Coulomb Excitation of Light Mercury Isotopes

The study of shape-coexistence near the Z=82 shell closure

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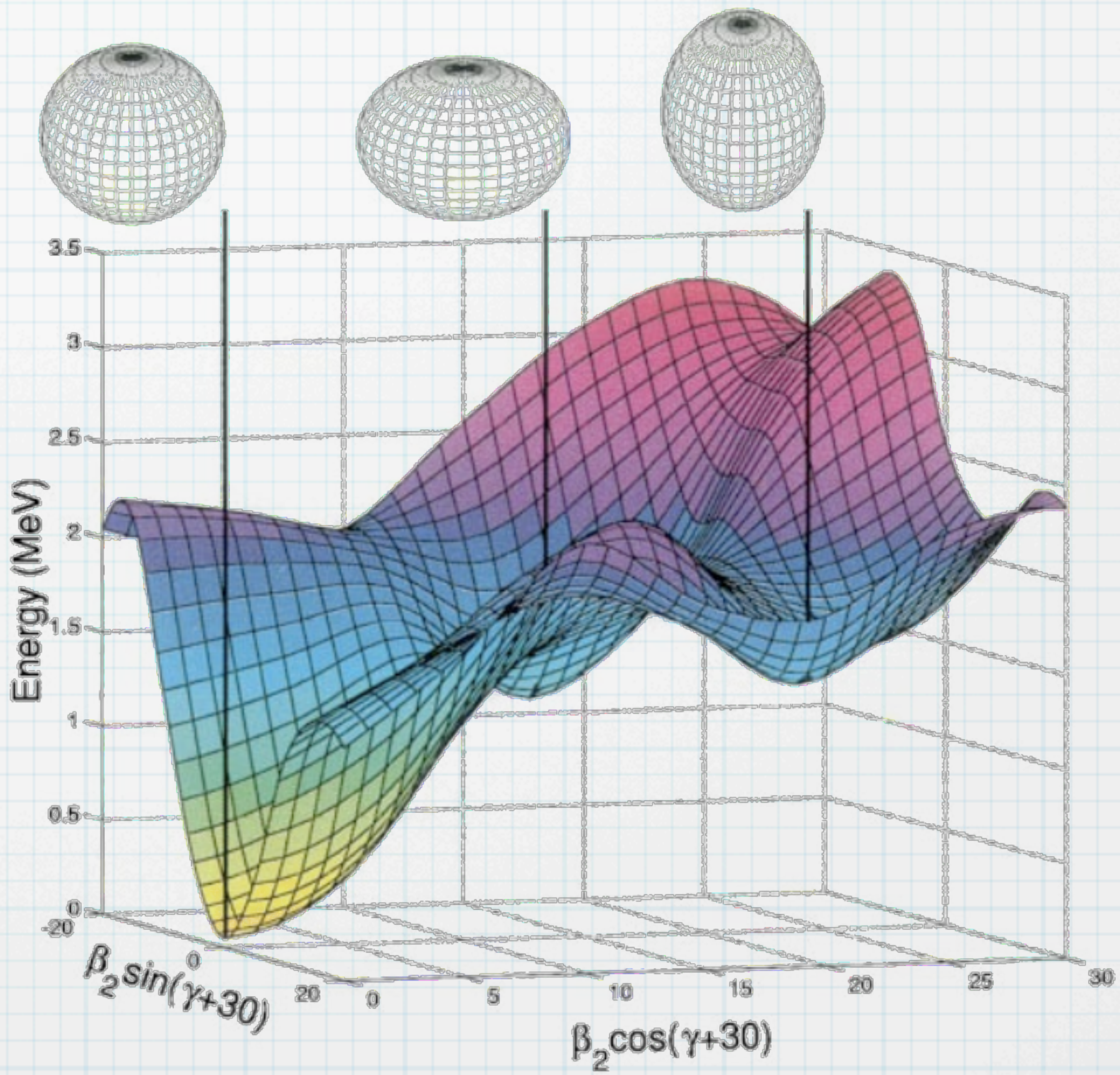
Introduction

