The modeling of a proton detector for energies from 1MeV to 15MeV

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CNES Supervisor : **Julien MEKKI**

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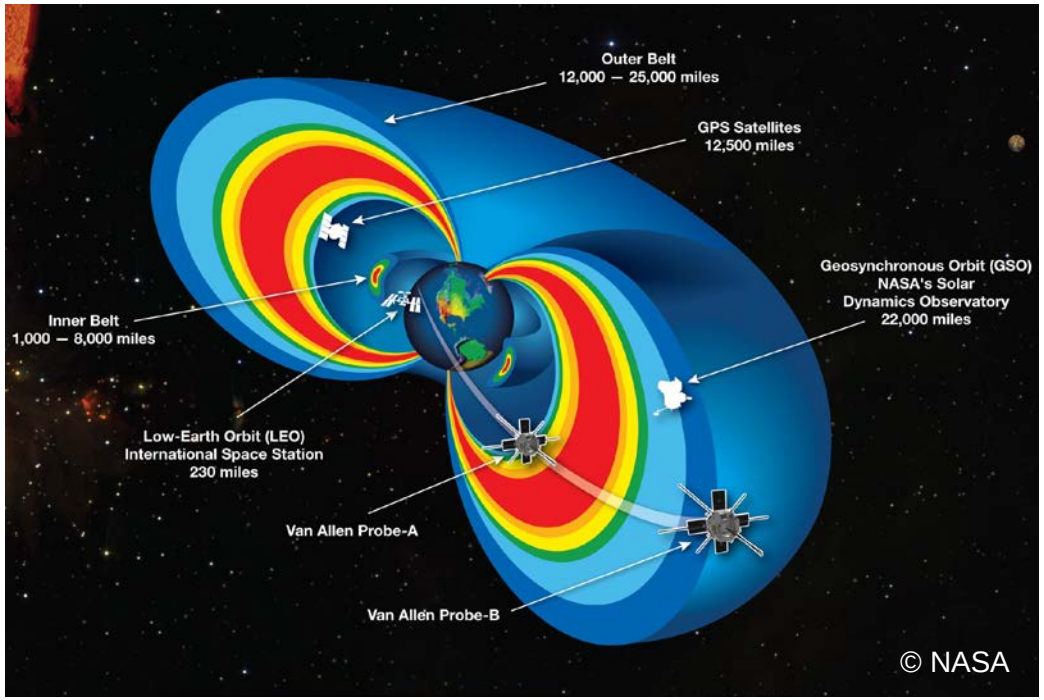
Outline

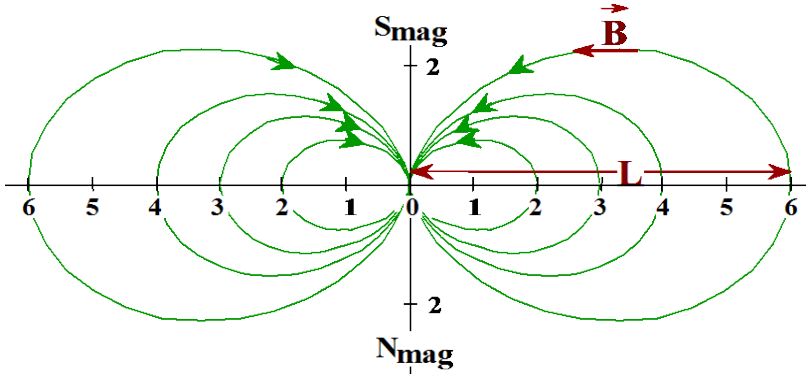
- Context
  - Radiation belts
  - Electric propulsion
- Detection of protons with an energy from 1MeV to 15MeV
  - Design of the detector
  - Response functions
  - Counts of particles
- Conclusion

Context

- Radiation belts



First order approximation of the Earth's magnetic field

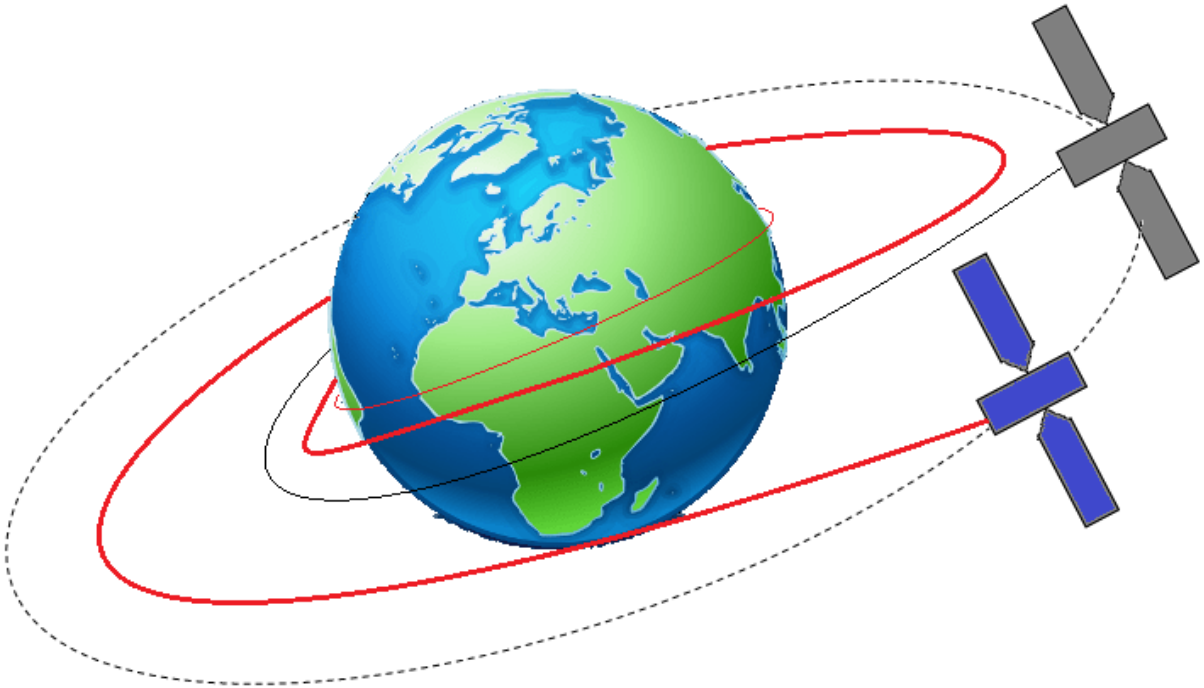


dipole model of the Earth's magnetic field

McIlwain L-parameter

Context

- Electric propulsion
  - To position satellites on geostationary orbit
  - More time in radiation belts
  - Radiation models : AP8 (protons) and AE8 (electrons)
  - Proton fluxes (1MeV – 15MeV) under-estimated by AP8



Satellite with chemical propulsion

~ 1 week transfer time to geostationary orbit

Satellite with electric propulsion

Up to 6 months transfer time to geostationary orbit

Detection of protons with an energy from 1MeV to 15MeV

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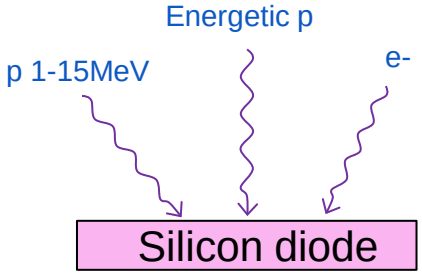
  - Mixed field of particles :

    => protons 1MeV-15MeV

    => protons E<1MeV and E>15MeV

    => electrons



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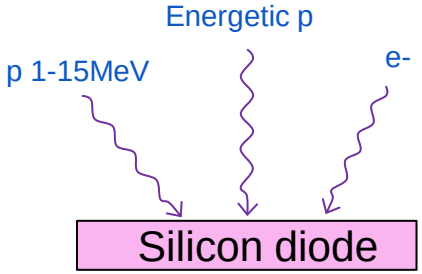

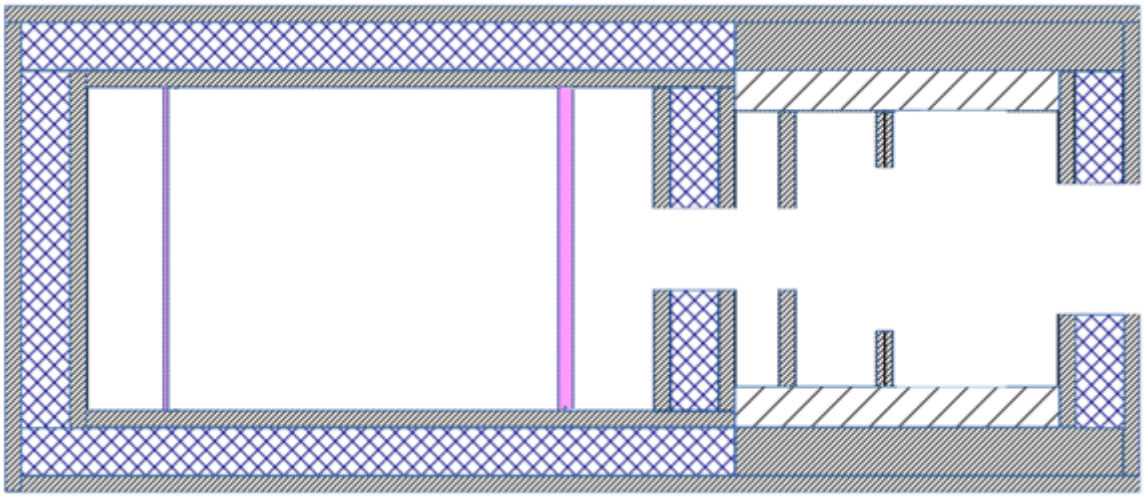

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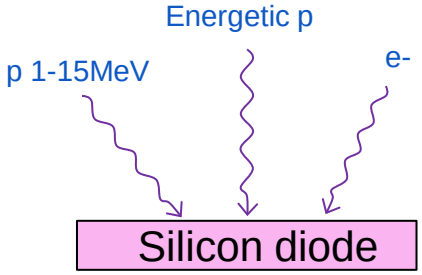

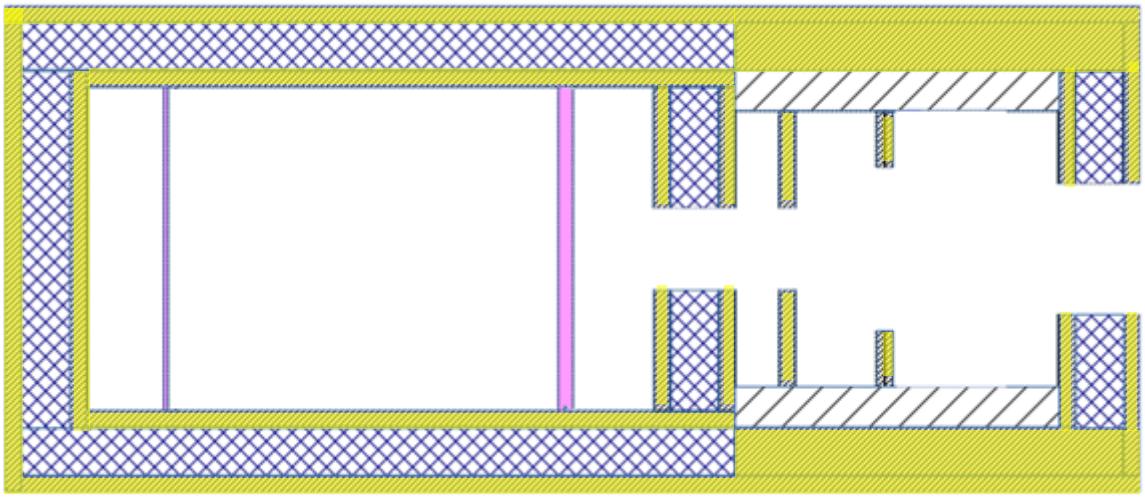

Aluminum

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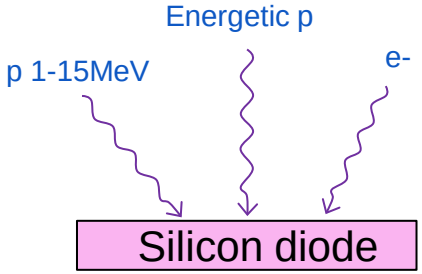

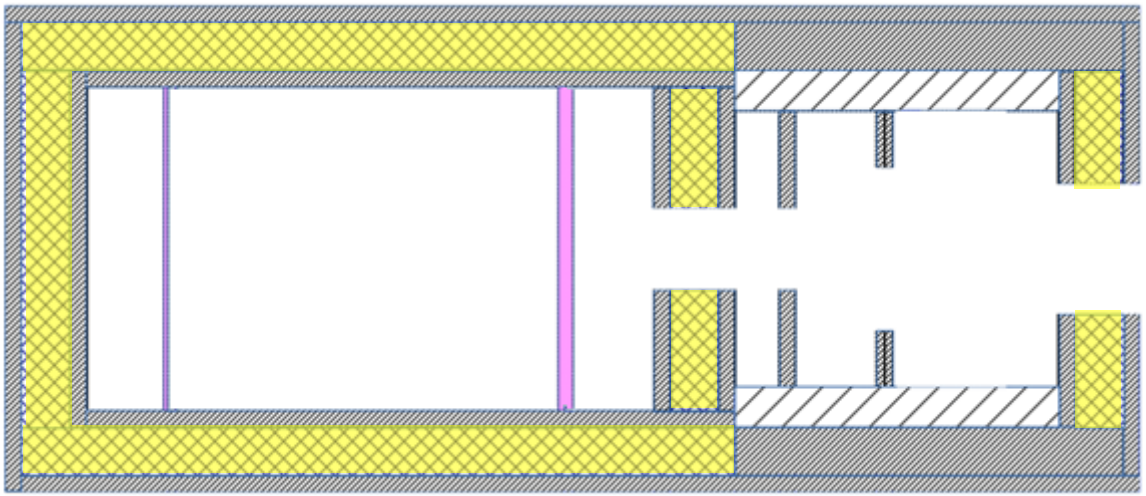

Tungsten

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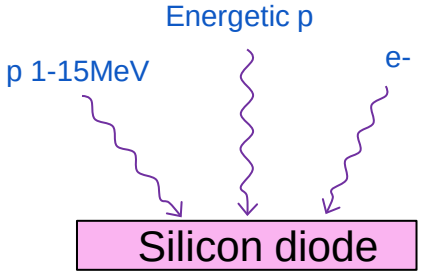

