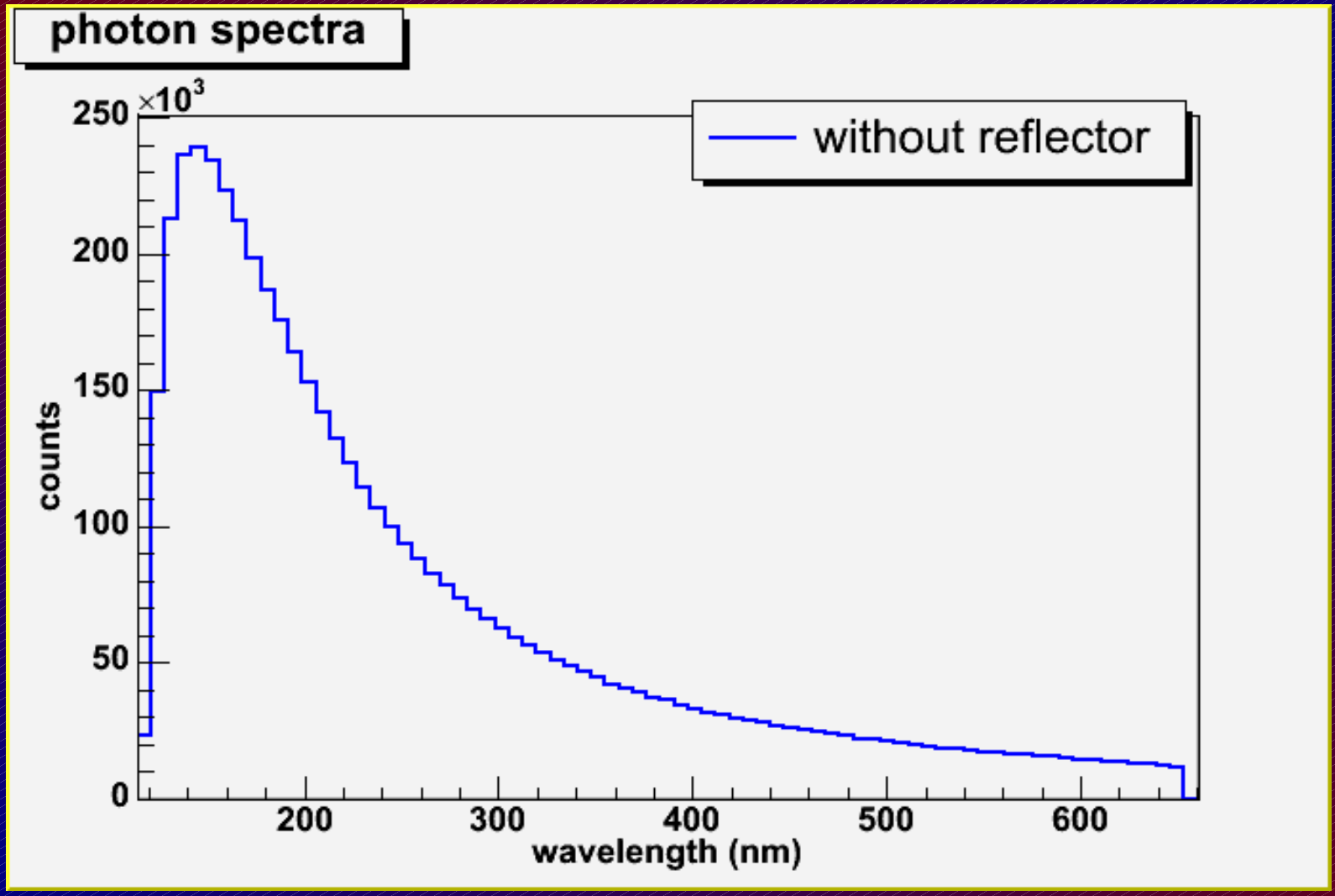
Watertank / Cherenkov-Veto

„Upper pillbox“

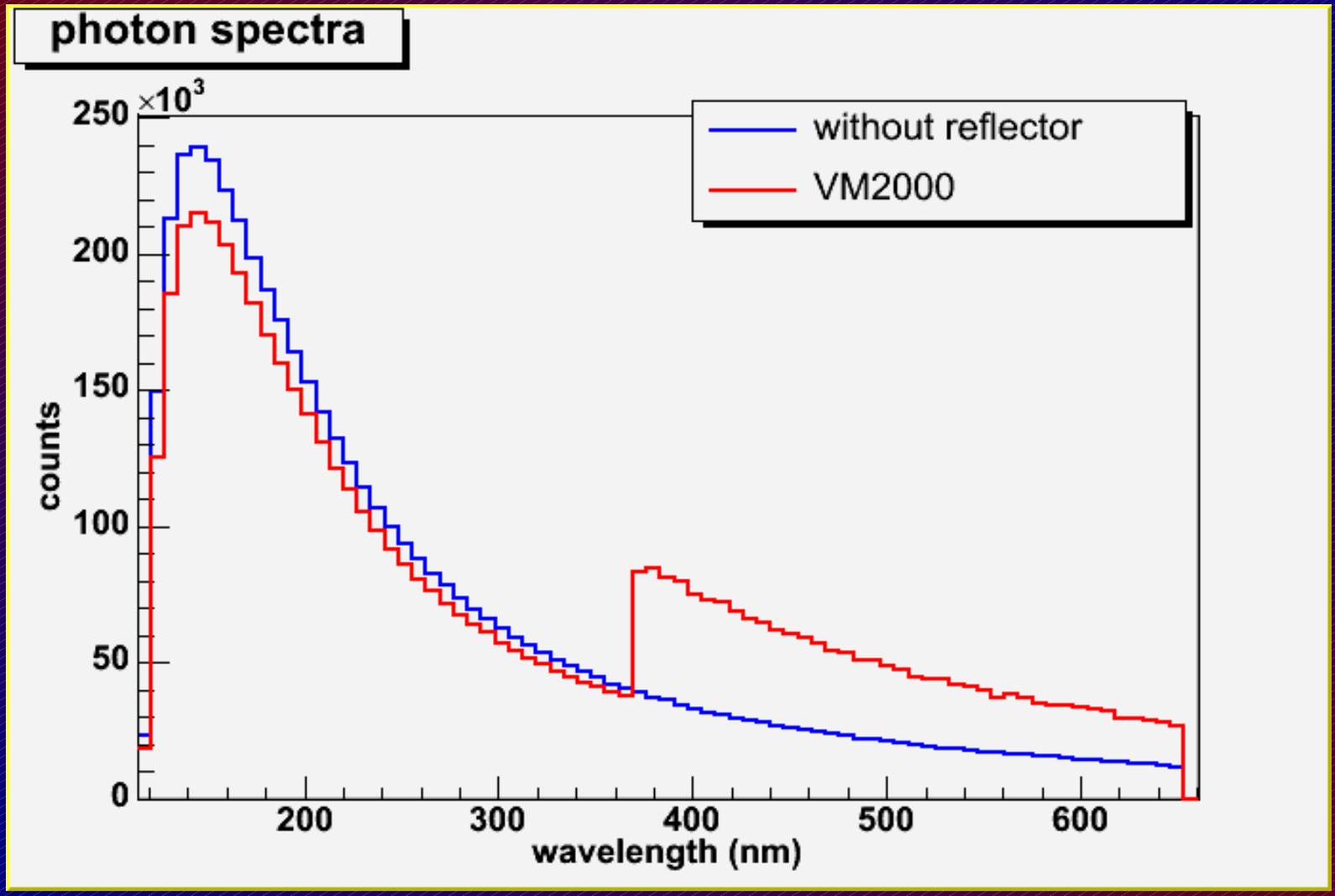
„Lower pillbox“

VM 2000

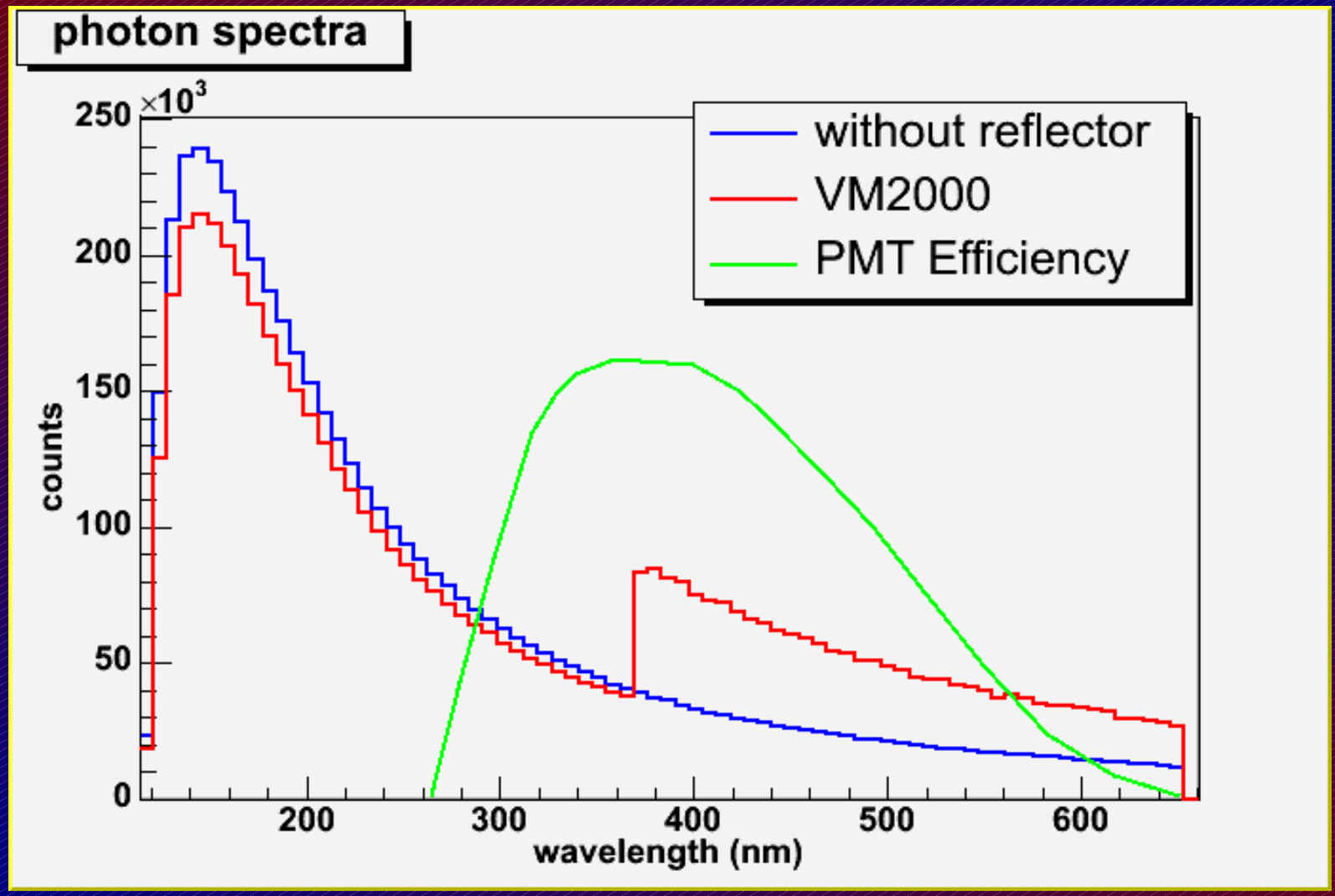
Photon spectra



Photon spectra



Photon spectra



Muon classification

Muon classification

- All muons

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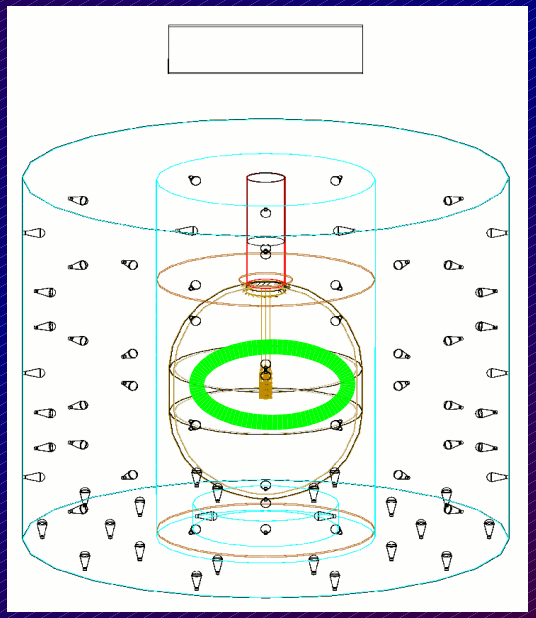
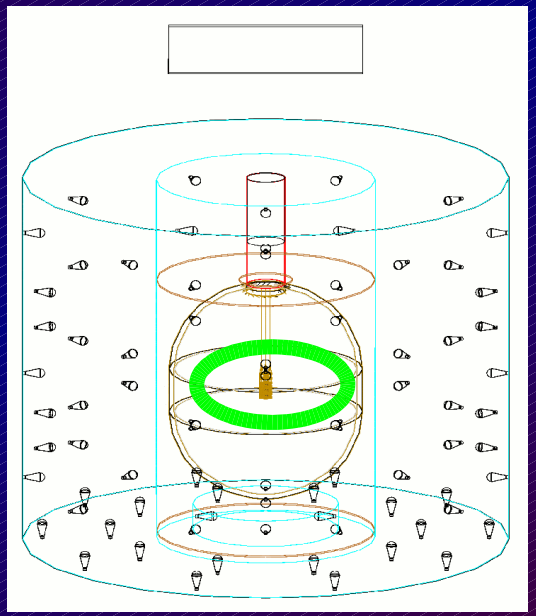
- Muons with energy deposition in the germanium detector



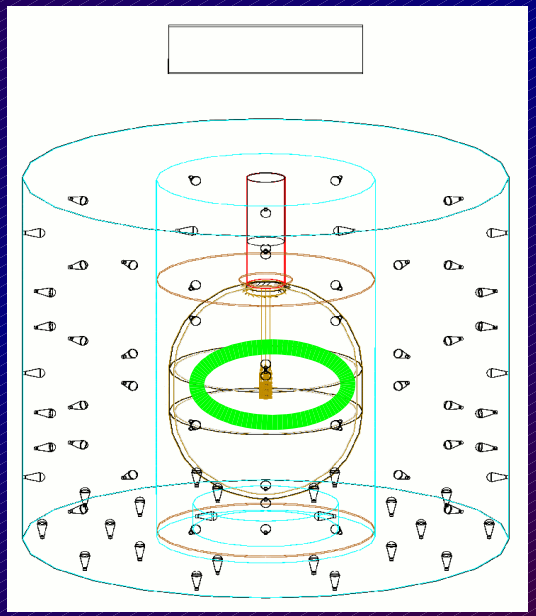