* Shape coexistence discovered over 30 years ago
* 0+ states: heads of differently shaped intrinsic structures
* ^{186}Pb: triplet of 0+ states
* Particle hole configurations

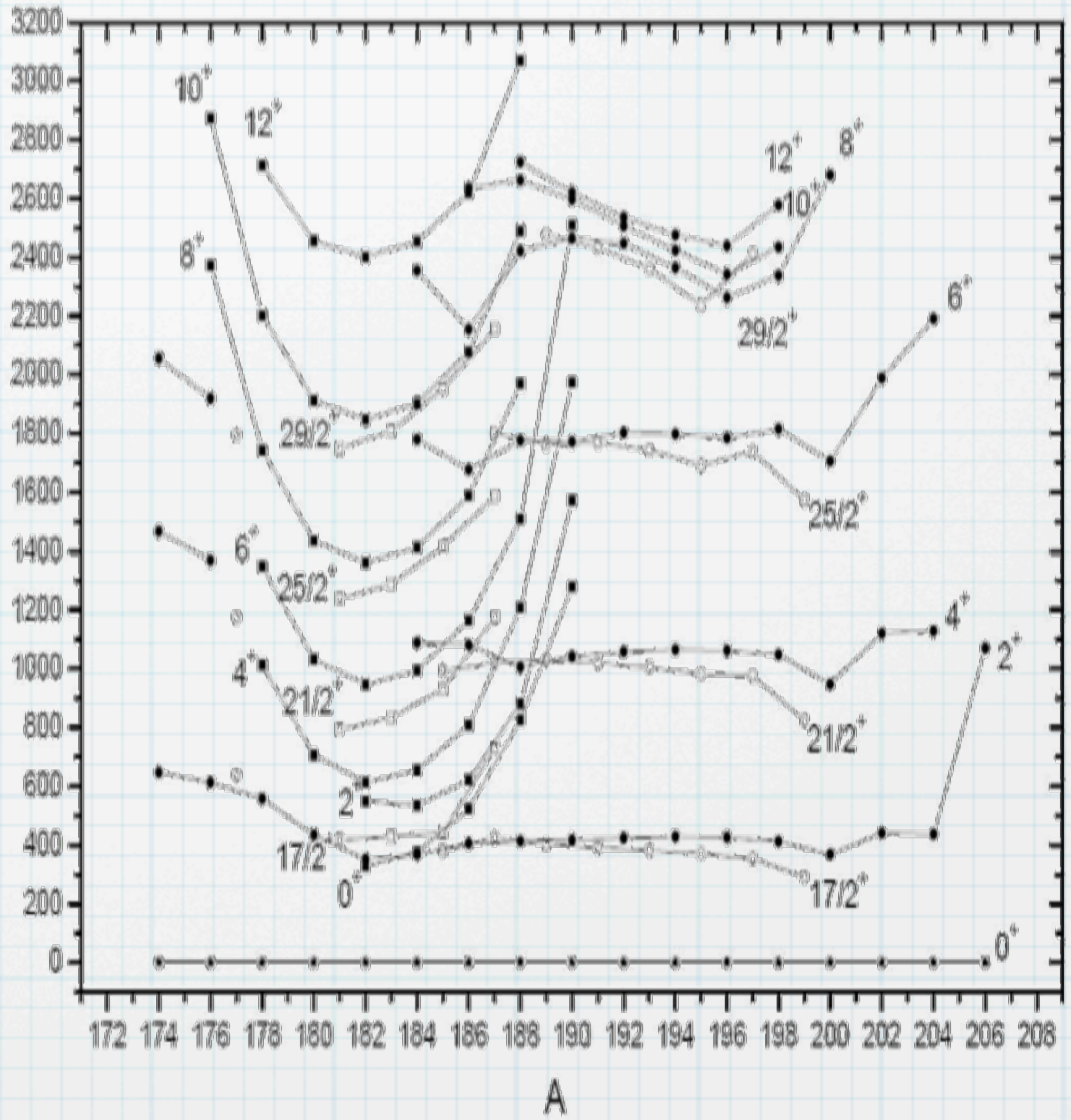
Spherical	Prolate	Oblate
0p-0h	2p-2h	4p-4h