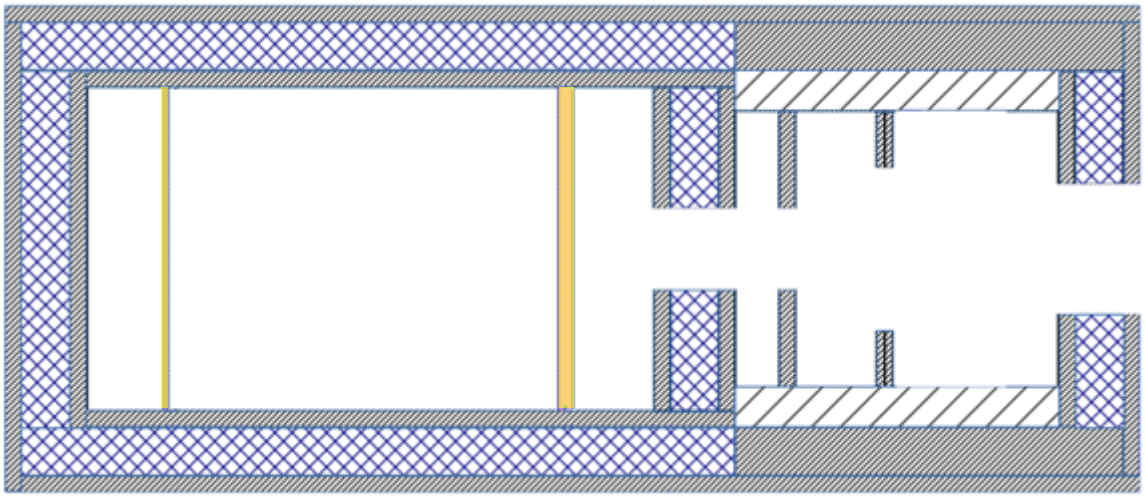

Silicon

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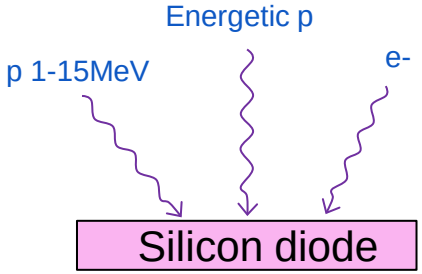

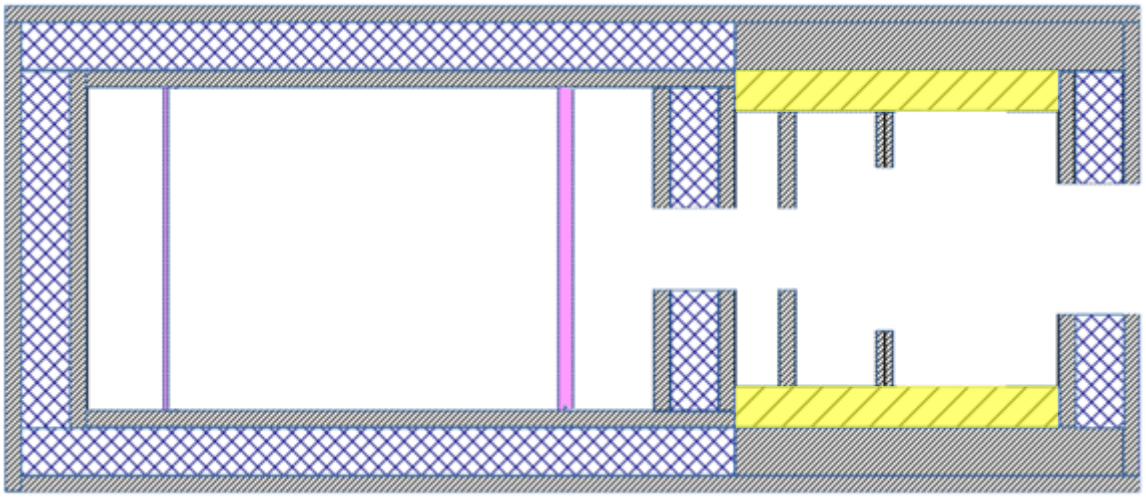

Magnet

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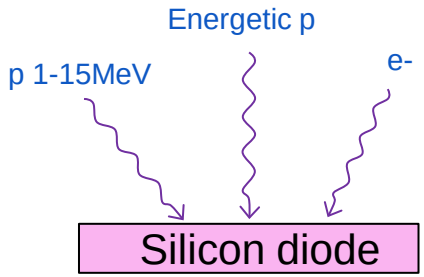

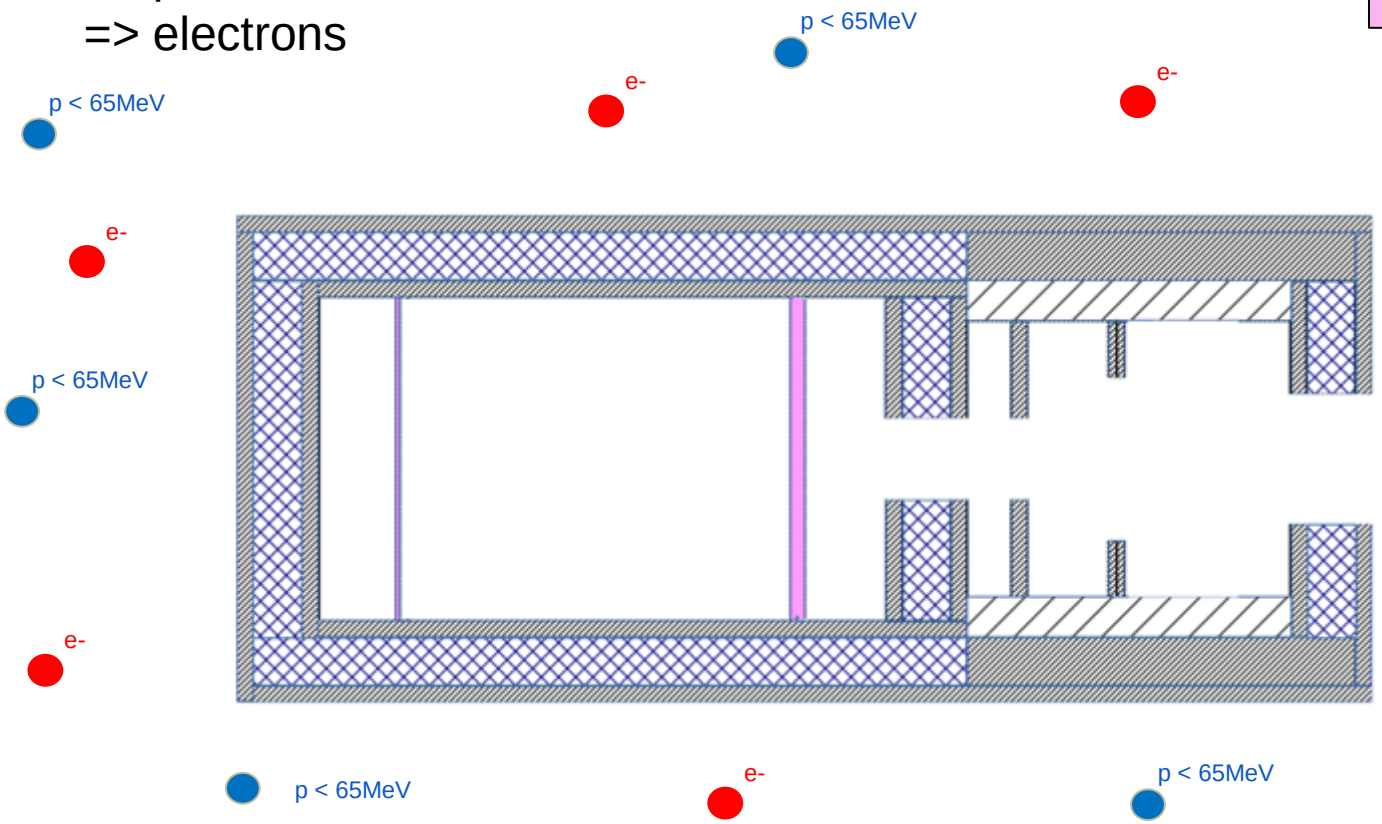

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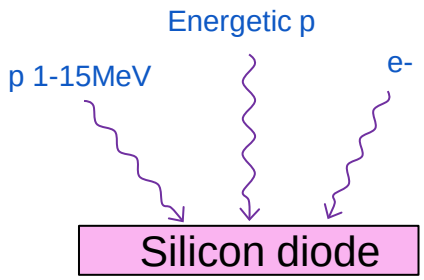

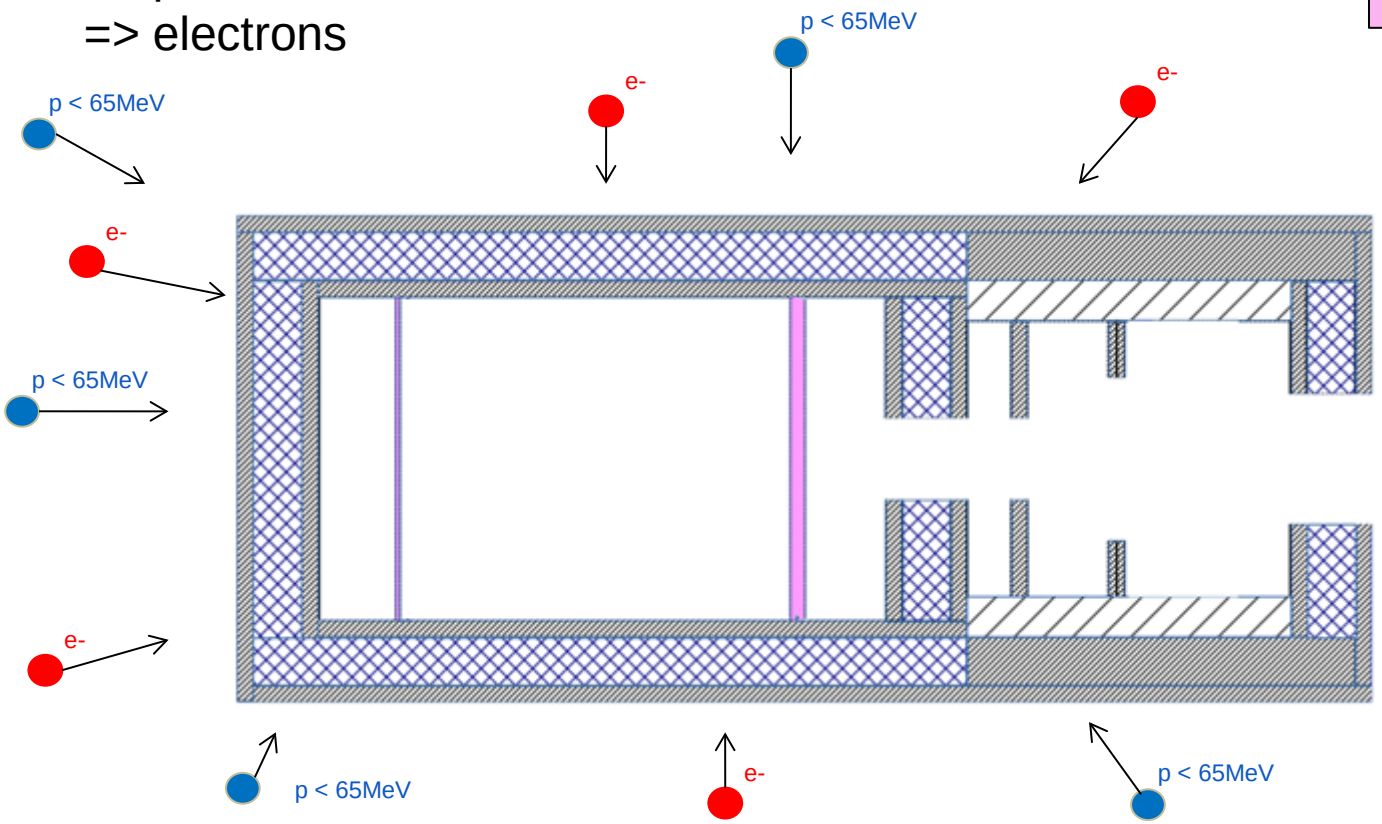

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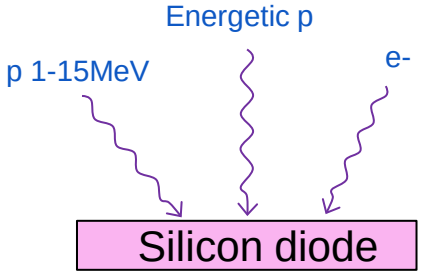

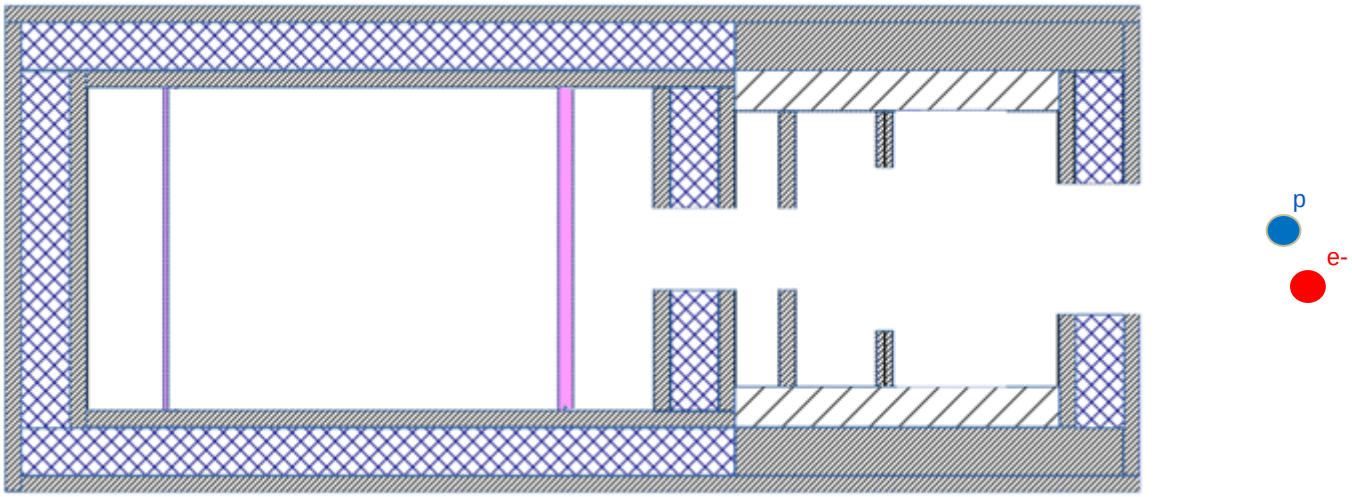

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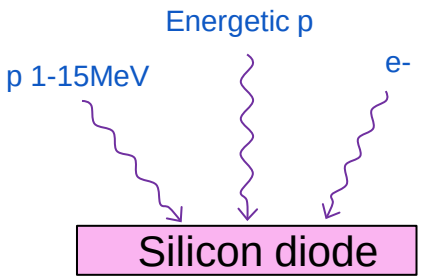