Muon classification

- All muons
- Muons with energy deposition in the germanium detector
- Dangerous muons with total energy deposition in the range of 1.5 MeV < E < 3 MeV



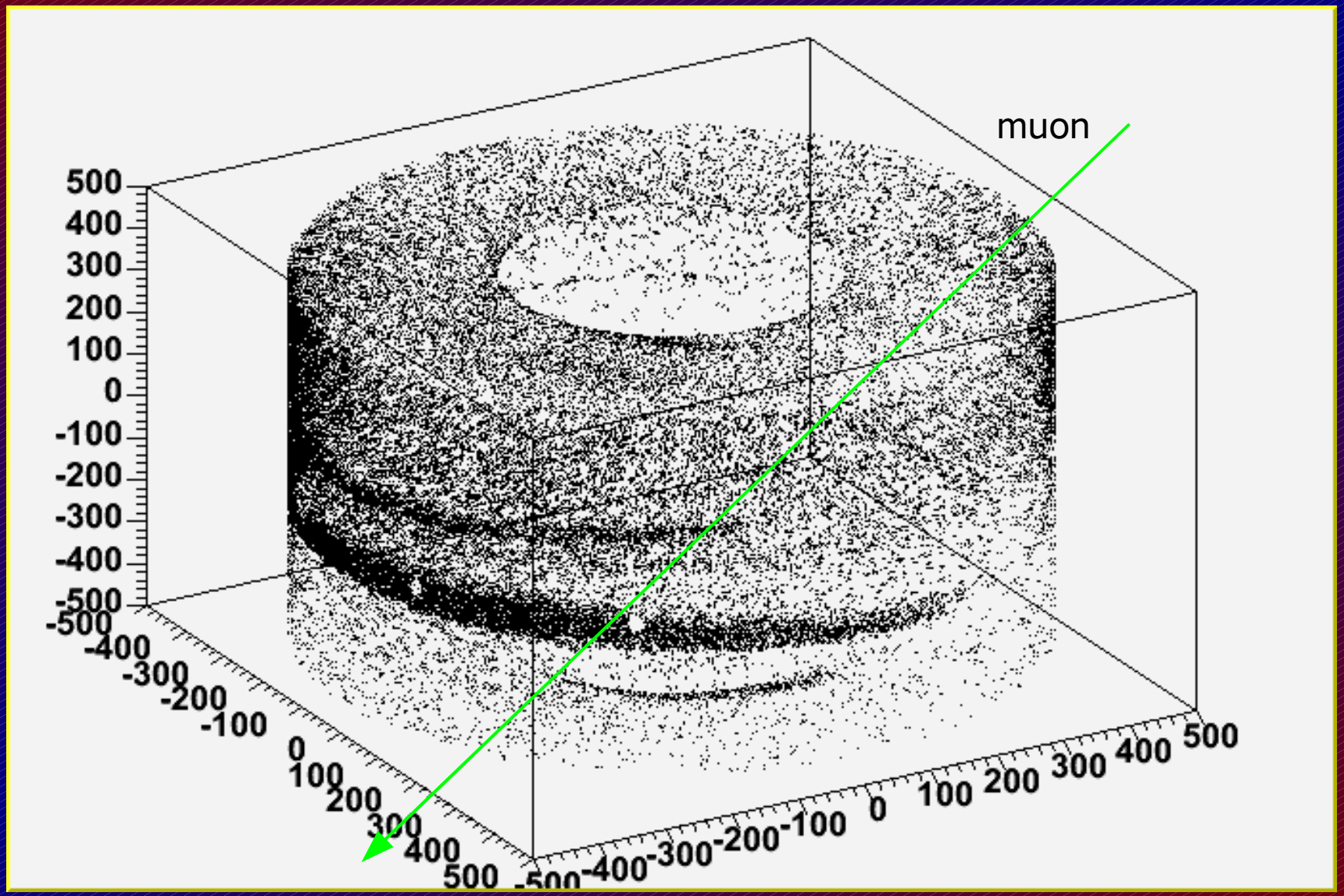
Muon classification

- All muons
- Muons with energy deposition in the germanium detector
- Dangerous muons with total energy deposition in the range of 1.5 MeV < E < 3 MeV
- Ultra-dangerous muons with total energy deposition in the energy window and only one hit in the Ge detector