A. N. Andreyev, Nature **405** (2000) Pg 430-433

Introduction • Mercury

- Protons excited across Z=82 shell gap driving deformation
- Ground state predicted slightly oblate, excited band prolate
- Model-independent determination of quadrupole moment, Q_0, required
- Sign of diagonal matrix-elements obtained from Coulomb Excitation



S. Frauendorf and V.V. Pashkevich Phys. Lett. 55B 4 (1974)

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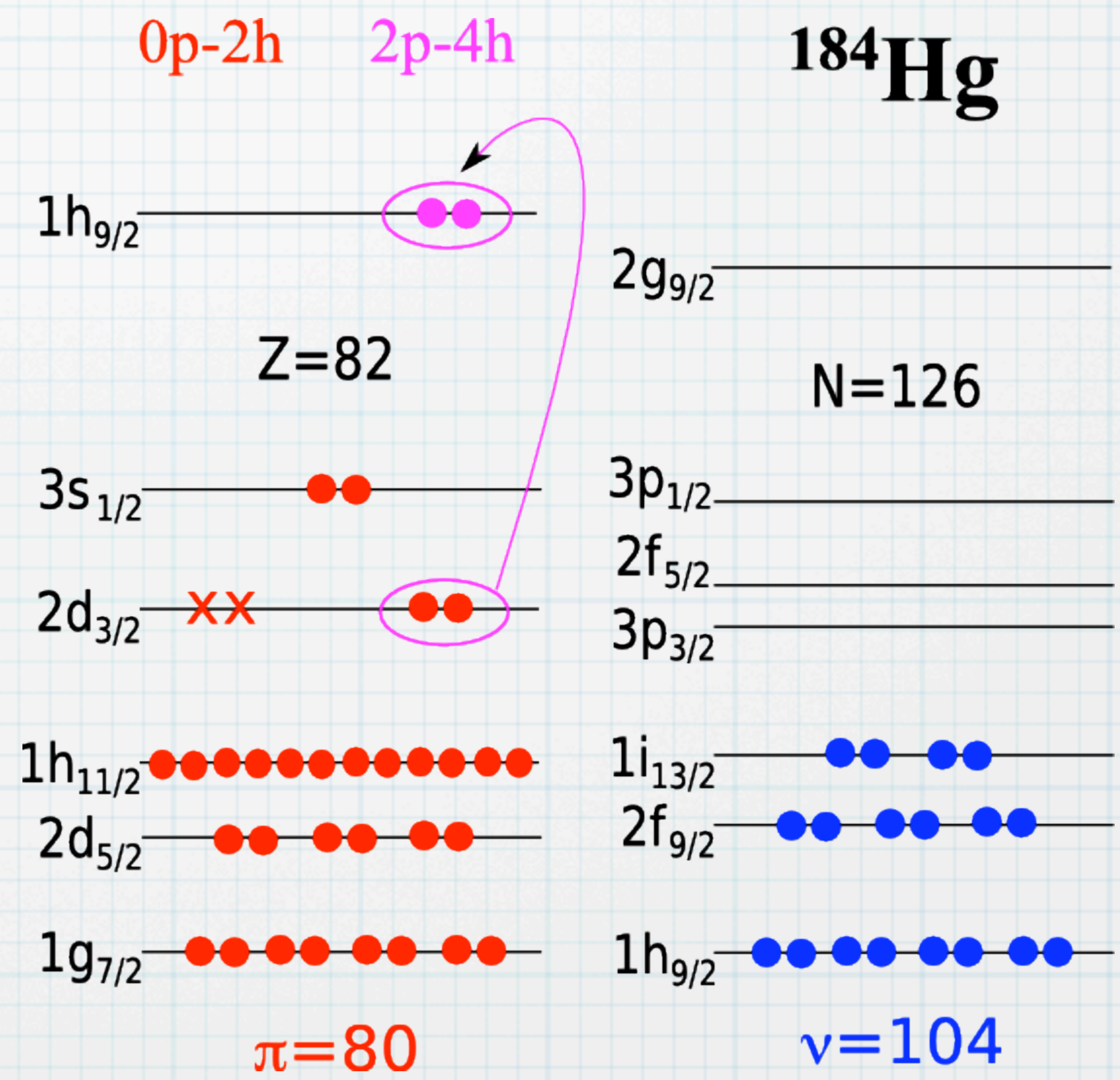