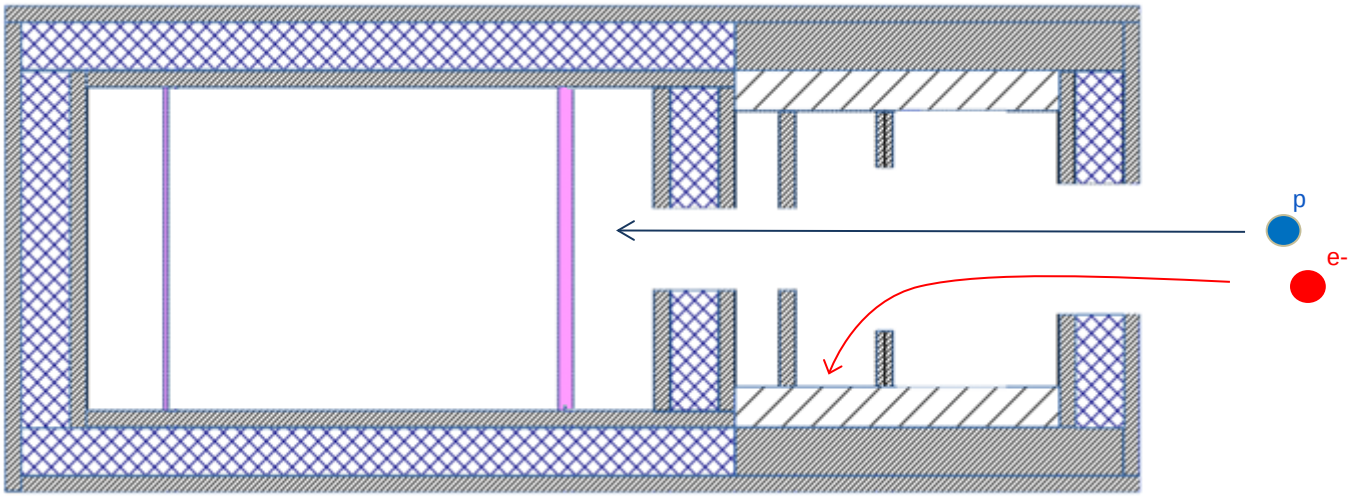

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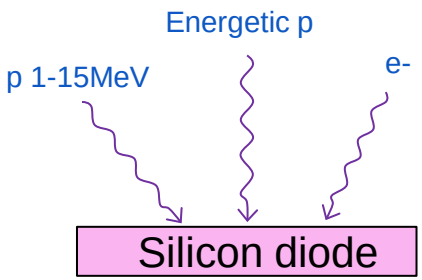
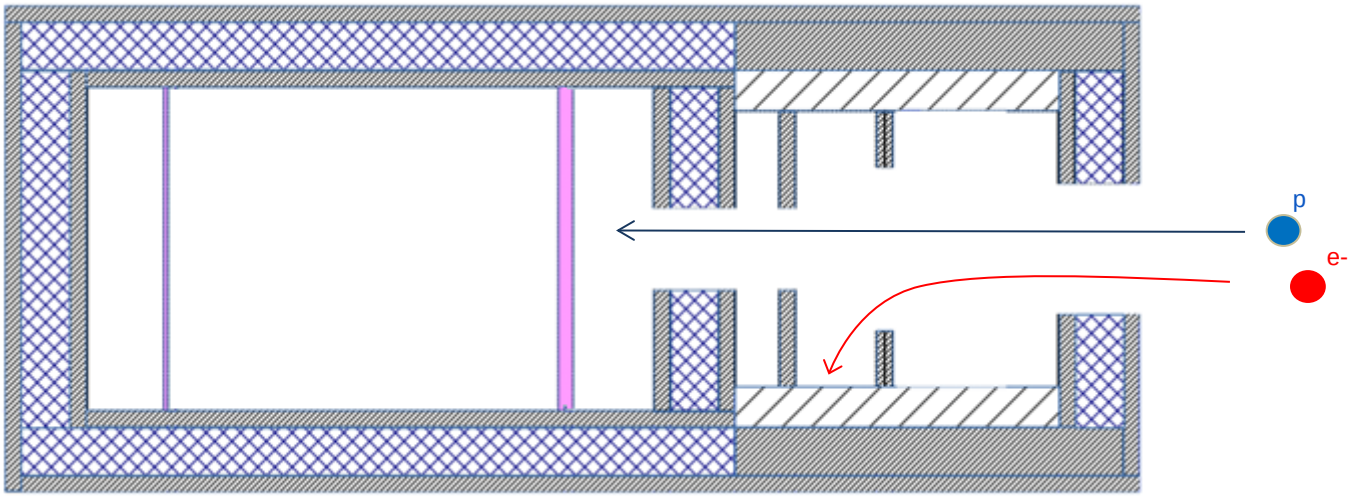
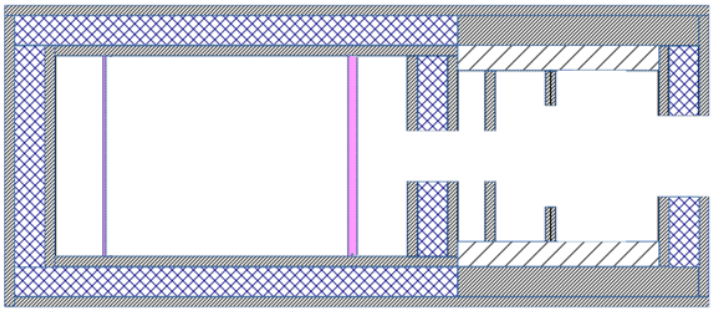




- Minimisation of energetic protons : shielding
- Minimisation of electrons : shielding + magnet

Detection of protons with an energy from 1MeV to 15MeV

- Response functions



- GEANT4 simulations
- Spherical source
- Particles : 5 millions x 282 incident energies

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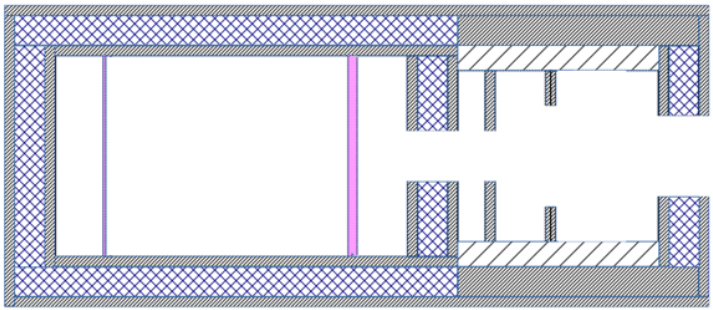
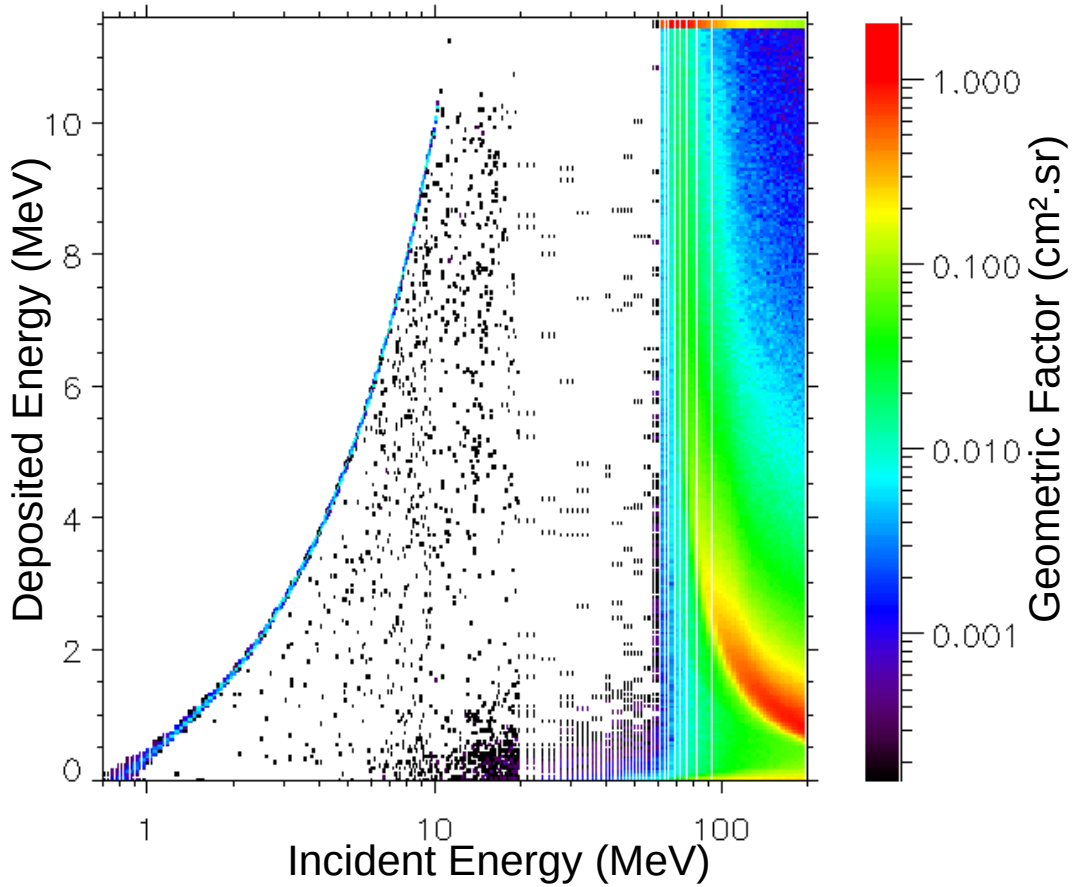


- GEANT4 simulations
- Spherical source
- Particles : 5 millions x 282
- 256 channels :
  0MeV → 11.5MeV

$$\text{Geometric factor} = 4\pi^2 R^2 \frac{N_{detected}}{N_{incident}}$$

protons anti-coincidence mode



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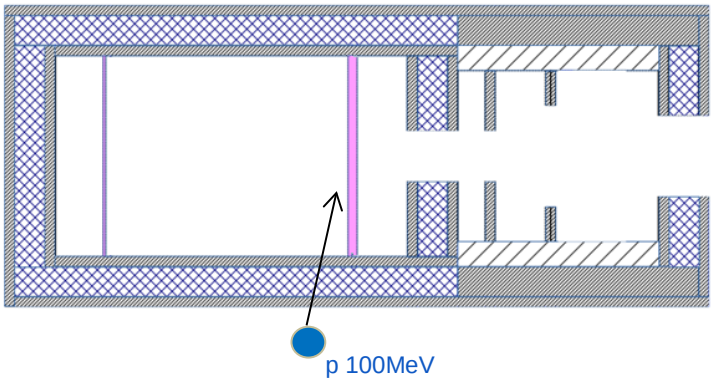

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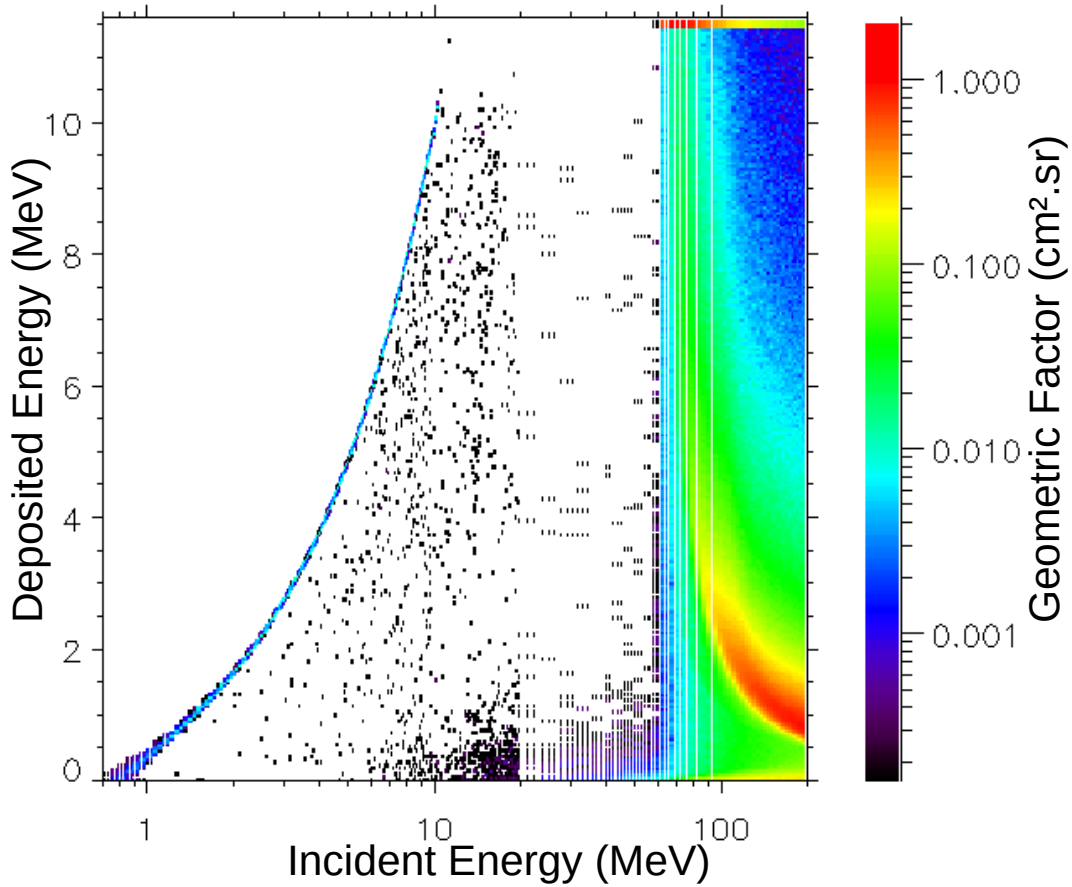

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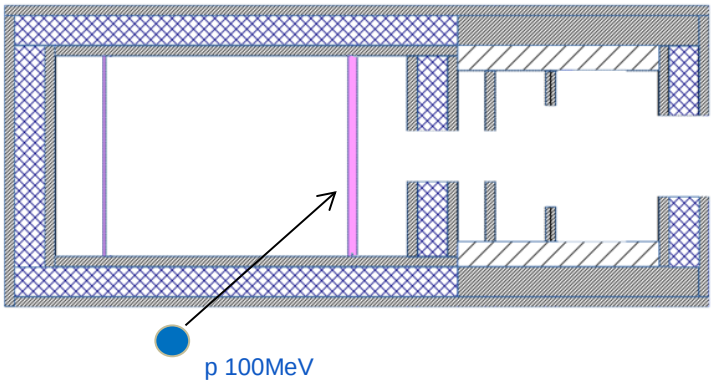