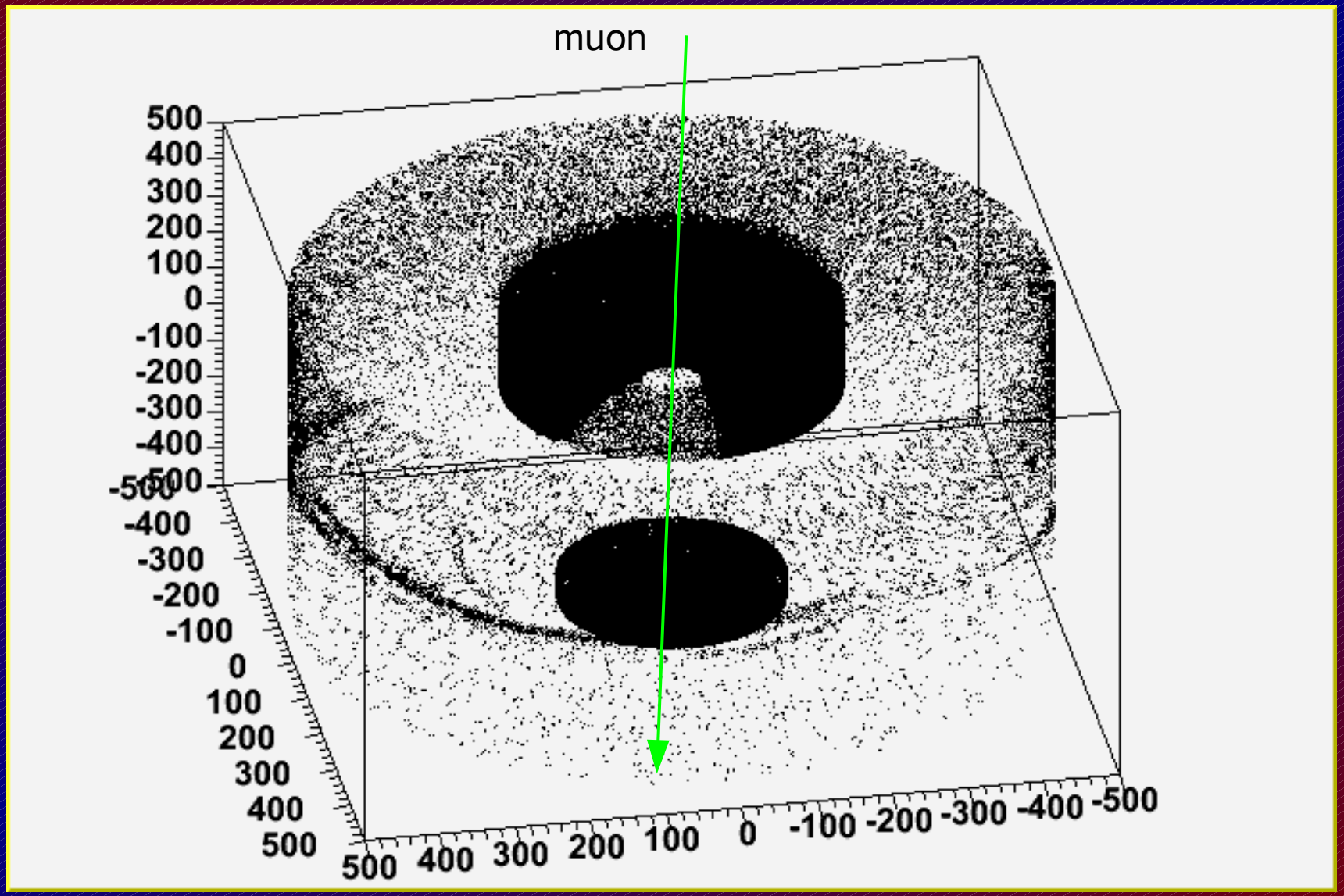


Cherenkov Cones

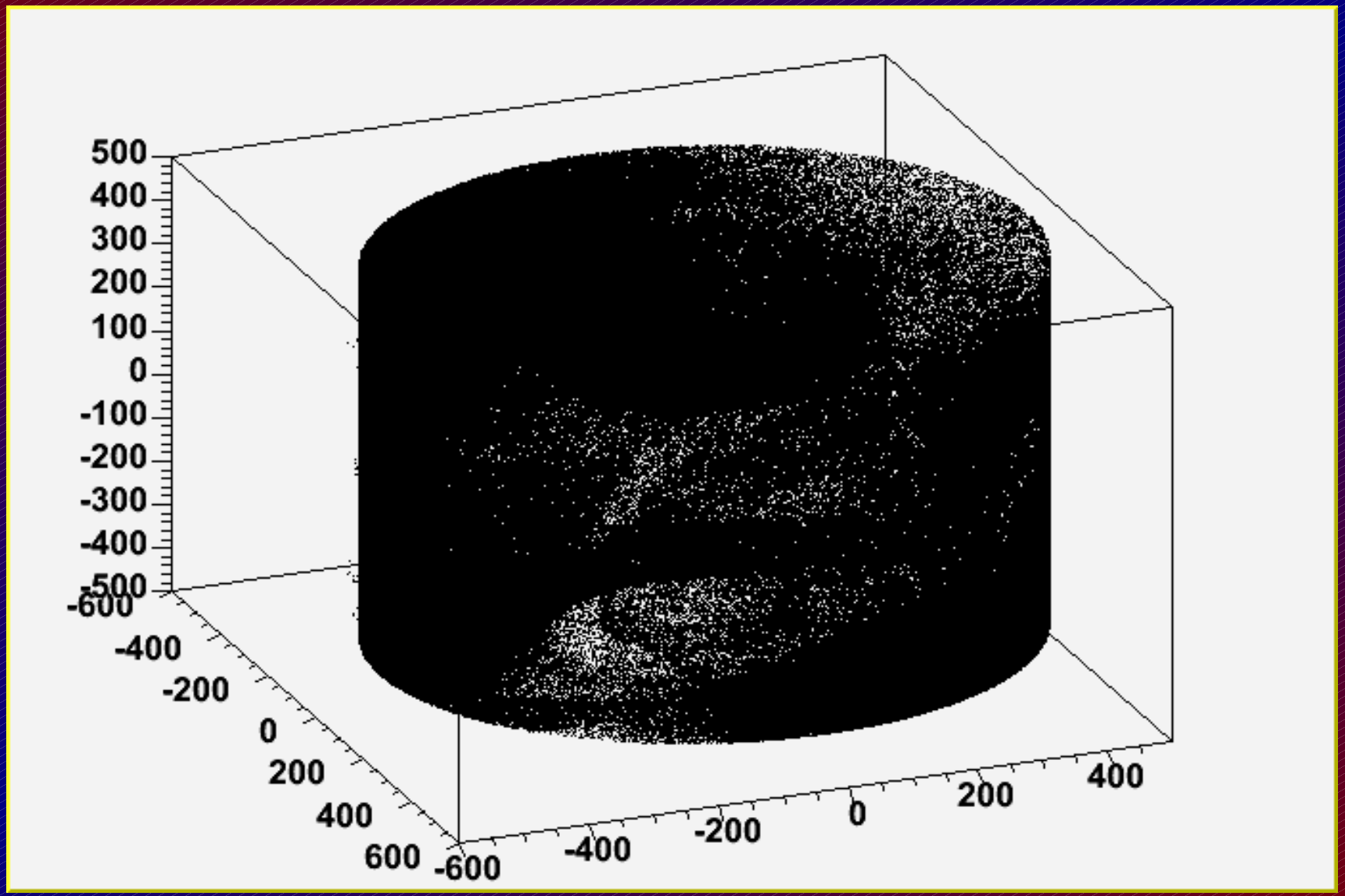
Cherenkov Cones



Cherenkov Cones

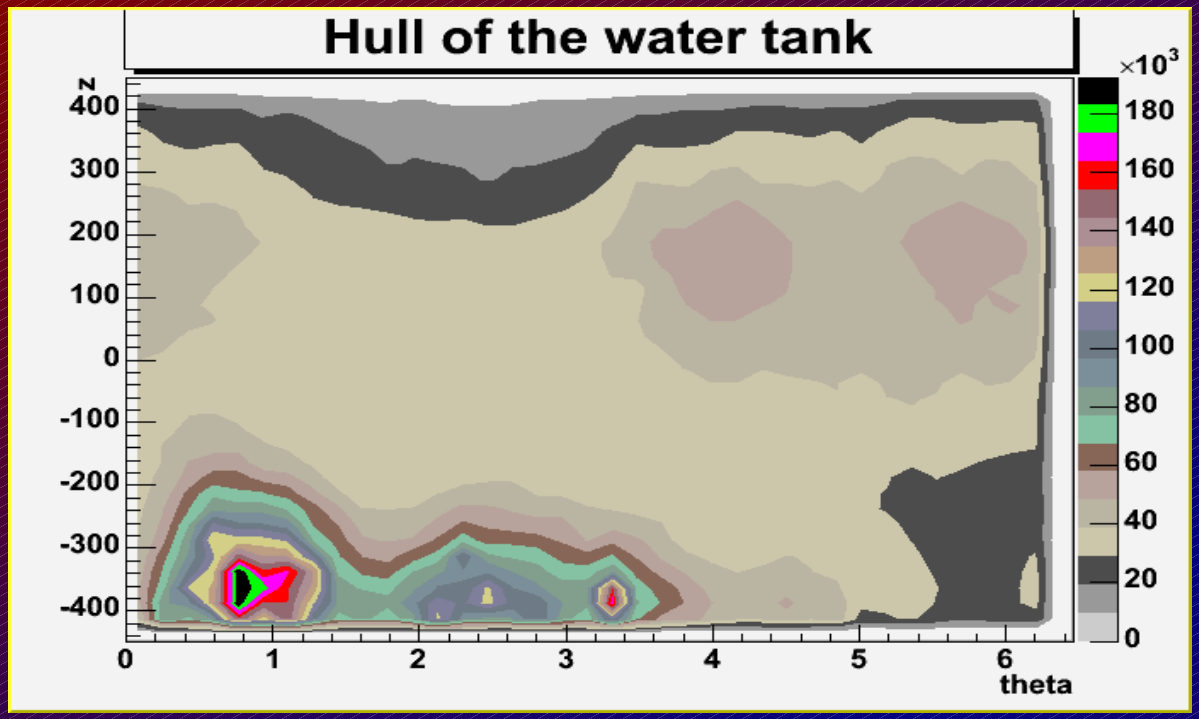


Cherenkov Cones

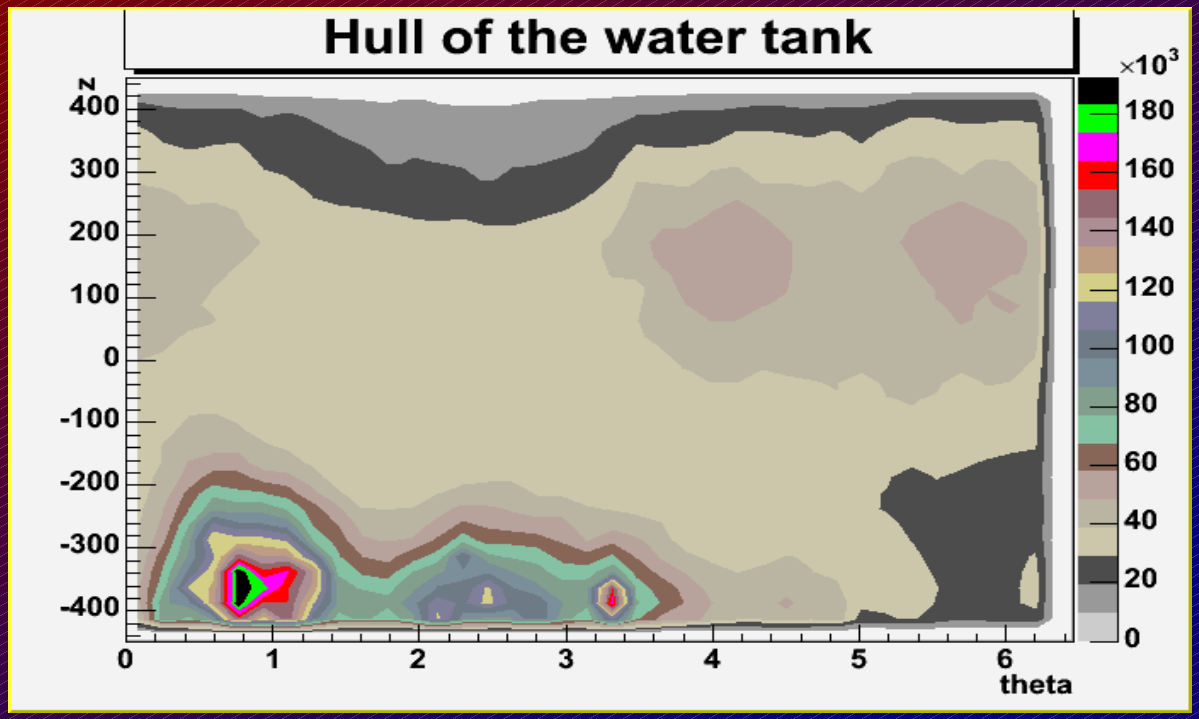


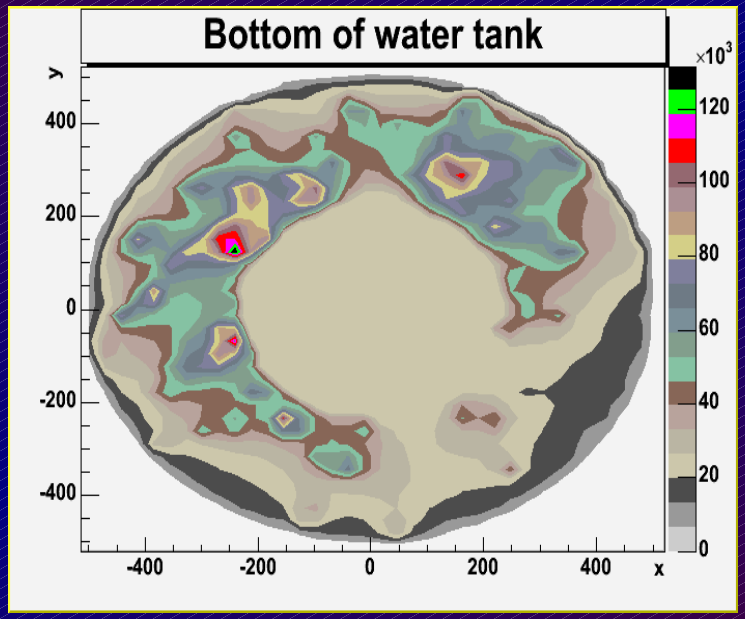
Photon maps

Photon maps

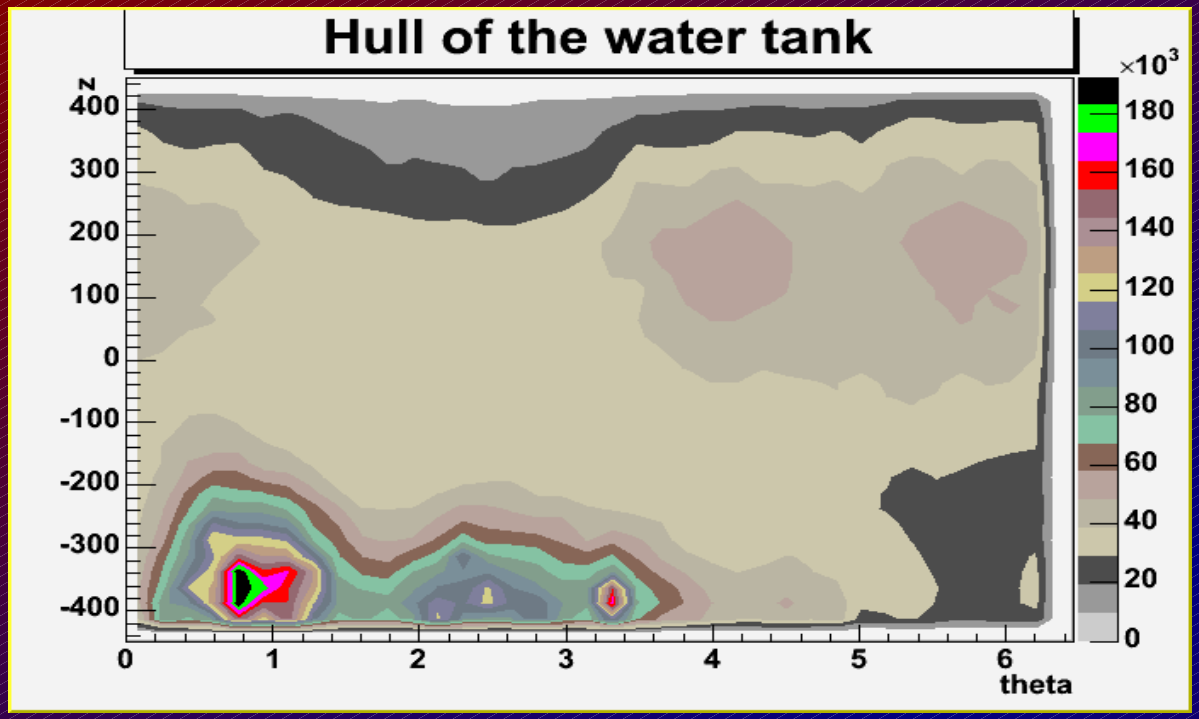