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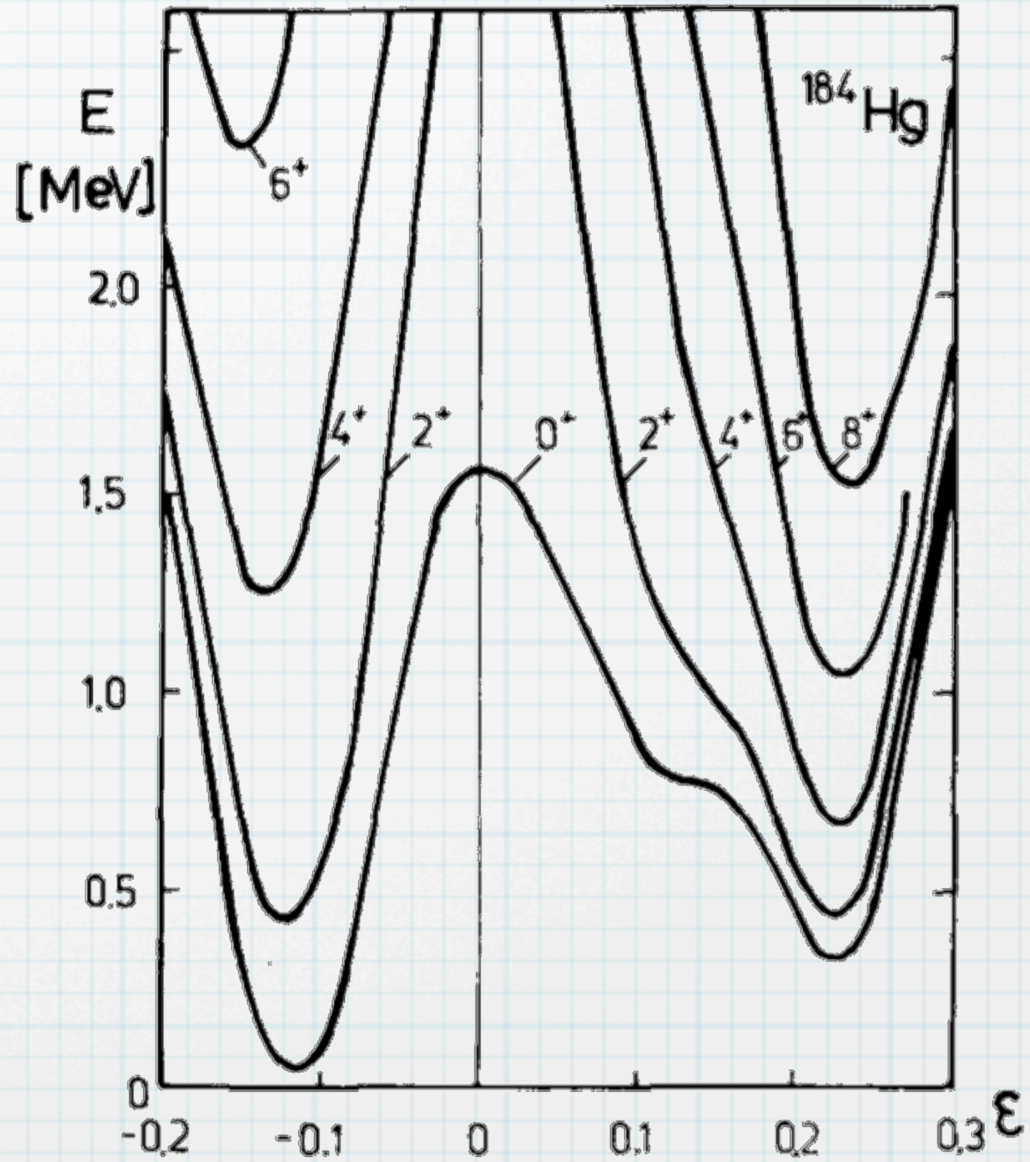