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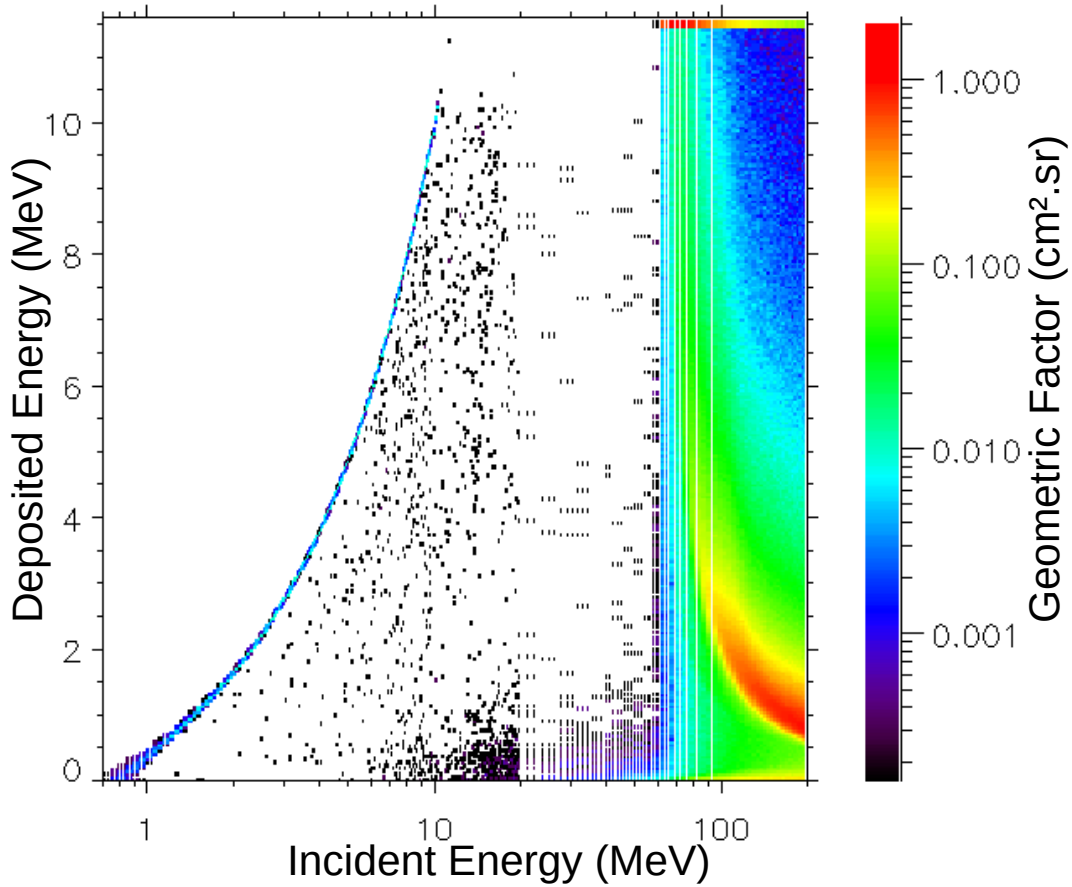

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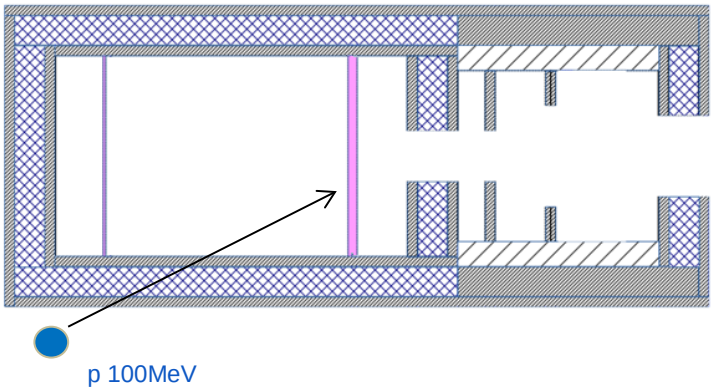

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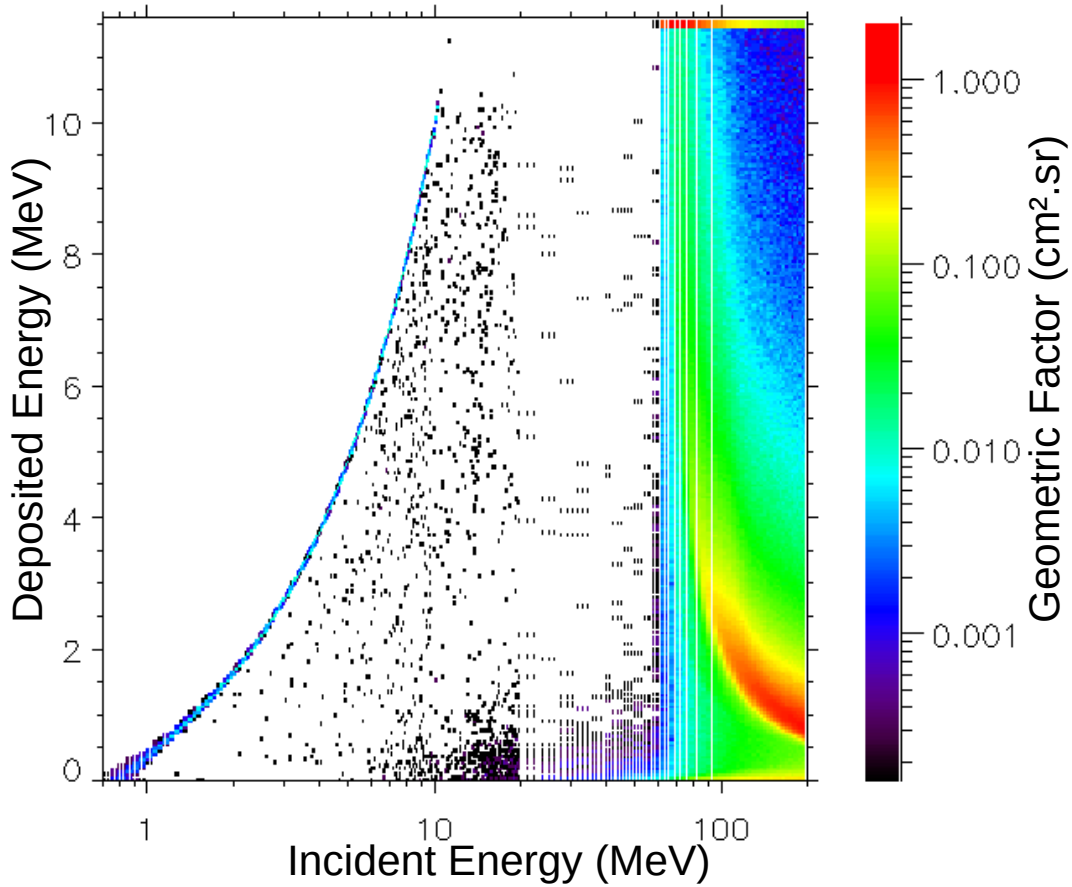

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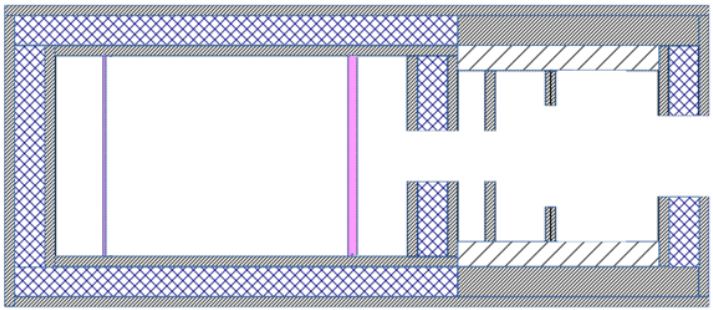

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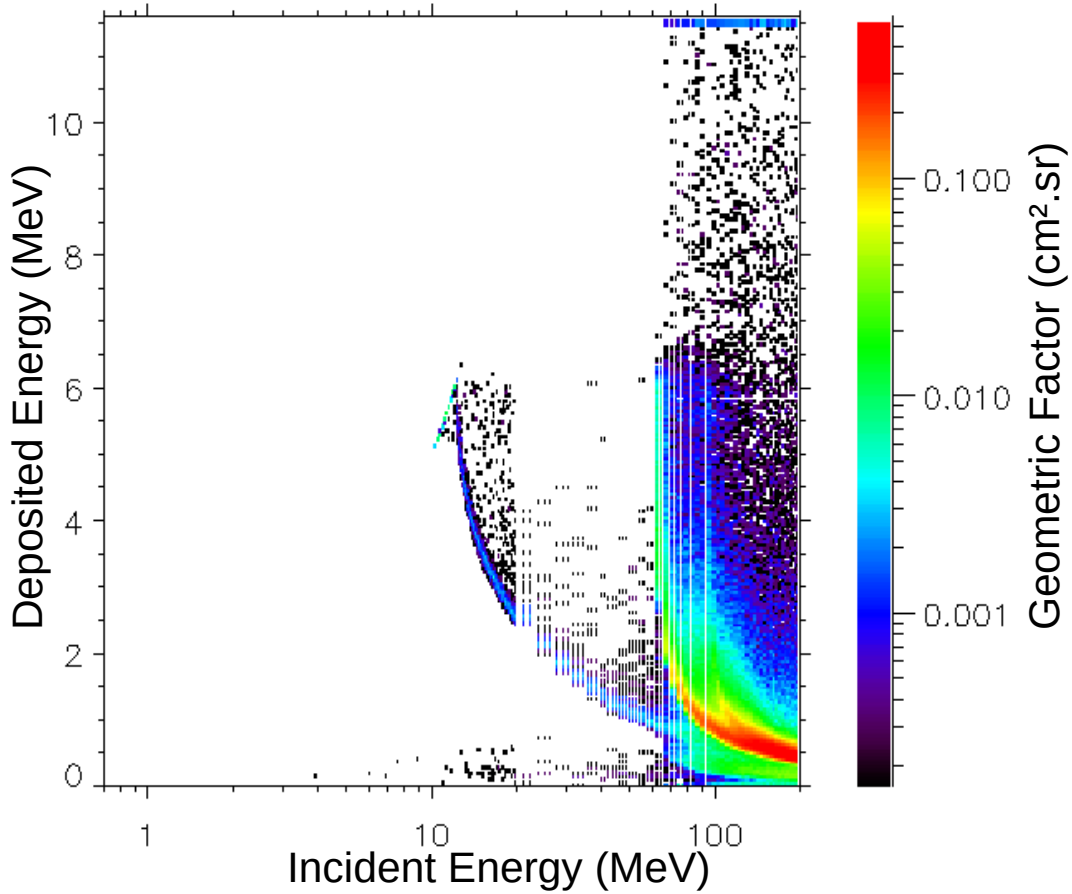
protons coincidence mode



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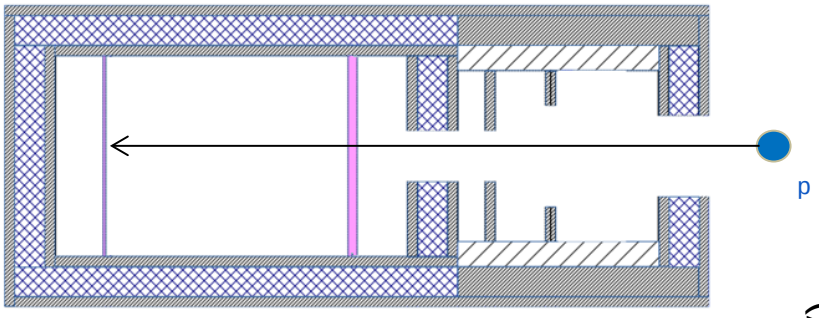

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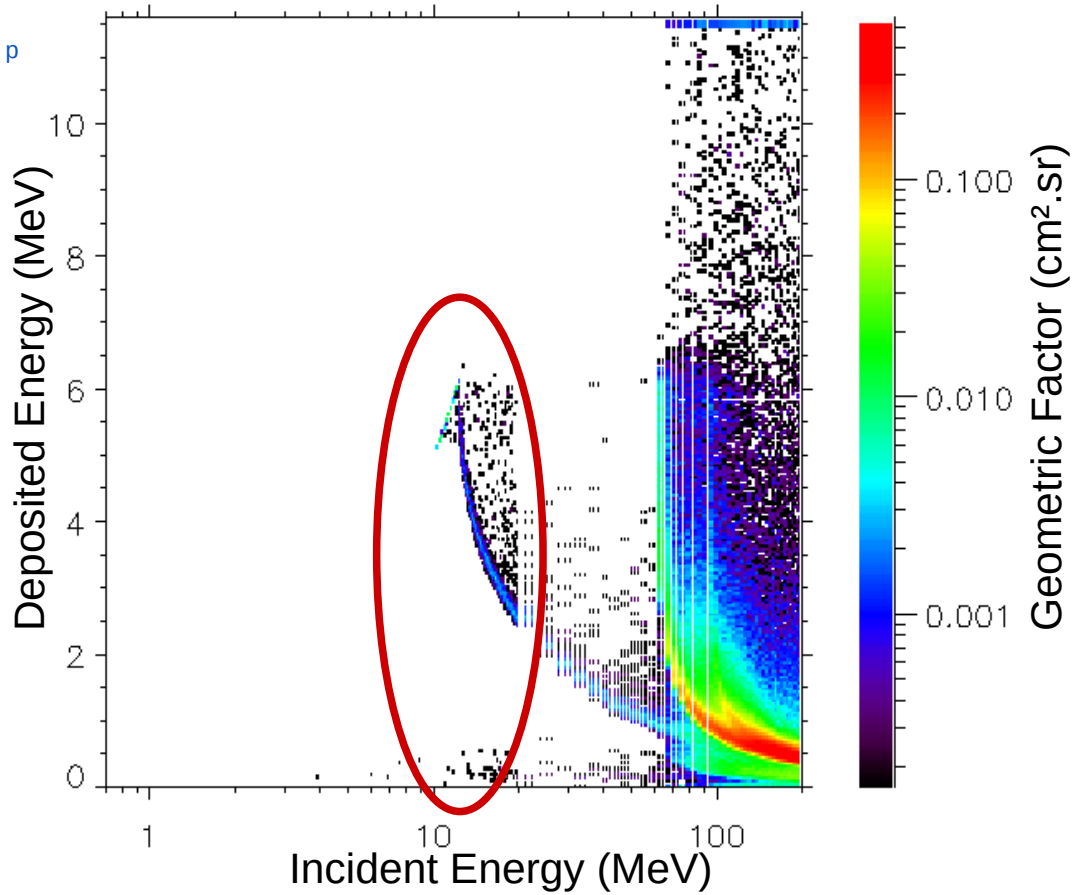