Hull of the water tank
N
400
300
200
100
0
-100
-200
-300
-400
0
1
2
3
4
5
6
theta
×10³
180
160
140
120
100
80
60
40
20
0

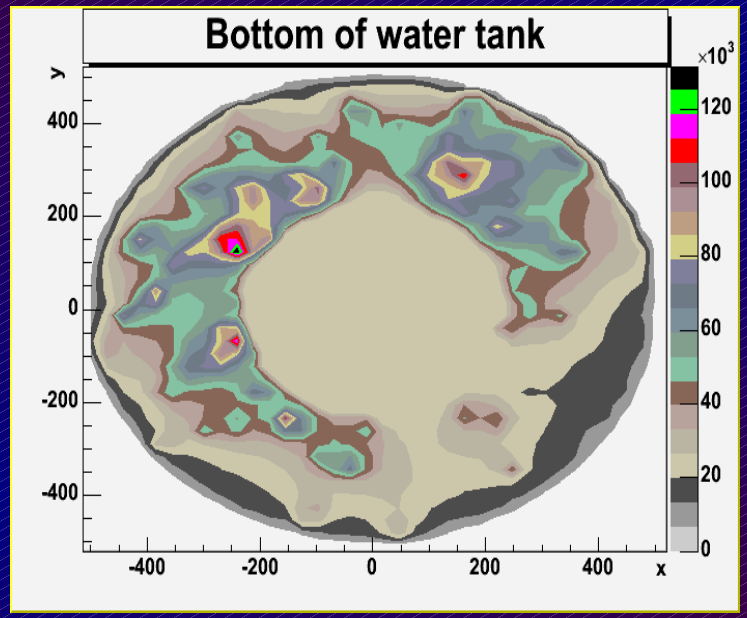
Photon maps

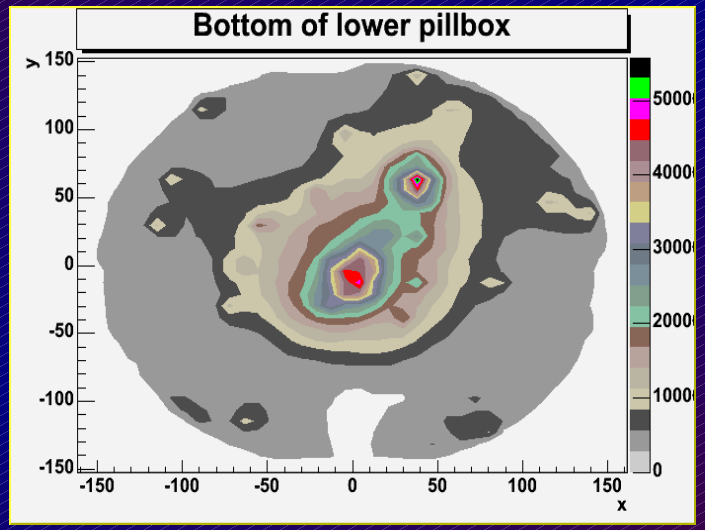

Hull of the water tank
z
400
300
200
100
0
-100
-200
-300
-400
0
1
2
3
4
5
6
theta
×10³
180
160
140
120
100
80
60
40
20
0