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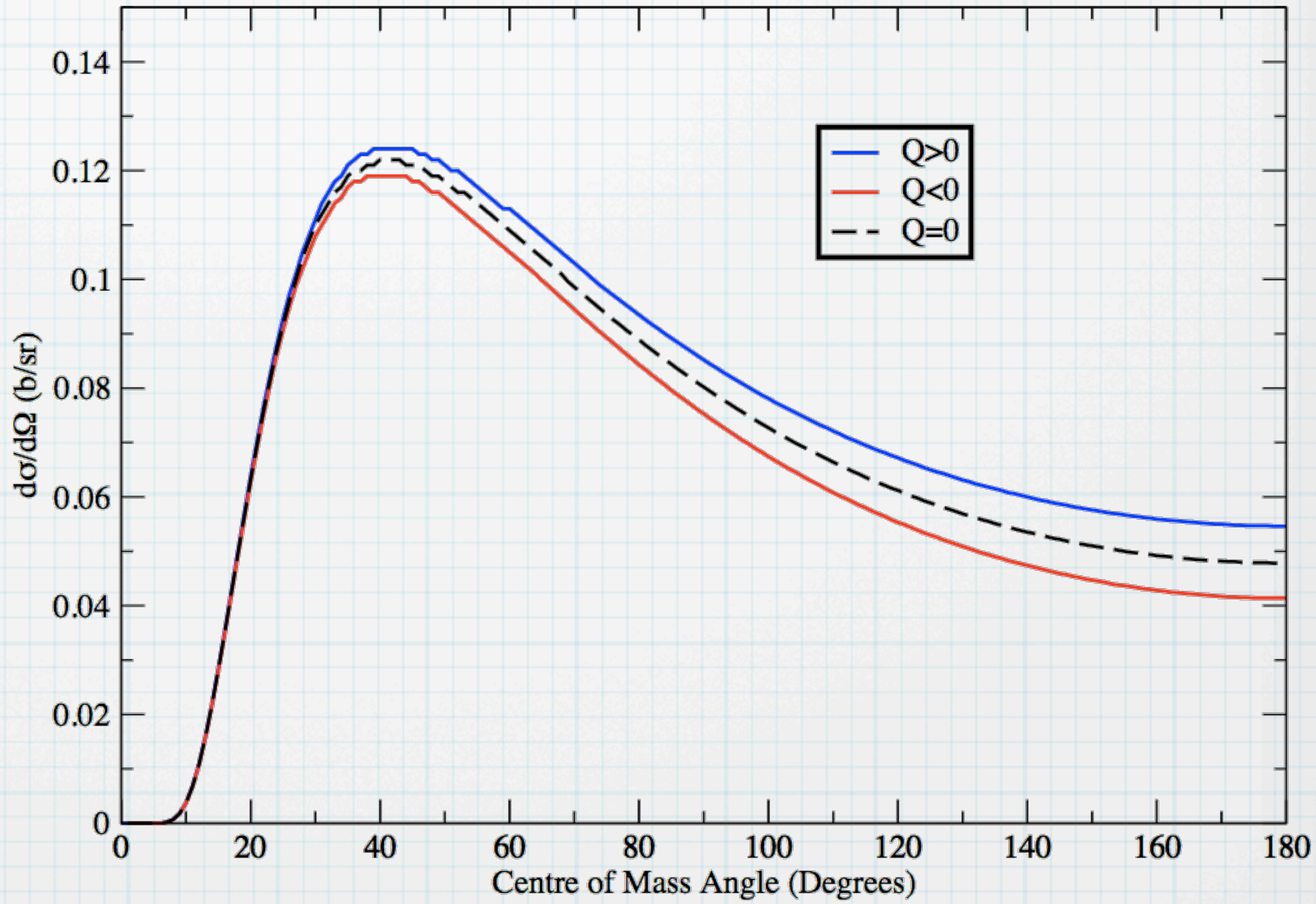
Introduction • Coulex