Detection of protons with an energy from 1MeV to 15MeV

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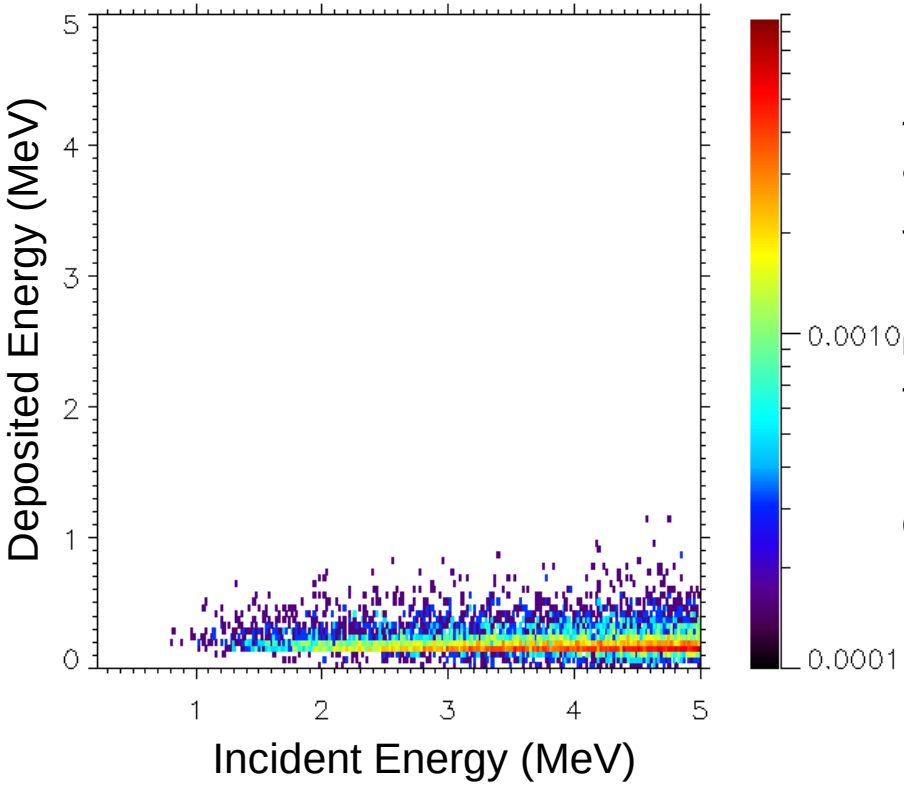
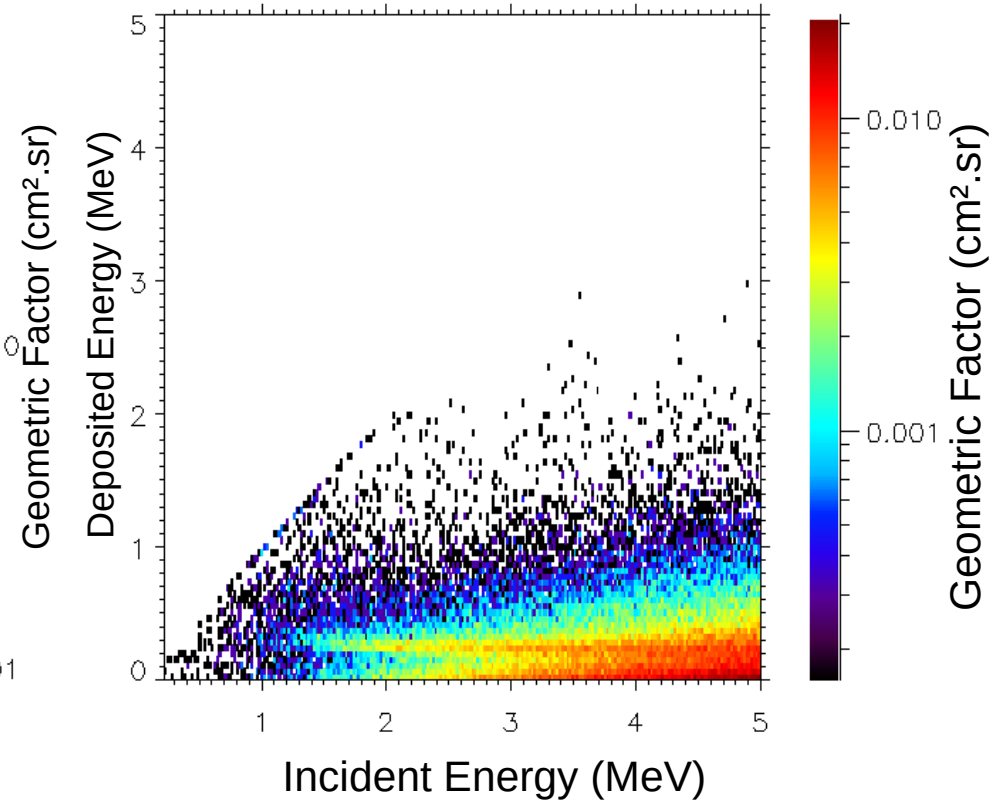
Electrons coincidence mode



Electrons anti-coincidence mode



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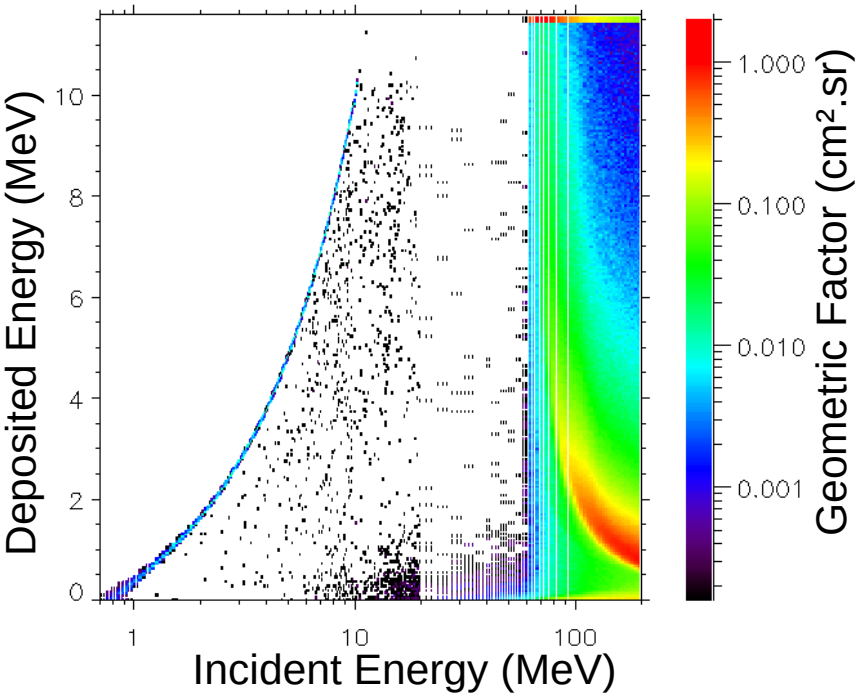

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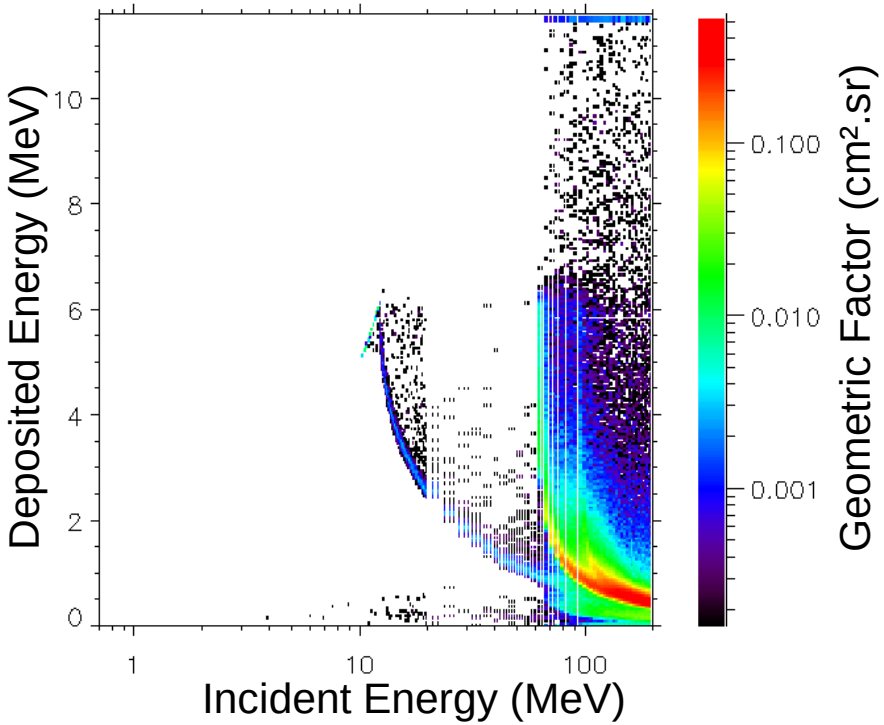
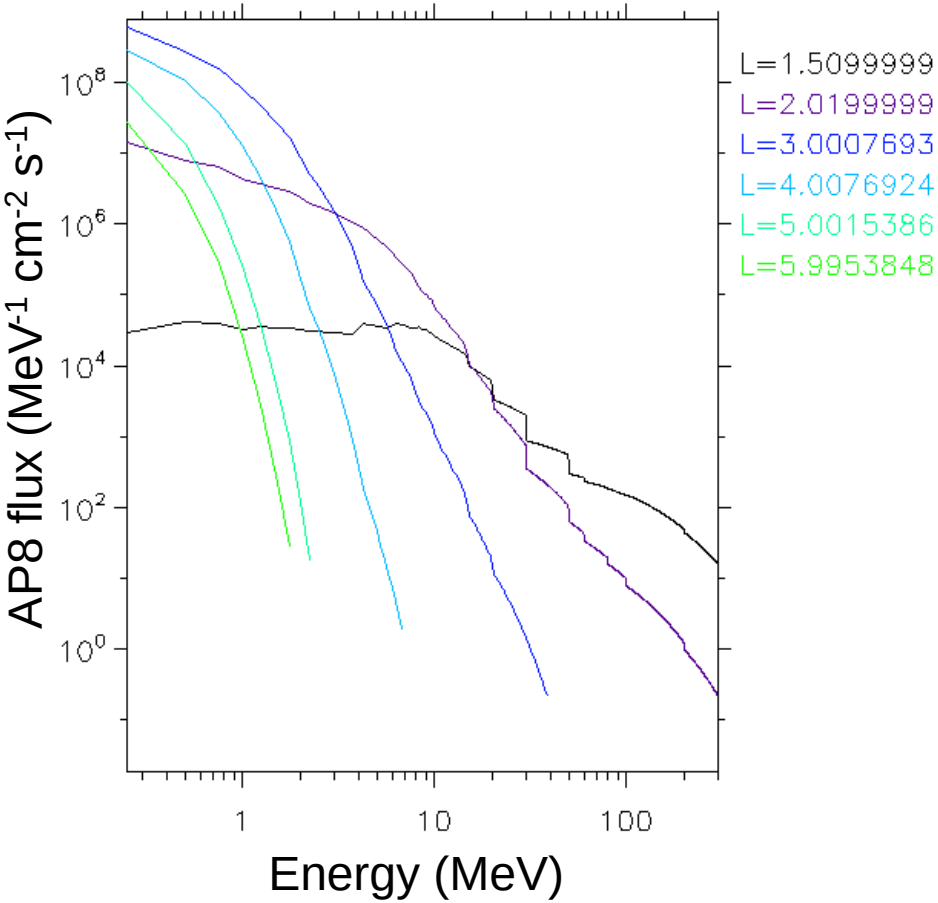


Detection of protons with an energy from 1MeV to 15MeV

- Counts of particles

Proton fluxes AP8



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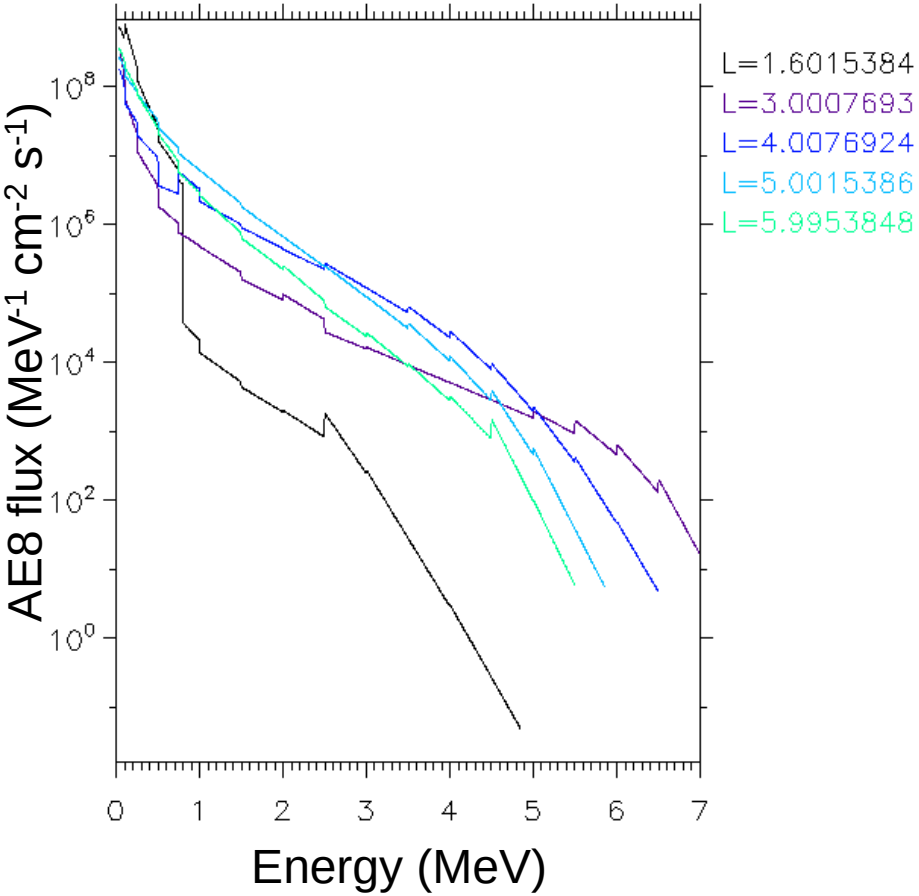