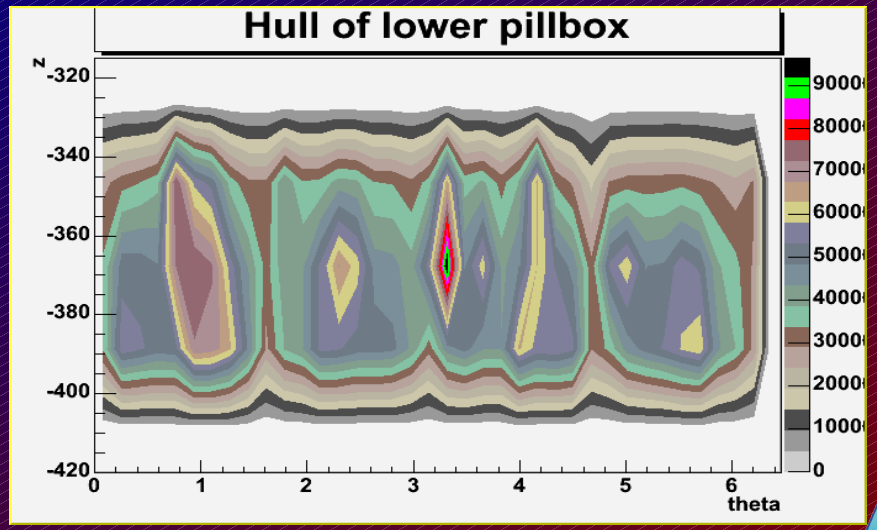

Bottom of water tank
y
400
200
0
-200
-400
-400
-200
0
200
400
x
×10³
120
100
80
60
40
20
0

Photon maps

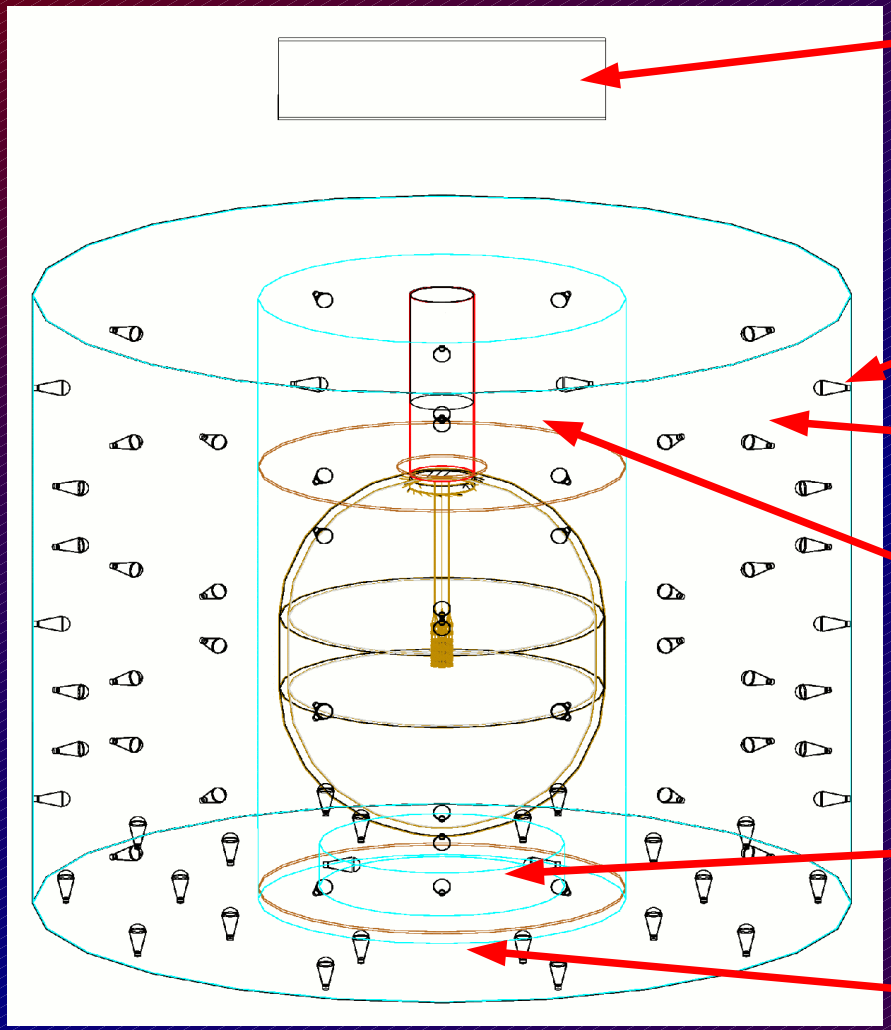

Hull of the water tank
z
theta
×10³


Bottom of water tank
y
x
×10³


Bottom of lower pillbox
y
x


Hull of lower pillbox
z
theta

GERDA – Muon veto system



Plasticscintillator

Watertank / Cherenkov-Veto

„Upper Pillbox“

„Lower pillbox“

VM 2000

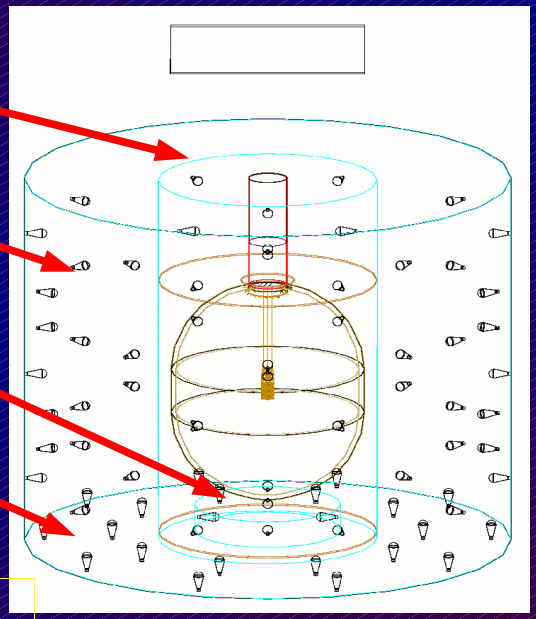
Different PM-Distributions

upper pillbox

ring on watertank wall

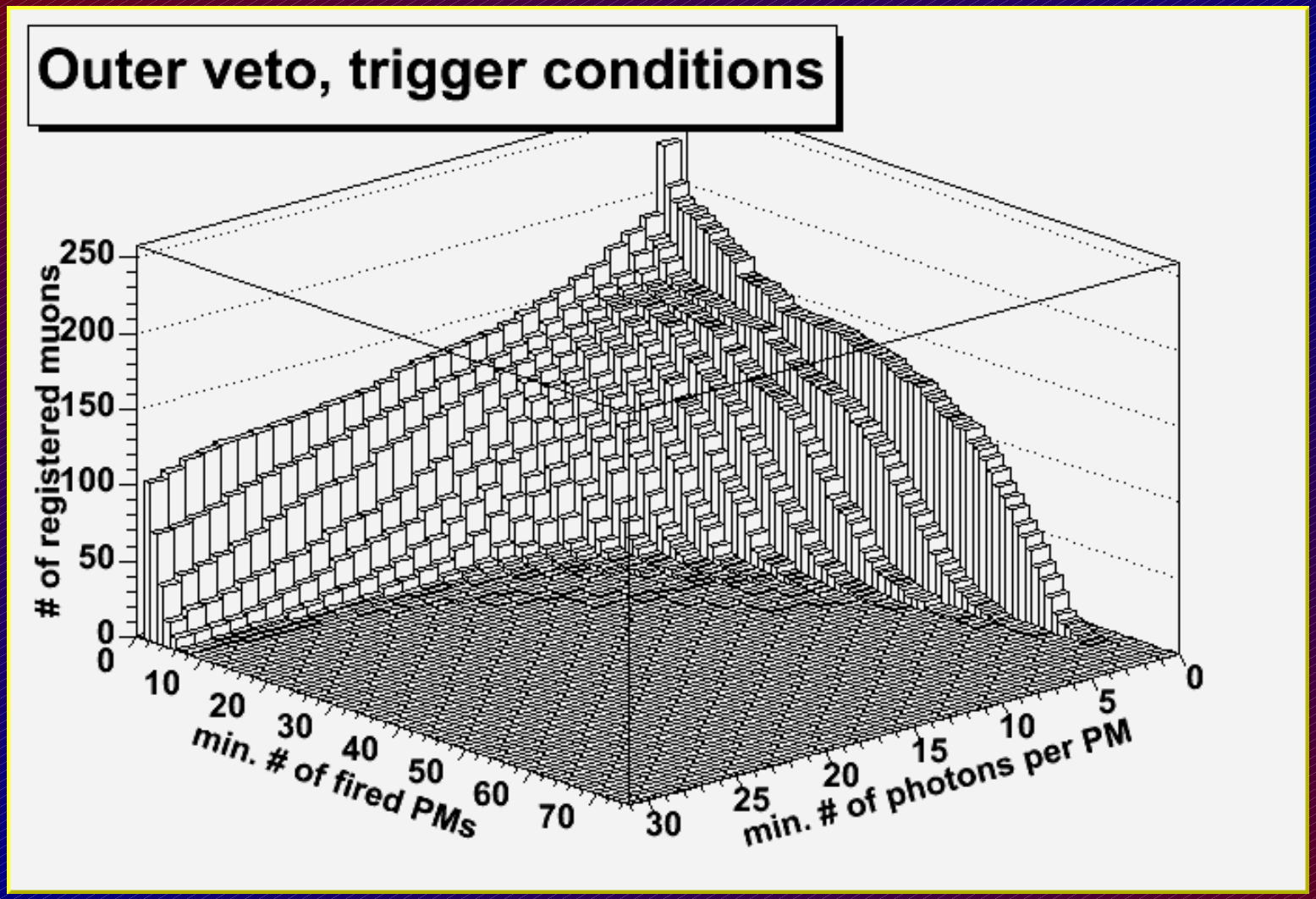
ring on watertank bottom

lower pillbox



Name	# of PMs	l. pillbox	u. pillbox	# bo. rings	# wa. Rings	PMs/ring
Dist 1	78	4	4	2	5	10
Dist 2	72	4	4	0	4	16
Dist 3	78	4	4	2	5	10
Dist 4	78	4	4	2	5	10
Dist 5	68	4	4	2	4	10
Dist 6	74	4	0	2	5	10
Dist 7	64	4	4	2	5	8
Dist 8	56	4	4	2	4	8
Dist 9	60	4	0	2	5	8
Dist 10	52	4	0	2	4	8