$^{112}\mathrm{Cd}(^{184}\mathrm{Hg},^{184}\mathrm{Hg}^{*})^{112}\mathrm{Cd}^{*}$

* Inelastic scattering involving EM force
* Cross-section sensitive to quadrupole moment
* Different angular ranges exploits dependence
* Vary matrix elements to reproduce γ -ray yields



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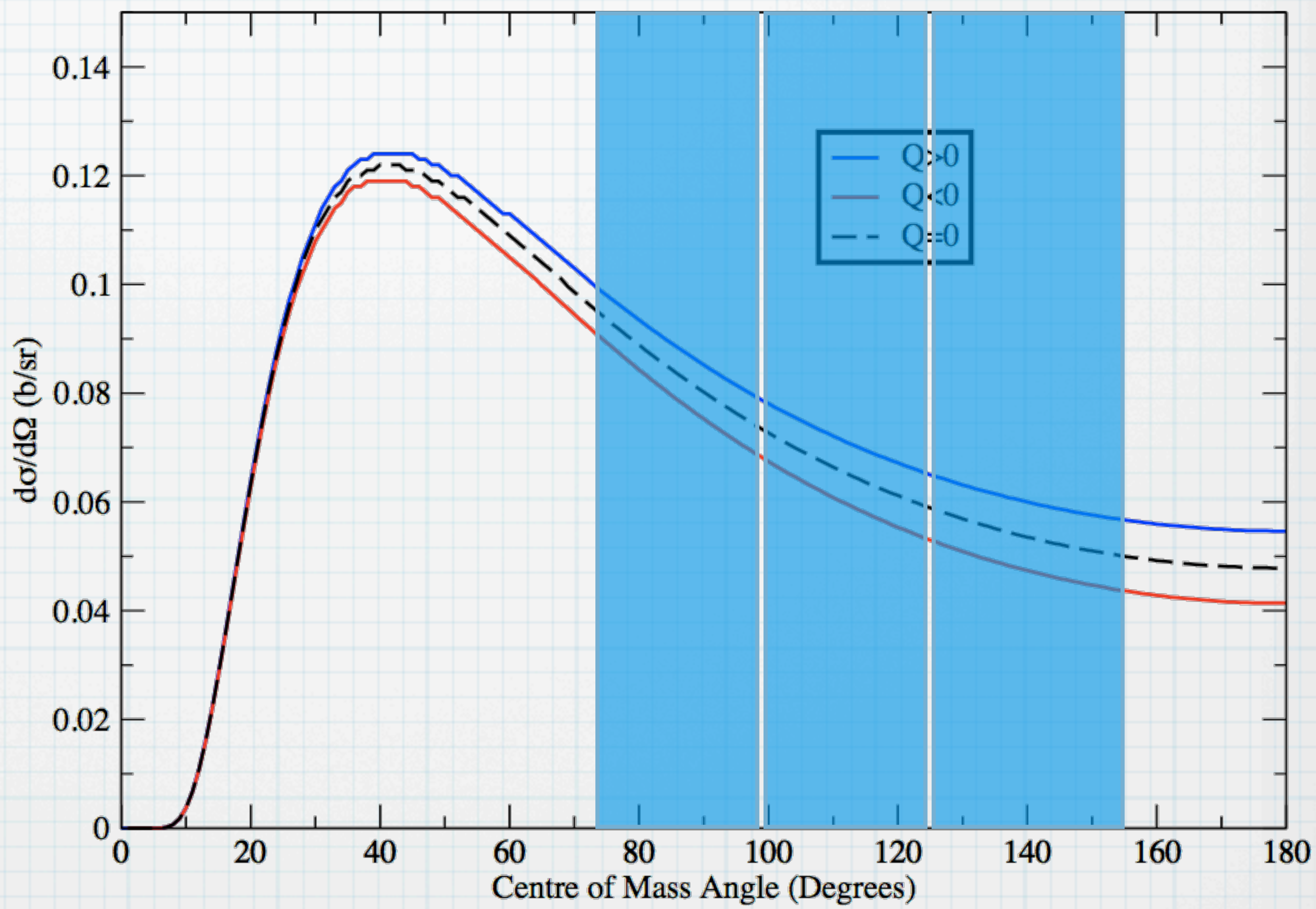
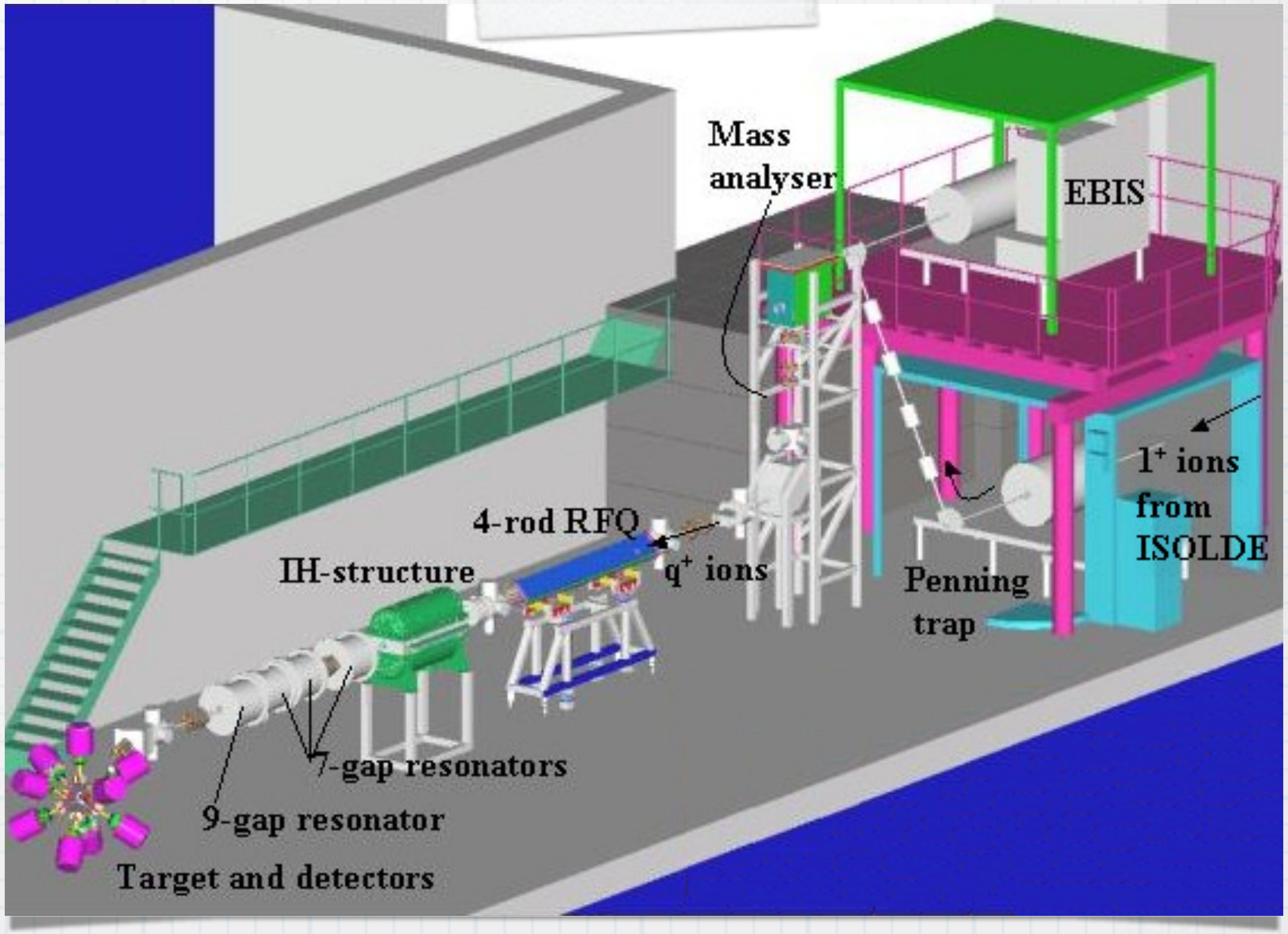