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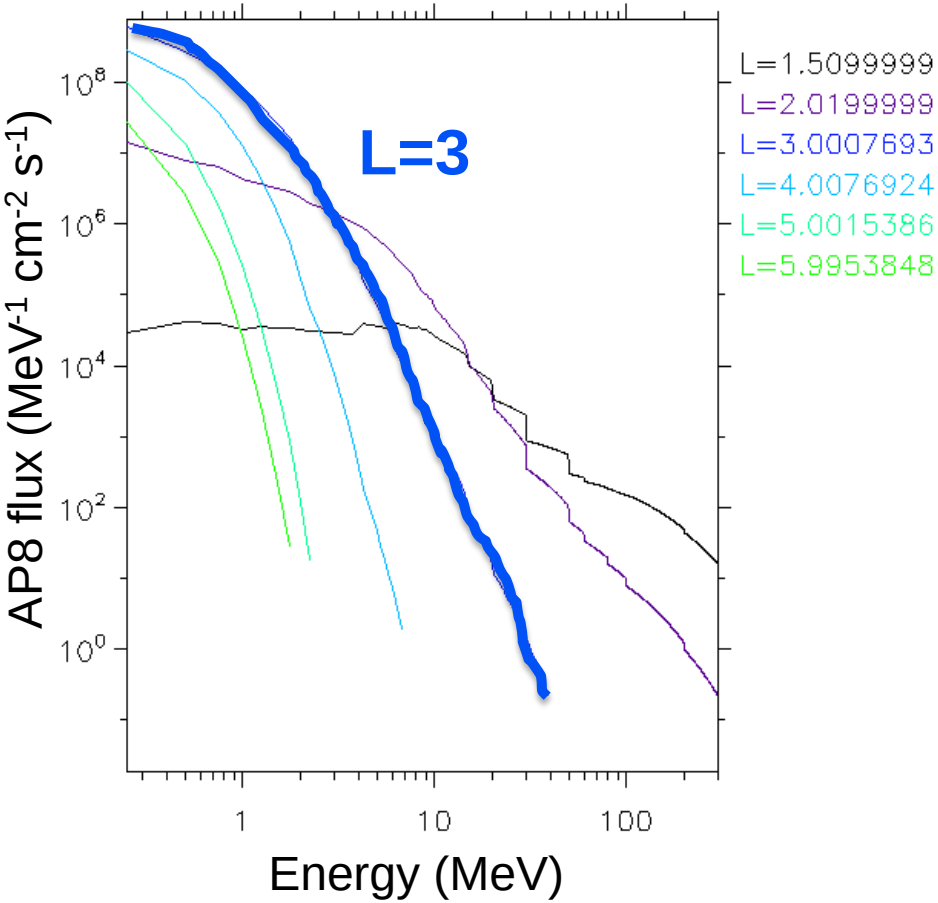

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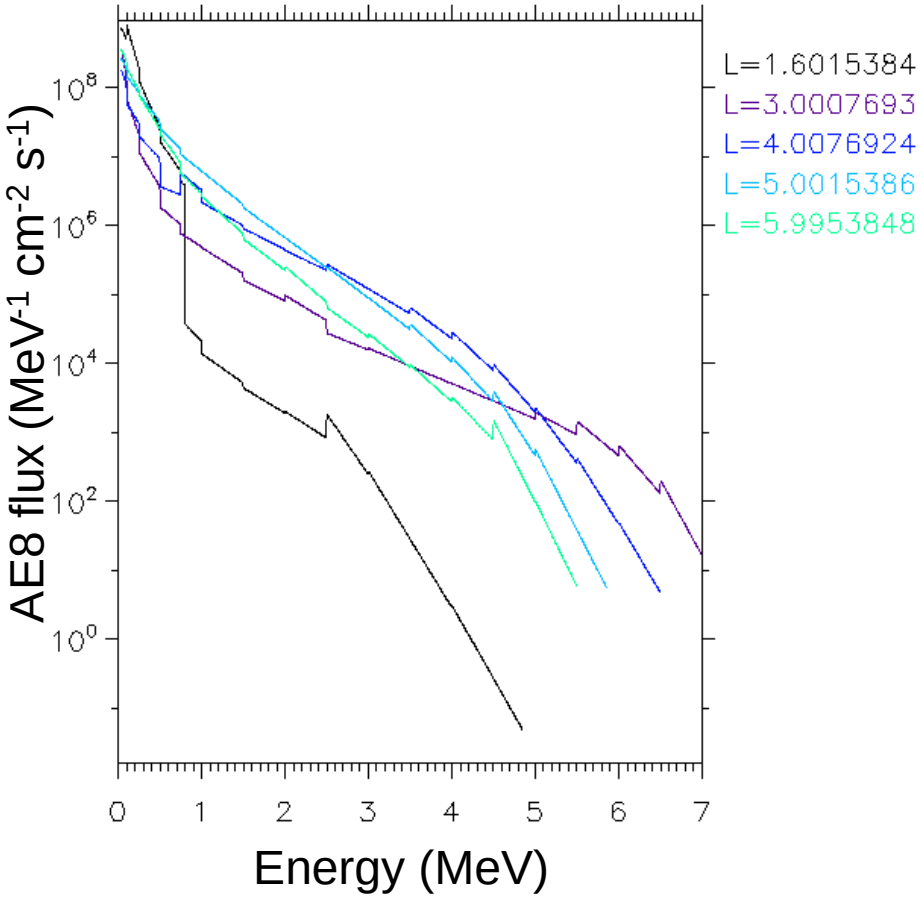

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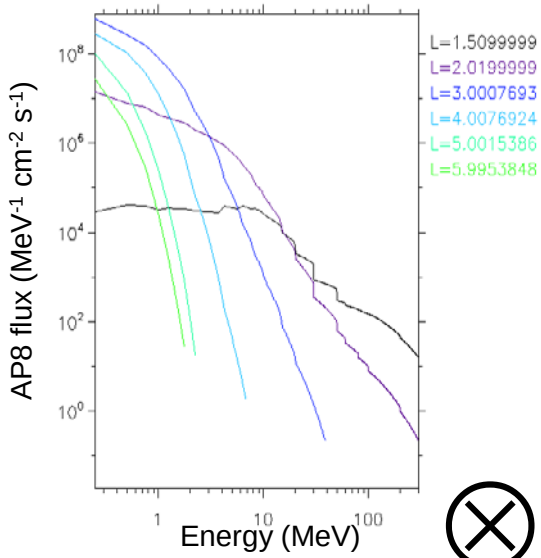

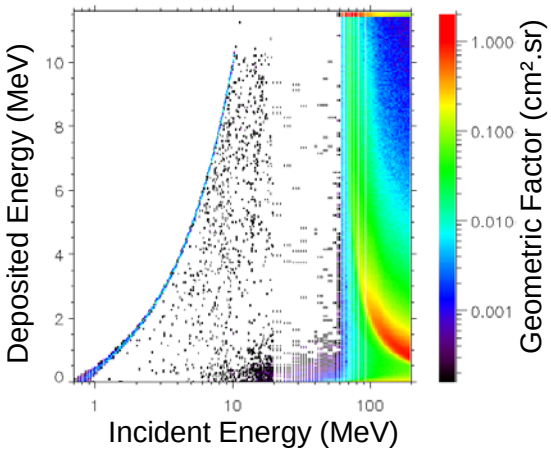

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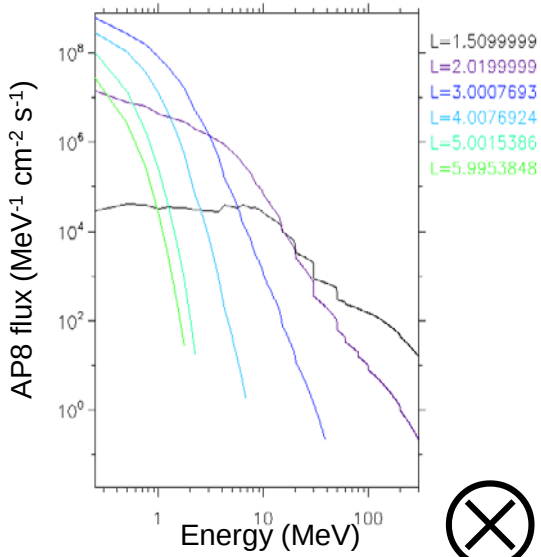
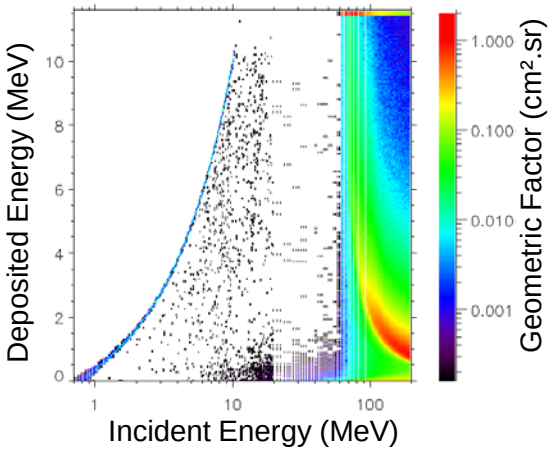
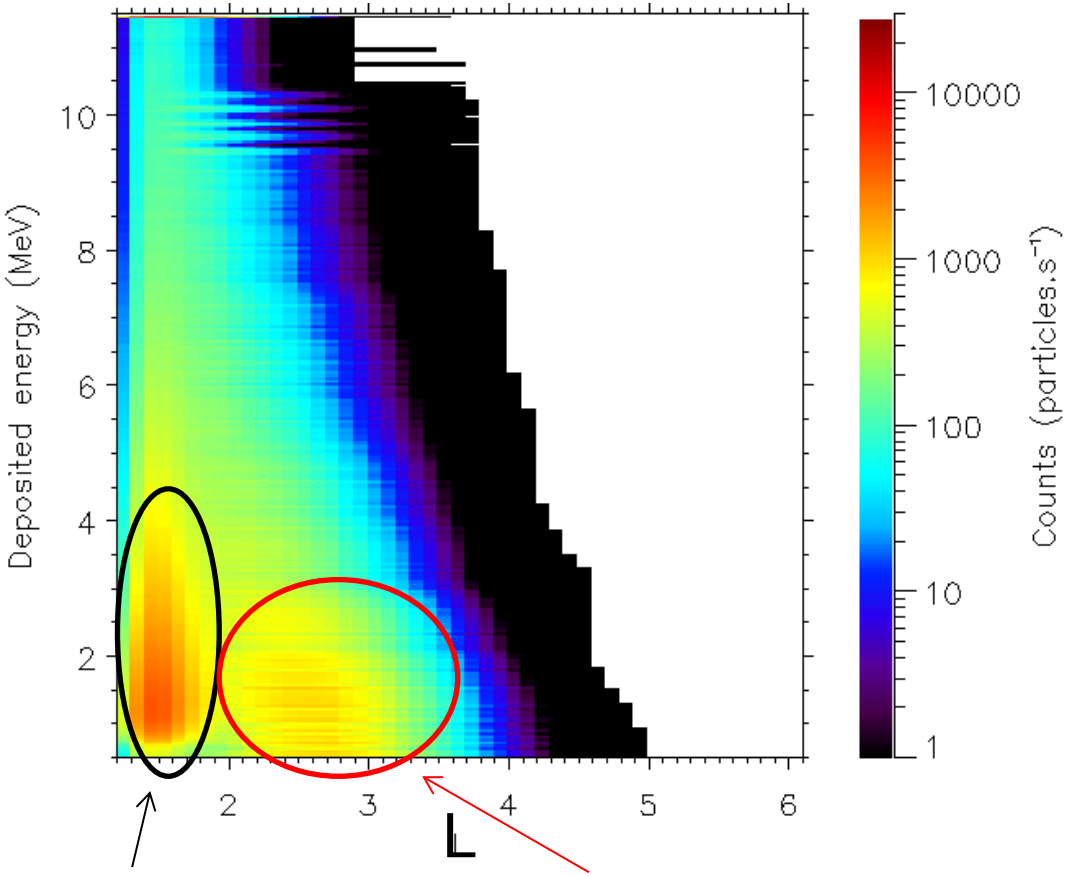




Protons : Anti-coincidence mode



Energetic protons

Protons 1MeV-10MeV

Conclusion

- Detection of protons from 1 MeV to 15MeV

  $2 < L < 4$

- Measurements of some electrons @ $L > 4$

- Design still in progress

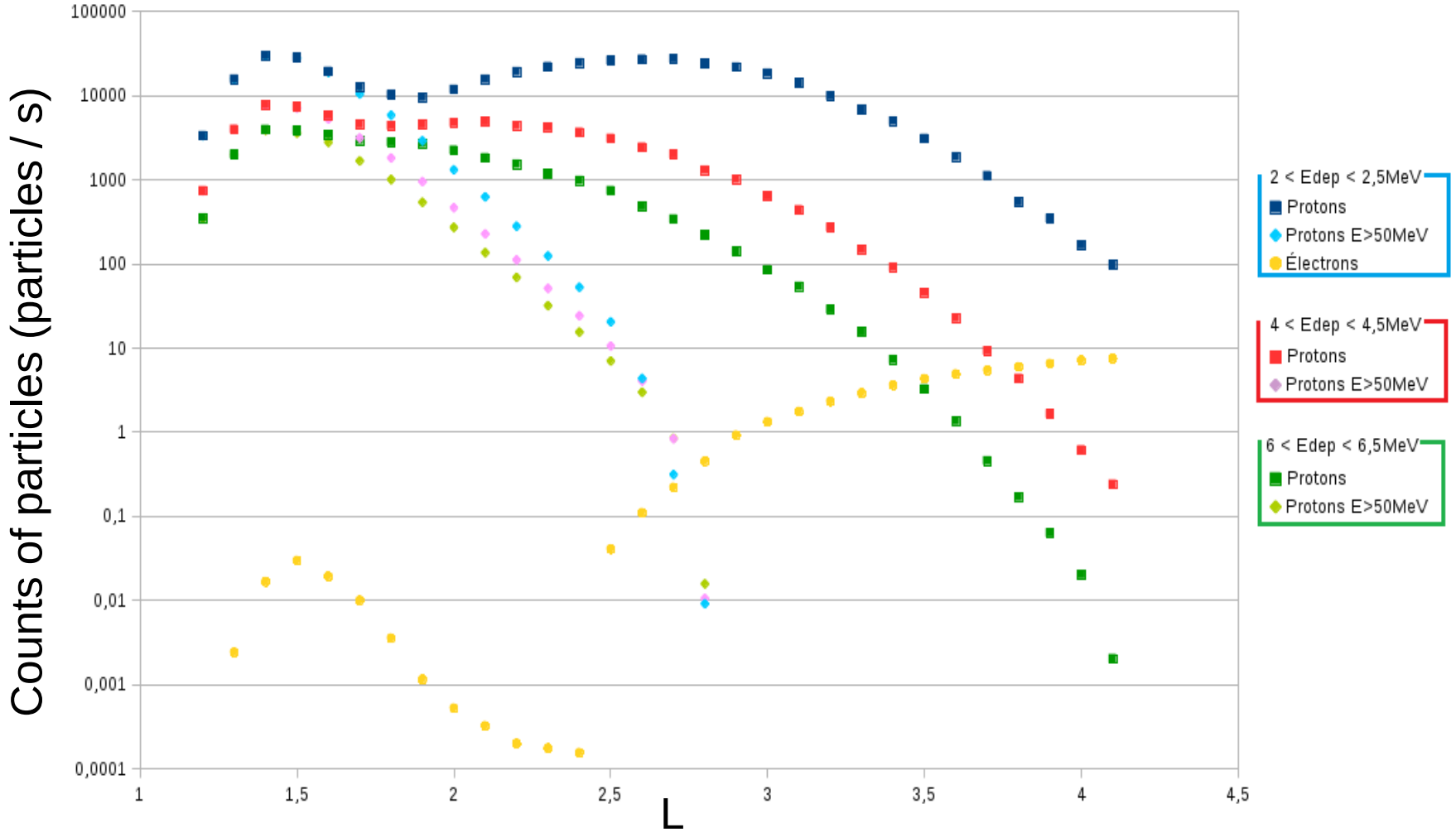
  => Reduction of the background noise (p > 65MeV)

  => Improvement of the magnet geometry : 2 plates

Thank you for your attention !