Muon triggers



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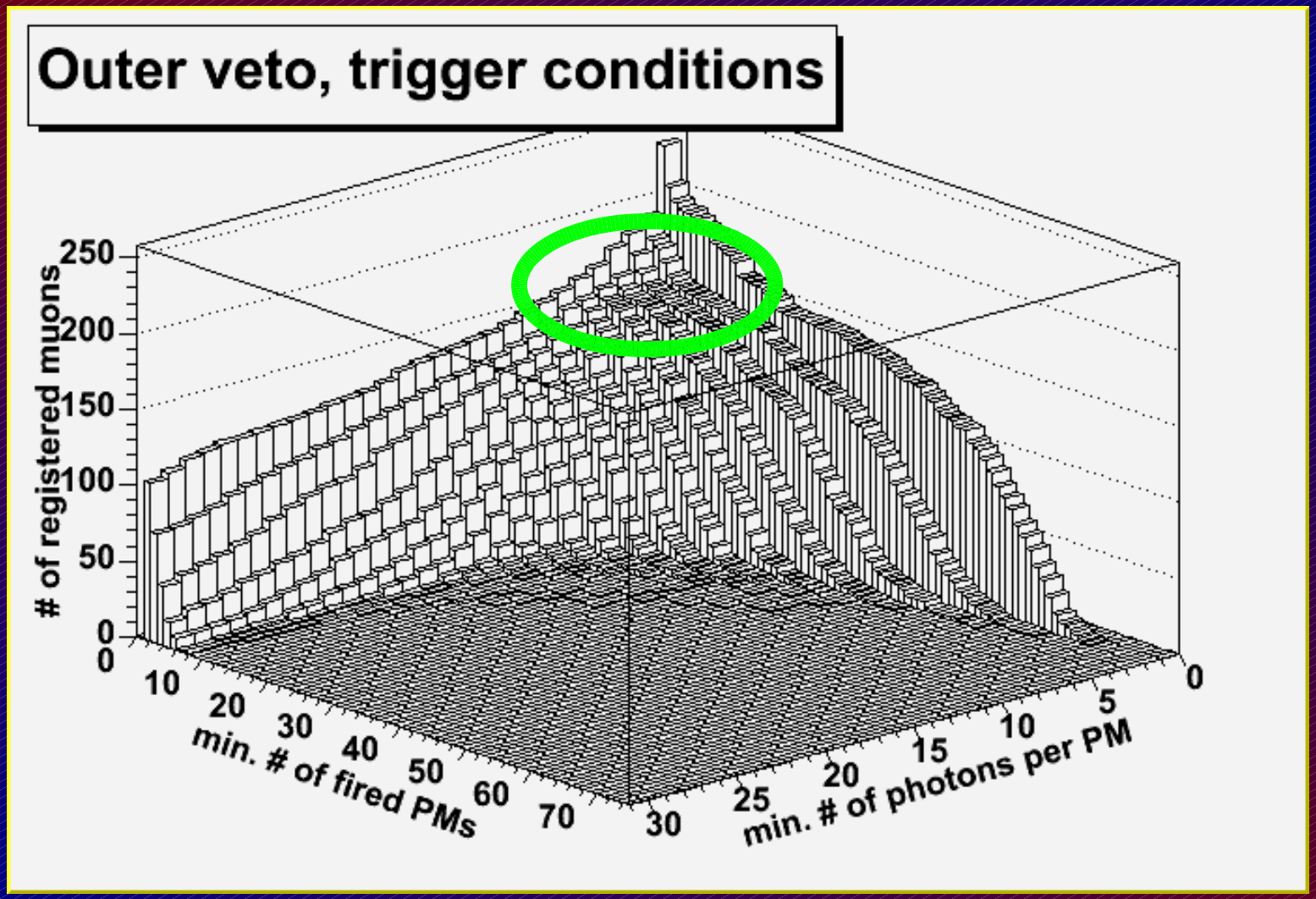

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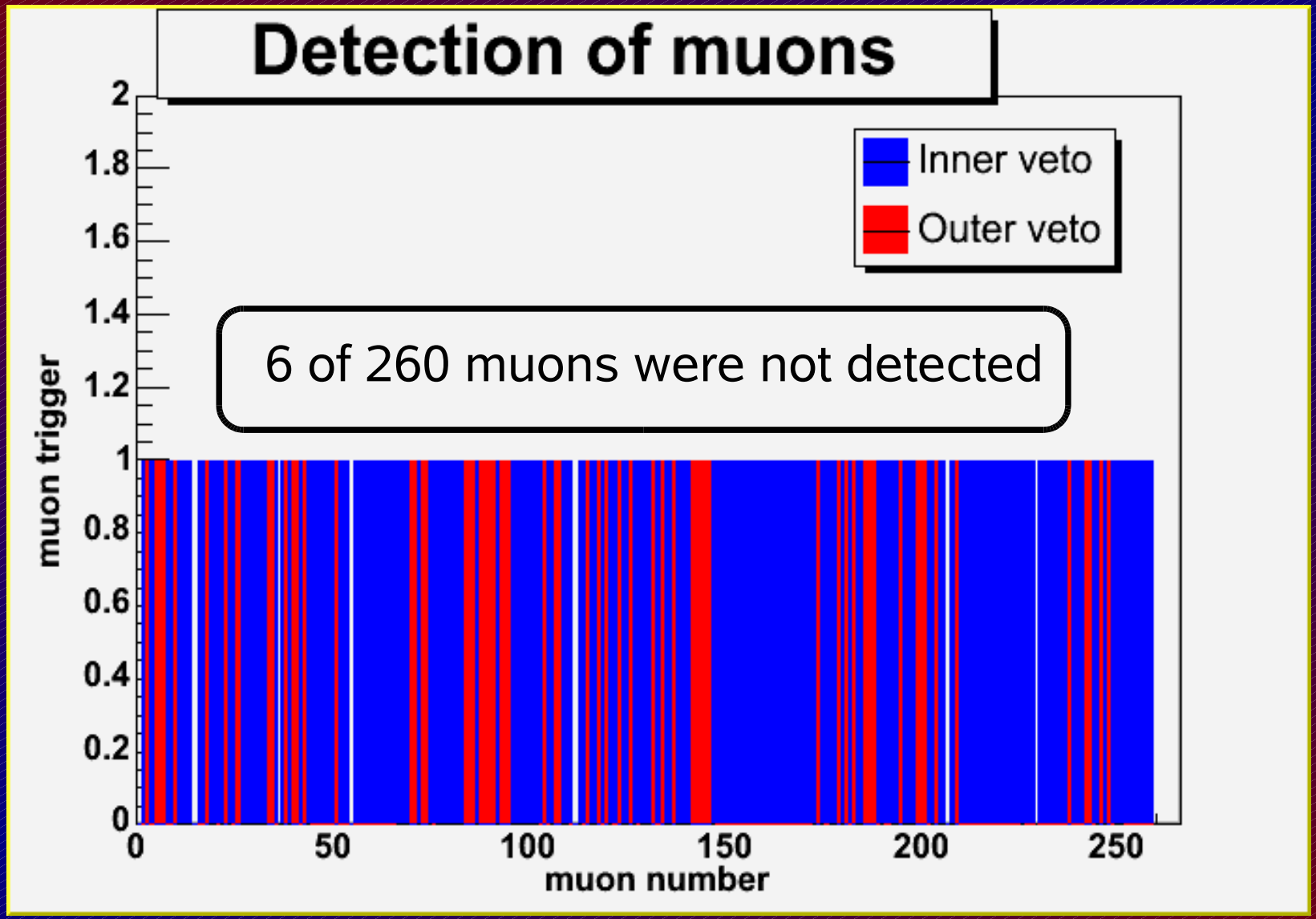

Different PM-Distributions

- 4 photon-electrons generated per PM
- 3 PMs triggered in the inner veto or
- 6 PMs triggered in the outer veto

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	73.33	55.13	96.92
Dist 2	72	yes	yes	0	4	16	72.31	51.28	95.9
Dist 3	78	yes	yes	2	5	10	72.82	54.87	97.18
Dist 4	78	yes	yes	2	5	10	73.72	55.13	97.44
Dist 5	68	yes	yes	2	4	10	71.54	53.97	96.54
Dist 6	74	yes	no	2	5	10	45.77	54.74	96.03
Dist 7	64	yes	yes	2	5	8	72.69	53.97	96.92
Dist 8	56	yes	yes	2	4	8	71.28	53.59	97.31
Dist 9	60	yes	no	2	5	8	46.15	53.97	96.15
Dist 10	52	yes	no	2	4	8	46.41	53.46	95.64

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- 4 photon-electrons generated per PM
- 3 PMs triggered in the inner veto or
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72.53%