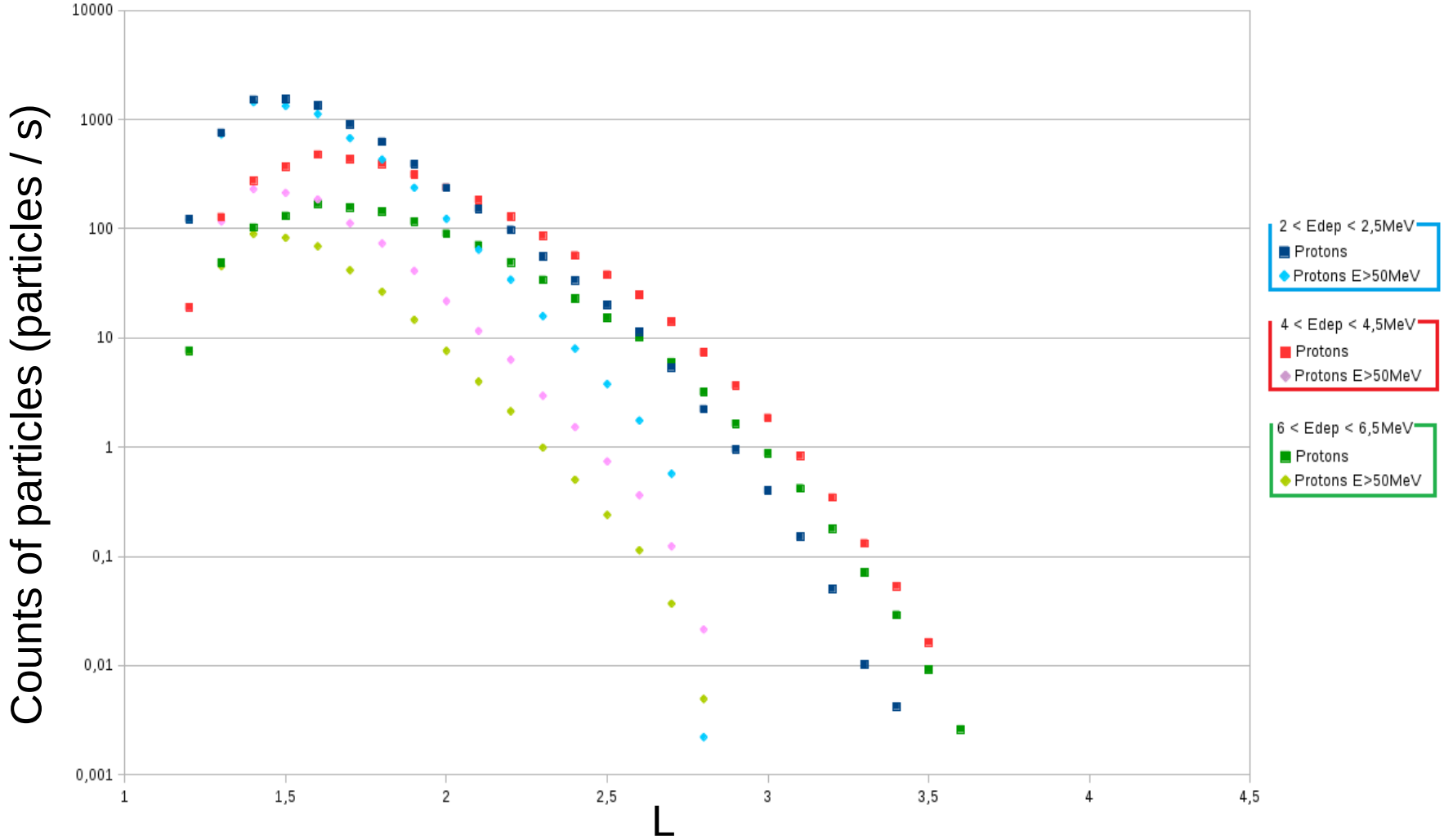
Detection of protons with an energy from 1MeV to 15MeV

- Counts of particles as a function of L : anti-coincidence mode



Detection of protons with an energy from 1MeV to 15MeV

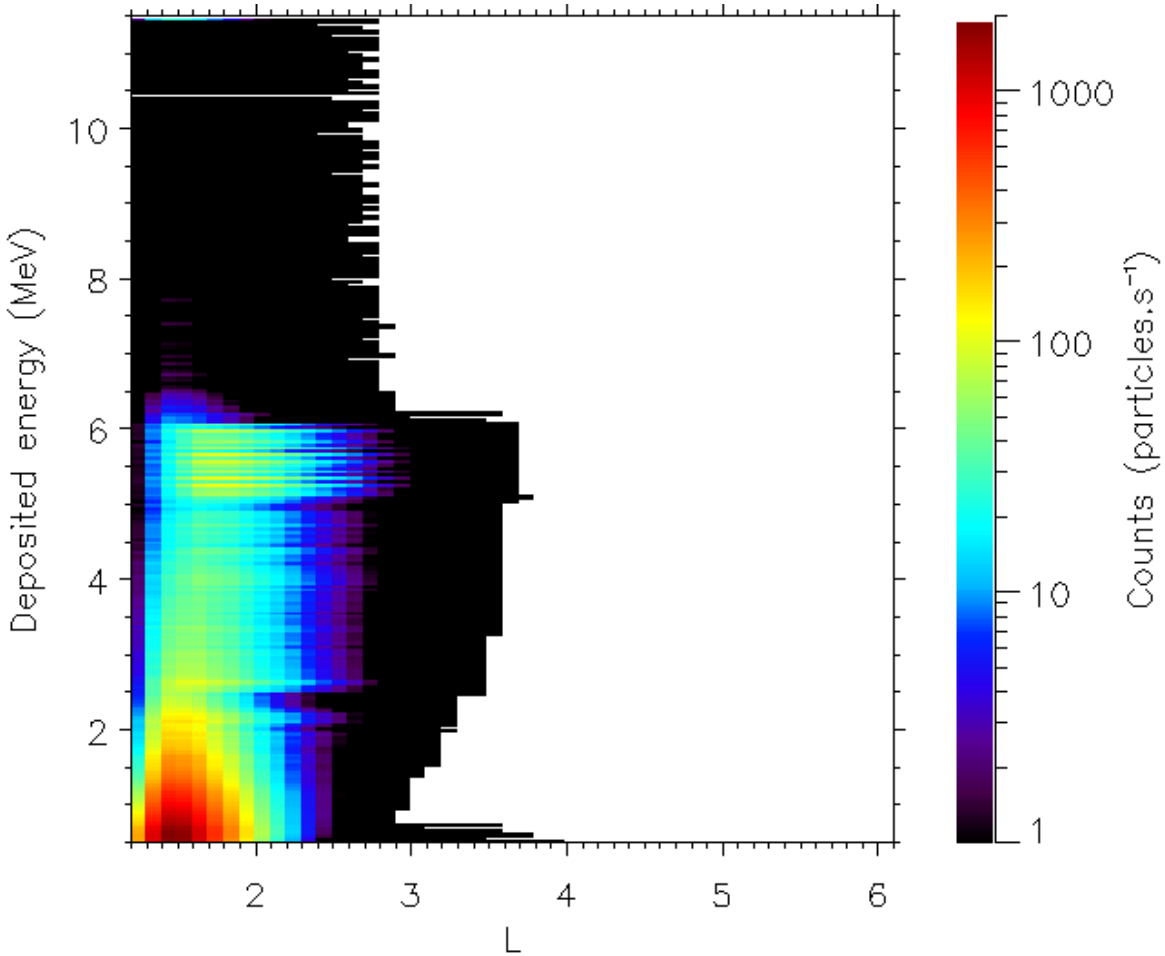
- Counts of particles as a function of L : coincidence mode