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	73.33	55.13	96.92
Dist 2	72	yes	yes	0	4	16	72.31	51.28	95.9
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Dist 4	78	yes	yes	2	5	10	73.72	55.13	97.44
Dist 5	68	yes	yes	2	4	10	71.54	53.97	96.54
Dist 6	74	yes	no	2	5	10	45.77	54.74	96.03
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46.11%

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Dist 10	52	yes	no	2	4	8	46.41	53.46	95.64

Conclusion

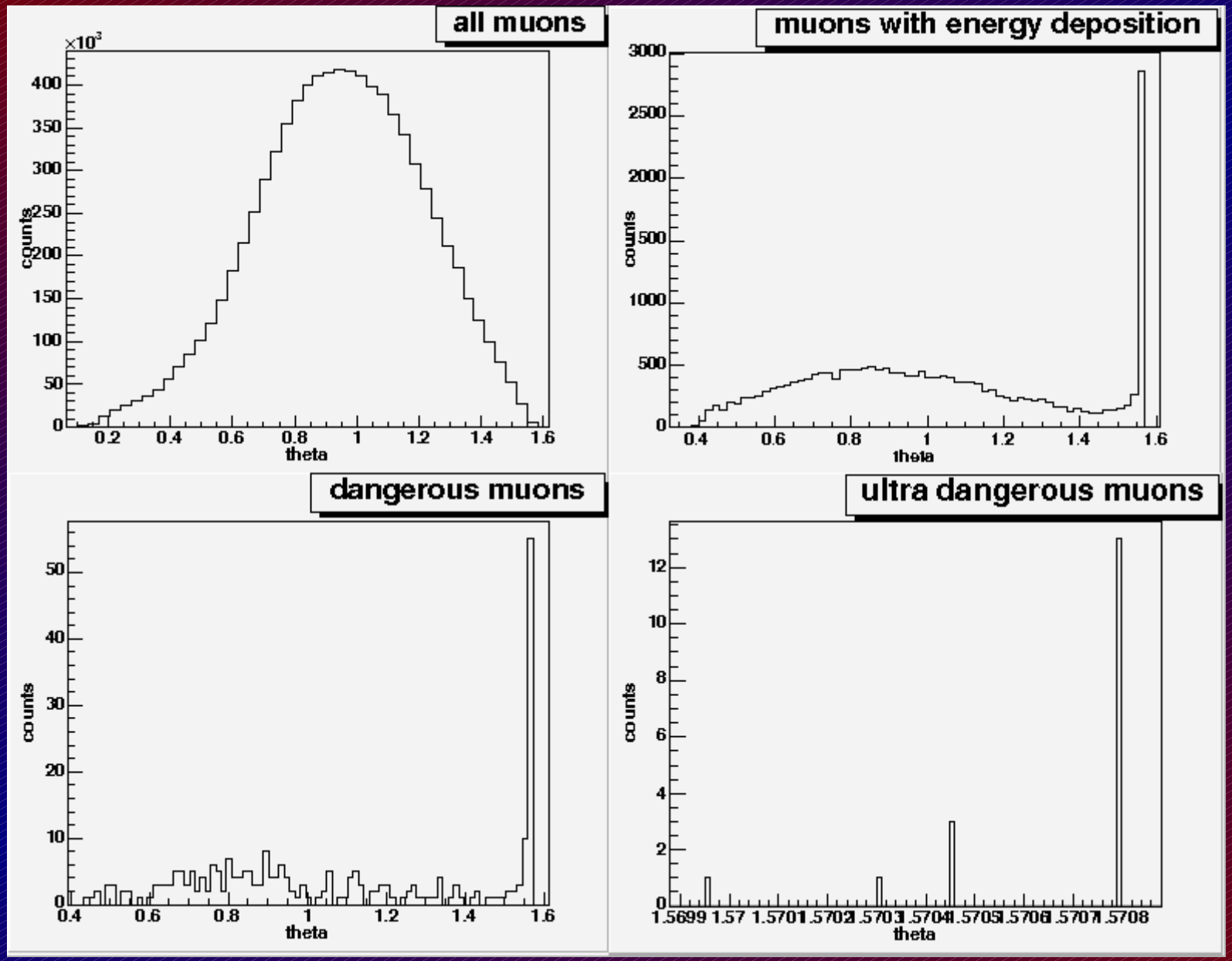
- At the moment several distributions of photomultiplier are analysed.
- First results show, that all three veto systems are necessary to detect most of the muons.
- Optimize trigger conditions.

Outlook

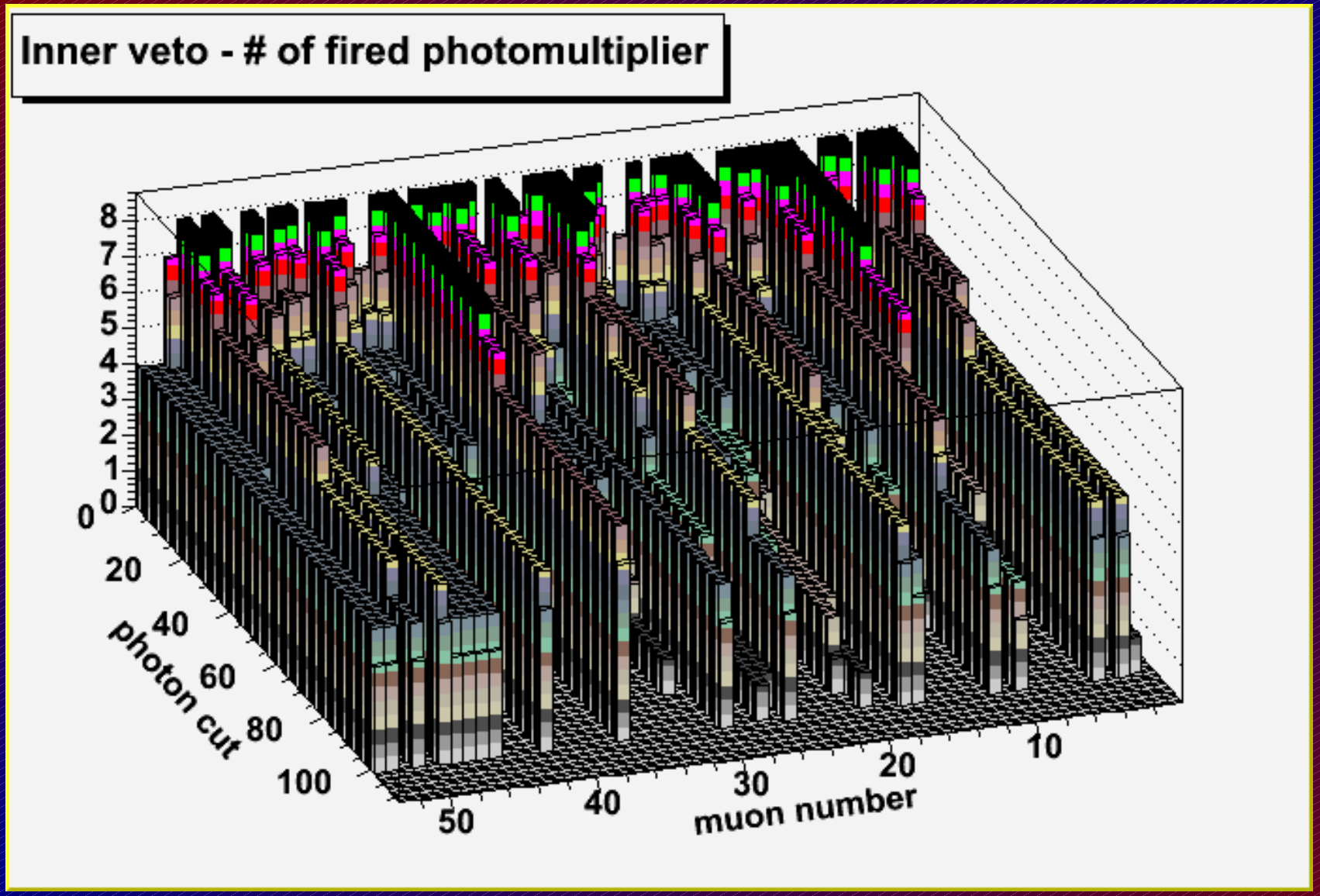
- The most important task will be to simulate different distributions of photomultiplier to optimize the Cherenkov veto and especially to reduce the number of necessary PMs.
- Optimize trigger conditions
- Also several tests must be done before, e.g. pressure tests of the encapsulation.
- Finally the veto must be constructed at the LNGS.