Detection of protons with an energy from 1MeV to 15MeV

- Counts of particles

Counts of protons coincidence mode

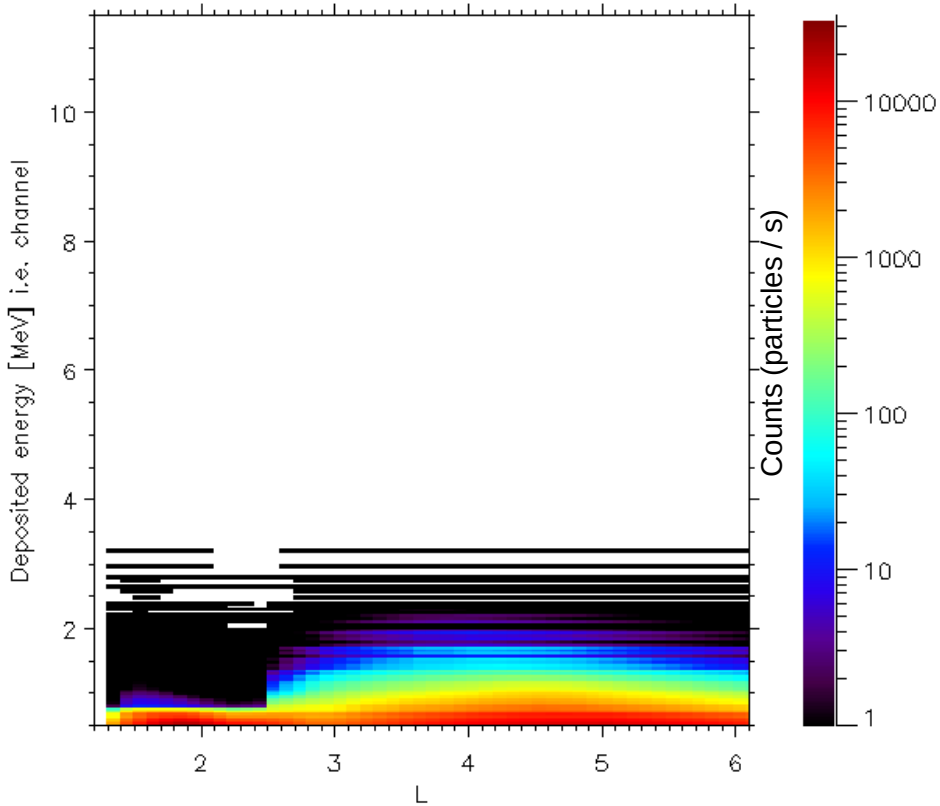


Detection of protons with an energy from 1MeV to 15MeV

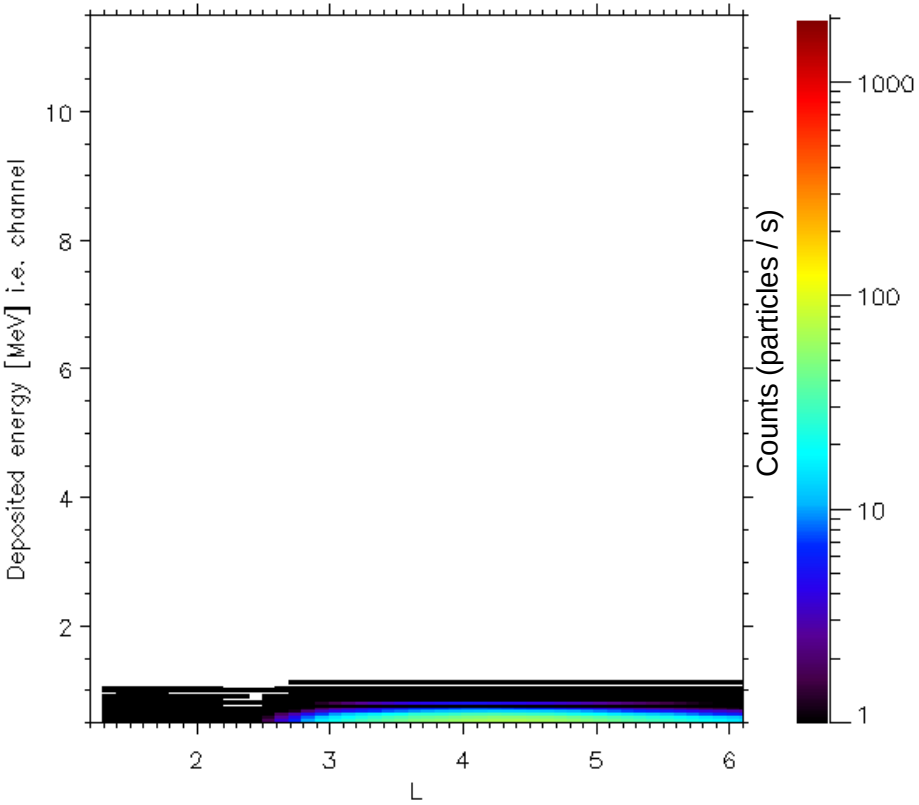
- Counts of particles

Counts of electrons

anti-coincidence



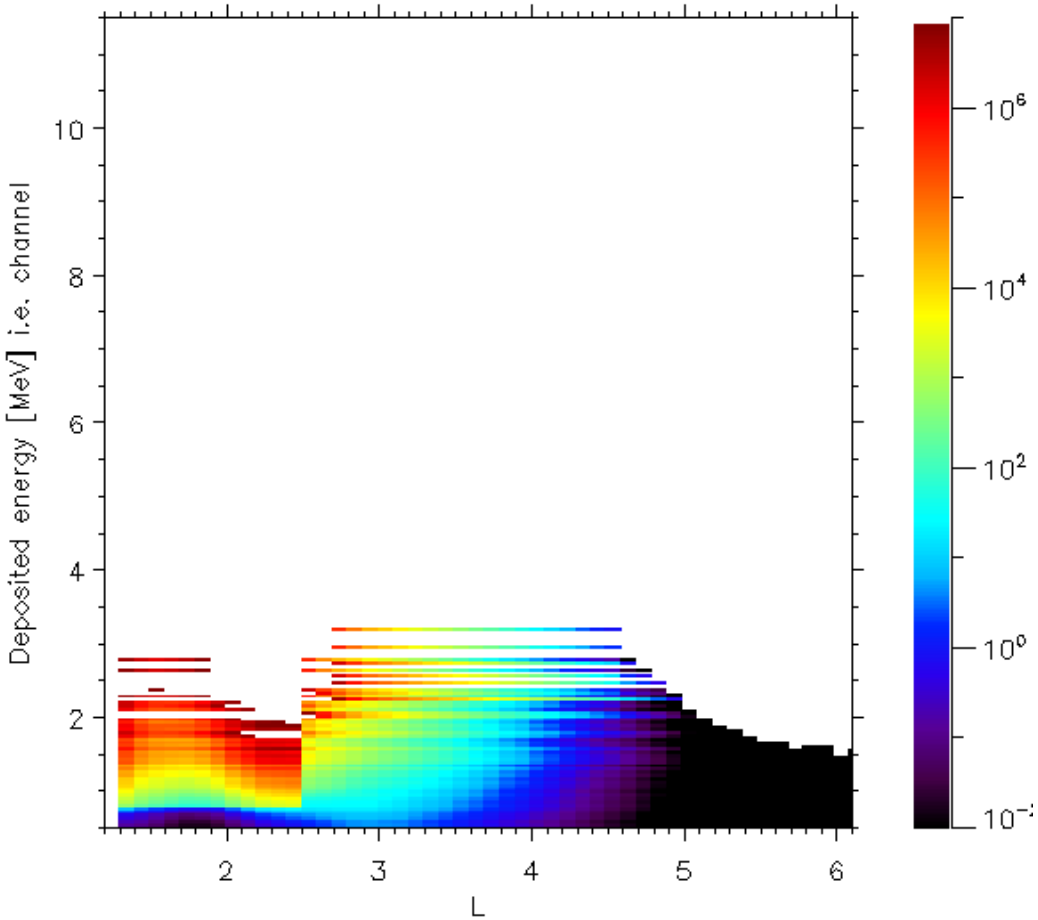
coincidence



Detection of protons with an energy from 1MeV to 15MeV

- Counts of particles

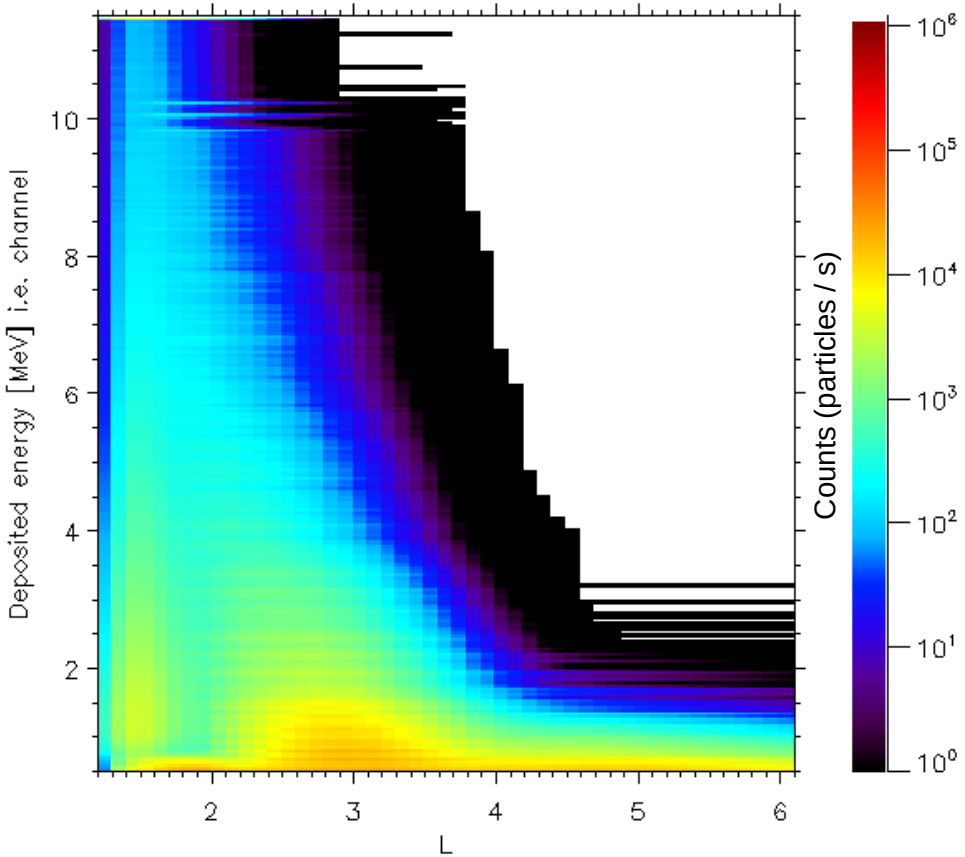
Counts of protons over counts of electrons anti-coincidence mode



Detection of protons with an energy from 1MeV to 15MeV

- Counts of particles

Sum of counts of protons and electrons anti-coincidence mode

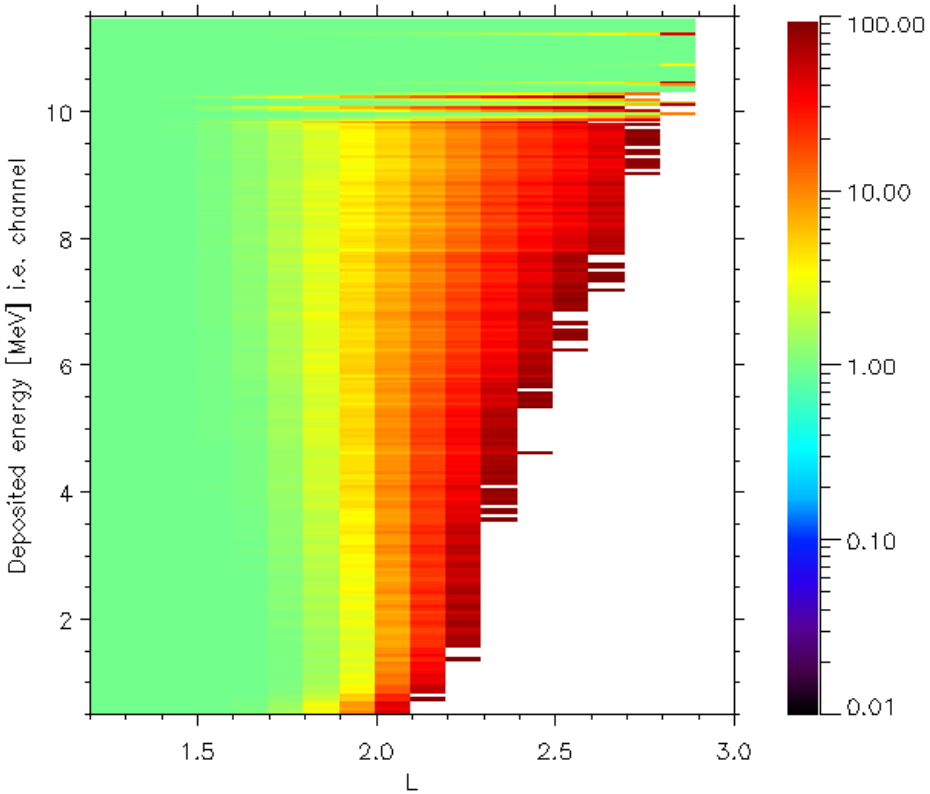


Detection of protons with an energy from 1MeV to 15MeV

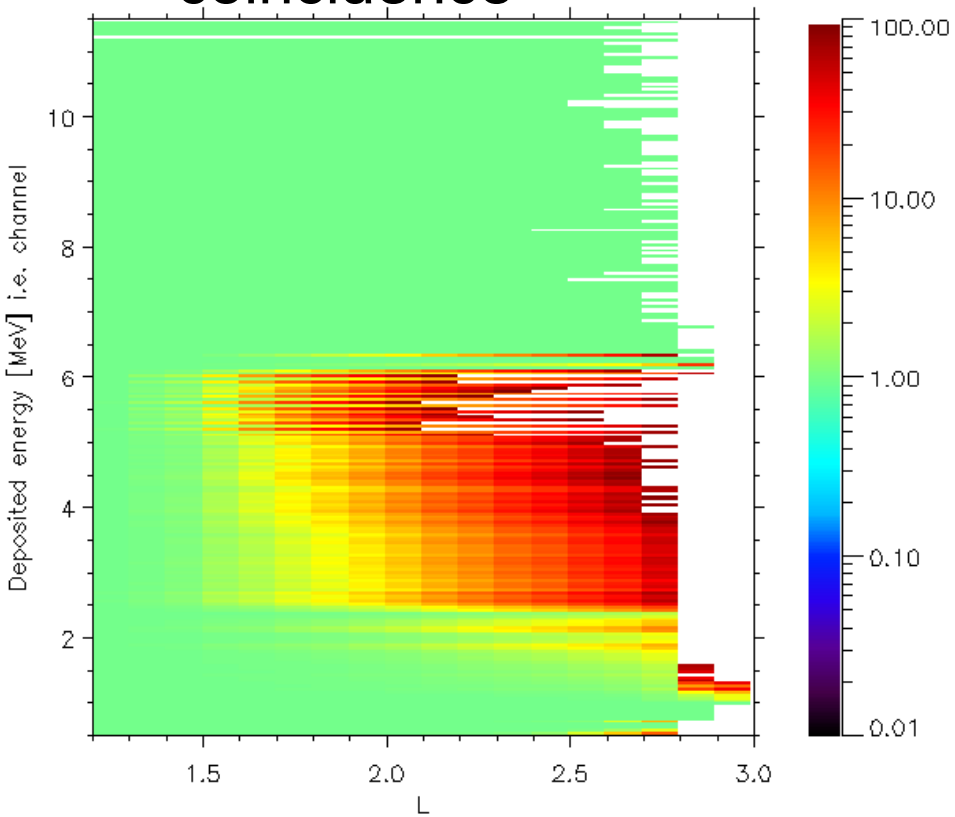
- Counts of particles

Counts of protons over protons with an energy > 50MeV

anti-coincidence



coincidence



Back-Up : Incident Energies of protons (MeV)

0,70	2,20	3,70	5,20	6,70	8,20	9,70	14,80	36,00	156,00
0,75	2,25	3,75	5,25	6,75	8,25	9,75	15,00	40,00	160,00
0,80	2,30	3,80	5,30	6,80	8,30	9,80	15,20	44,00	164,00
0,85	2,35	3,85	5,35	6,85	8,35	9,85	15,40	48,00	168,00
0,90	2,40	3,90	5,40	6,90	8,40	9,90	15,60	52,00	172,00
0,95	2,45	3,95	5,45	6,95	8,45	9,95	15,80	56,00	176,00
1,00	2,50	4,00	5,50	7,00	8,50	10,00	16,00	60,00	180,00
1,05	2,55	4,05	5,55	7,05	8,55	10,20	16,20	64,00	184,00
1,10	2,60	4,10	5,60	7,10	8,60	10,40	16,40	68,00	188,00
1,15	2,65	4,15	5,65	7,15	8,65	10,60	16,60	72,00	192,00
1,20	2,70	4,20	5,70	7,20	8,70	10,80	16,80	76,00	196,00
1,25	2,75	4,25	5,75	7,25	8,75	11,00	17,00	80,00	200,00
1,30	2,80	4,30	5,80	7,30	8,80	11,20	17,20	84,00	
1,35	2,85	4,35	5,85	7,35	8,85	11,40	17,40	88,00	
1,40	2,90	4,40	5,90	7,40	8,90	11,60	17,60	92,00	
1,45	2,95	4,45	5,95	7,45	8,95	11,80	17,80	96,00	
1,50	3,00	4,50	6,00	7,50	9,00	12,00	18,00	100,00	
1,55	3,05	4,55	6,05	7,55	9,05	12,20	18,20	104,00	
1,60	3,10	4,60	6,10	7,60	9,10	12,40	18,40	108,00	
1,65	3,15	4,65	6,15	7,65	9,15	12,60	18,60	112,00	
1,70	3,20	4,70	6,20	7,70	9,20	12,80	18,80	116,00	
1,75	3,25	4,75	6,25	7,75	9,25	13,00	19,00	120,00	
1,80	3,30	4,80	6,30	7,80	9,30	13,20	19,20	124,00	
1,85	3,35	4,85	6,35	7,85	9,35	13,40	19,40	128,00	
1,90	3,40	4,90	6,40	7,90	9,40	13,60	19,60	132,00	
1,95	3,45	4,95	6,45	7,95	9,45	13,80	19,80	136,00	
2,00	3,50	5,00	6,50	8,00	9,50	14,00	20,00	140,00	
2,05	3,55	5,05	6,55	8,05	9,55	14,20	24,00	144,00	
2,10	3,60	5,10	6,60	8,10	9,60	14,40	28,00	148,00	
2,15	3,65	5,15	6,65	8,15	9,65	14,60	32,00	152,00	

Back-Up : Incident Energies of electrons (keV)

40.0000	60.0000	80.0000	100.000	120.000	140.000	160.000	180.000	200.000
340.000	360.000	380.000	400.000	420.000	440.000	460.000	480.000	500.000
640.000	660.000	680.000	700.000	720.000	740.000	760.000	780.000	800.000
940.000	960.000	980.000	1000.00	1020.00	1040.00	1060.00	1080.00	1100.00
1240.00	1260.00	1280.00	1300.00	1320.00	1340.00	1360.00	1380.00	1400.00
1540.00	1560.00	1580.00	1600.00	1620.00	1640.00	1660.00	1680.00	1700.00
1840.00	1860.00	1880.00	1900.00	1920.00	1940.00	1960.00	1980.00	2000.00
2140.00	2160.00	2180.00	2200.00	2220.00	2240.00	2260.00	2280.00	2300.00
2440.00	2460.00	2480.00	2500.00	2520.00	2540.00	2560.00	2580.00	2600.00
2740.00	2760.00	2780.00	2800.00	2820.00	2840.00	2860.00	2880.00	2900.00
3040.00	3060.00	3080.00	3100.00	3120.00	3140.00	3160.00	3180.00	3200.00
3340.00	3360.00	3380.00	3400.00	3420.00	3440.00	3460.00	3480.00	3500.00
3640.00	3660.00	3680.00	3700.00	3720.00	3740.00	3760.00	3780.00	3800.00
3940.00	3960.00	3980.00	4000.00	4020.00	4040.00	4060.00	4080.00	4100.00
4240.00	4260.00	4280.00	4300.00	4320.00	4340.00	4360.00	4380.00	4400.00
4540.00	4560.00	4580.00	4600.00	4620.00	4640.00	4660.00	4680.00	4700.00
4840.00	4860.00	4880.00	4900.00	4920.00	4940.00	4960.00	4980.00	5000.00

220.000	240.000	260.000	280.000	300.000	320.000
520.000	540.000	560.000	580.000	600.000	620.000
820.000	840.000	860.000	880.000	900.000	920.000
1120.00	1140.00	1160.00	1180.00	1200.00	1220.00
1420.00	1440.00	1460.00	1480.00	1500.00	1520.00
1720.00	1740.00	1760.00	1780.00	1800.00	1820.00
2020.00	2040.00	2060.00	2080.00	2100.00	2120.00
2320.00	2340.00	2360.00	2380.00	2400.00	2420.00
2620.00	2640.00	2660.00	2680.00	2700.00	2720.00
2920.00	2940.00	2960.00	2980.00	3000.00	3020.00
3220.00	3240.00	3260.00	3280.00	3300.00	3320.00
3520.00	3540.00	3560.00	3580.00	3600.00	3620.00
3820.00	3840.00	3860.00	3880.00	3900.00	3920.00
4120.00	4140.00	4160.00	4180.00	4200.00	4220.00
4420.00	4440.00	4460.00	4480.00	4500.00	4520.00
4720.00	4740.00	4760.00	4780.00	4800.00	4820.00

Step : 20keV