Finish

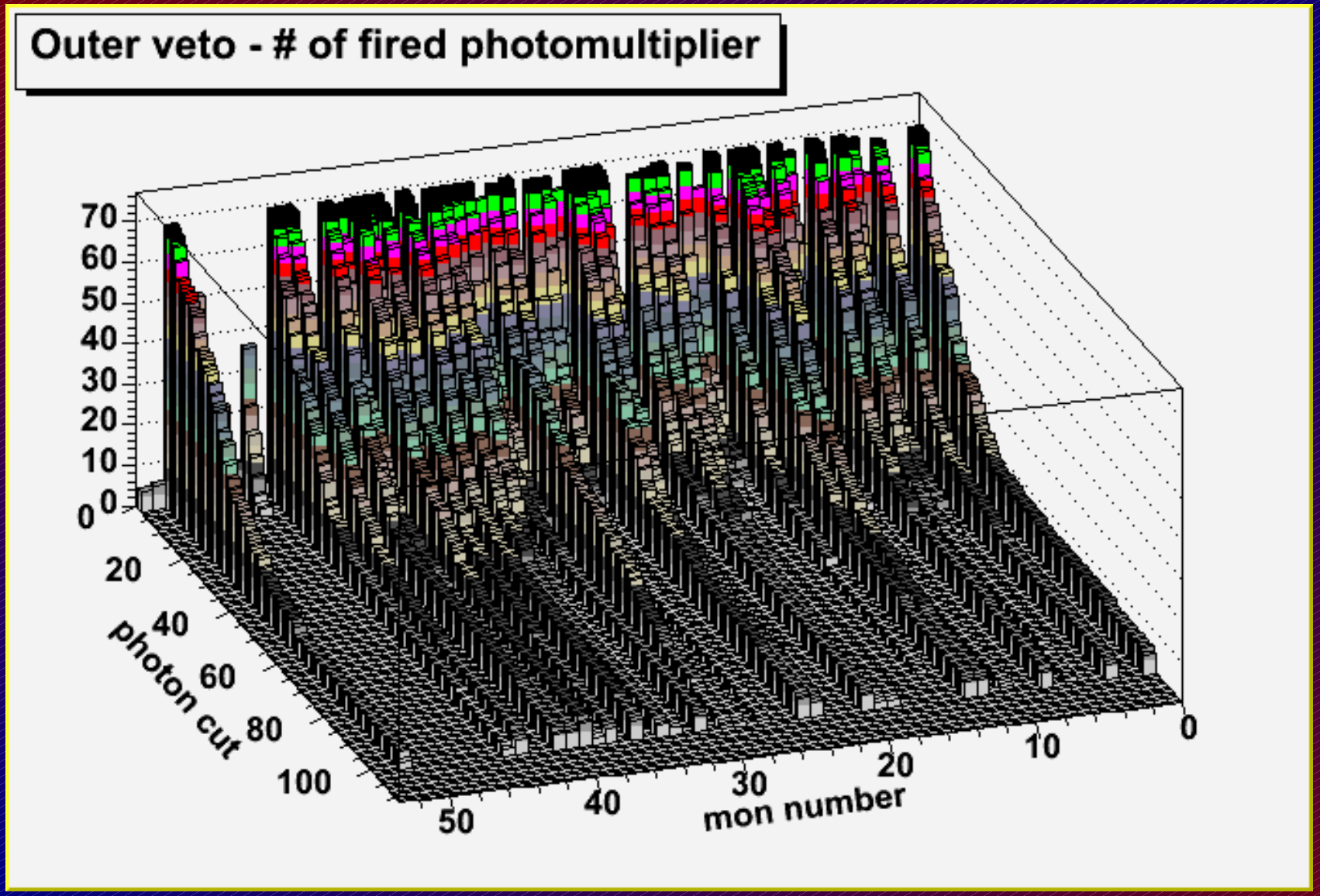
angular distribution



Detection: IV vs. OV - IV



Detection: IV vs. OV - OV



Different PM-Distributions

- 8 photon-electrons generated per PM
- 4 PMs triggered in the inner veto or
- 10 PMs triggered in the outer veto

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	47.95	27.82	73.59
Dist 2	72	yes	yes	0	4	16	47.95	4.87	52.05
Dist 3	78	yes	yes	2	5	10	48.46	24.74	71.15
Dist 4	78	yes	yes	2	5	10	48.08	26.54	73.21
Dist 5	68	yes	yes	2	4	10	47.69	21.41	66.92
Dist 6	74	yes	no	2	5	10	44.62	23.59	67.18
Dist 7	64	yes	yes	2	5	8	48.59	14.87	61.54
Dist 8	56	yes	yes	2	4	8	48.72	13.85	60.26
Dist 9	60	yes	no	2	5	8	44.49	15.13	58.72
Dist 10	52	yes	no	2	4	8	45.26	12.31	56.54

Different PM-Distributions

- 8 photon-electrons generated per PM
- 4 PMs triggered in the inner veto or
- 10 PMs triggered in the outer veto

48.21%

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	47.95	27.82	73.59
Dist 2	72	yes	yes	0	4	16	47.95	4.87	52.05
Dist 3	78	yes	yes	2	5	10	48.46	24.74	71.15
Dist 4	78	yes	yes	2	5	10	48.08	26.54	73.21
Dist 5	68	yes	yes	2	4	10	47.69	21.41	66.92
Dist 6	74	yes	no	2	5	10	[illegible]	23.59	67.18
Dist 7	64	yes	yes	2	5	8	48.59	14.87	61.54
Dist 8	56	yes	yes	2	4	8	48.72	13.85	60.26
Dist 9	60	yes	no	2	5	8	44.49	15.13	58.72
Dist 10	52	yes	no	2	4	8	45.26	12.31	56.54

Different PM-Distributions

- 8 photon-electrons generated per PM
- 4 PMs triggered in the inner veto or
- 10 PMs triggered in the outer veto

44.79%

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	47.95	27.82	73.59
Dist 2	72	yes	yes	0	4	16	47.95	4.87	52.05
Dist 3	78	yes	yes	2	5	10	48.46	24.74	71.15
Dist 4	78	yes	yes	2	5	10	48.08	26.54	73.21
Dist 5	68	yes	yes	2	4	10	47.69	21.41	66.92
Dist 6	74	yes	no	2	5	10	44.62	23.59	67.18
Dist 7	64	yes	yes	2	5	8	46.66	14.87	61.54
Dist 8	56	yes	yes	2	4	8	47.72	13.85	60.26
Dist 9	60	yes	no	2	5	8	44.49	15.13	58.72
Dist 10	52	yes	no	2	4	8	45.26	12.31	56.54

Different PM-Distributions

- 8 photon-electrons generated per PM
- 4 PMs triggered in the inner veto or
- 10 PMs triggered in the outer veto

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	47.95	27.82	73.59
Dist 2	72	yes	yes	0	4	16	47.95	4.87	52.05
Dist 3	78	yes	yes	2	5	10	48.46	24.74	71.15
Dist 4	78	yes	yes	2	5	10	48.08	26.54	73.21
Dist 5	68	yes	yes	2	4	10	47.69	21.41	66.92
Dist 6	74	yes	no	2	5	10	44.62	23.59	67.18
Dist 7	64	yes	yes	2	5	8	48.59	14.87	61.54
Dist 8	56	yes	yes	2	4	8	48.72	13.85	60.26
Dist 9	60	yes	no	2	5	8	44.49	15.13	58.72
Dist 10	52	yes	no	2	4	8	45.26	12.31	56.54

Different PM-Distributions

- 2 photon-electrons generated per PM
- 3 PMs triggered in the inner veto or
- 6 PMs triggered in the outer veto

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	85.64	58.59	98.21
Dist 2	72	yes	yes	0	4	16	85.13	58.85	97.56
Dist 3	78	yes	yes	2	5	10	84.62	58.08	98.33
Dist 4	78	yes	yes	2	5	10	85.64	57.82	98.46
Dist 5	68	yes	yes	2	4	10	86.41	57.18	97.95
Dist 6	74	yes	no	2	5	10	46.67	57.82	97.18
Dist 7	64	yes	yes	2	5	8	85.38	57.05	97.82
Dist 8	56	yes	yes	2	4	8	86.28	57.31	98.85
Dist 9	60	yes	no	2	5	8	47.18	57.05	96.92
Dist 10	52	yes	no	2	4	8	47.31	56.92	97.31

Different PM-Distributions

- 2 photon-electrons generated per PM
- 3 PMs triggered in the inner veto or
- 6 PMs triggered in the outer veto

85.59%

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	85.64	58.59	98.21
Dist 2	72	yes	yes	0	4	16	85.13	58.85	97.56
Dist 3	78	yes	yes	2	5	10	84.62	58.08	98.33
Dist 4	78	yes	yes	2	5	10	85.64	57.82	98.46
Dist 5	68	yes	yes	2	4	10	86.41	57.18	97.95
Dist 6	74	yes	no	2	5	10	46.67	57.82	97.18
Dist 7	64	yes	yes	2	5	8	85.38	57.05	97.82
Dist 8	56	yes	yes	2	4	8	86.28	57.31	98.85
Dist 9	60	yes	no	2	5	8	47.18	57.05	96.92
Dist 10	52	yes	no	2	4	8	47.31	56.92	97.31

Different PM-Distributions

- 2 photon-electrons generated per PM
- 3 PMs triggered in the inner veto or
- 6 PMs triggered in the outer veto

47.05%

Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	85.64	58.59	98.21
Dist 2	72	yes	yes	0	4	16	85.13	58.85	97.56
Dist 3	78	yes	yes	2	5	10	84.62	58.08	98.33
Dist 4	78	yes	yes	2	5	10	85.6	57.82	98.46
Dist 5	68	yes	yes	2	4	10	86.	57.18	97.95
Dist 6	74	yes	no	2	5	10	46.67	57.82	97.18
Dist 7	64	yes	yes	2	5	8	85.38	57.05	97.82
Dist 8	56	yes	yes	2	4	8	84.28	57.31	98.85
Dist 9	60	yes	no	2	5	8	47.18	57.05	96.92
Dist 10	52	yes	no	2	4	8	47.31	56.92	97.31

Different PM-Distributions

- 2 photon-electrons generated per PM
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Name	# of PMs	l. pb	u. pb	# bo. rings	# wa. Rings	PMs/ring	IV reg. mus	OV reg. mus	reg. mus
Dist 1	78	yes	yes	2	5	10	85.64	[illegible]	98.21
Dist 2	72	yes	yes	0	4	16	85.13	58.85	97.56
Dist 3	78	yes	yes	2	5	10	84.62	58.08	98.33
Dist 4	78	yes	yes	2	5	10	85.64	57.82	98.46
Dist 5	68	yes	yes	2	4	10	86.41	57.18	97.95
Dist 6	74	yes	no	2	5	10	46.67	57.82	97.18
Dist 7	64	yes	yes	2	5	8	85.38	57.05	97.82
Dist 8	56	yes	yes	2	4	8	86.28	57.31	98.85
Dist 9	60	yes	no	2	5	8	47.18	57.05	96.92
Dist 10	52	yes	no	2	4	8	47.31	56.92	97.31