Experimental Set-up

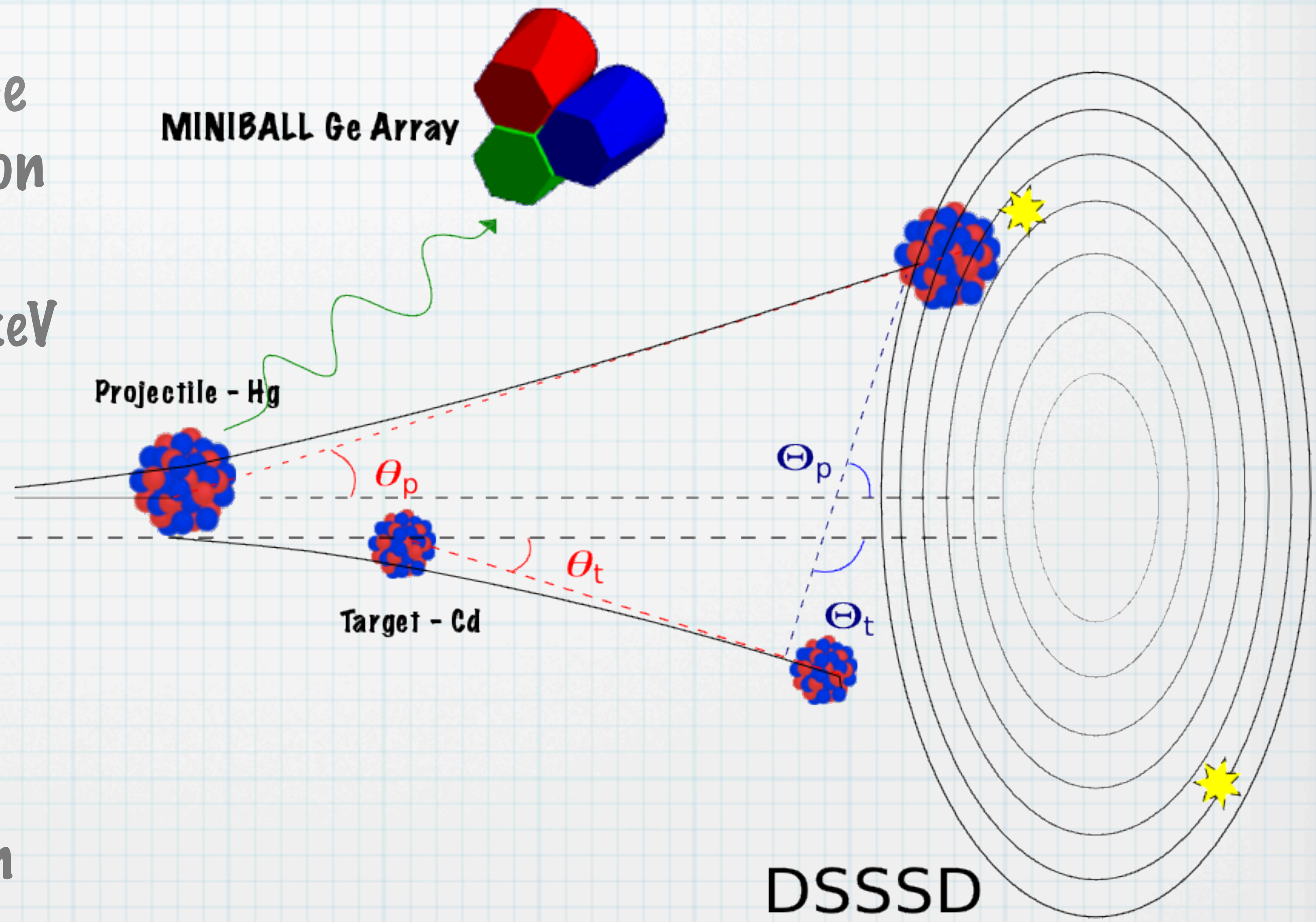
* REX-ISOLDE delivers > 600 isotopes post-accelerated up to 3.2 A.MeV to MINIBALL
* PS Booster: 1 or 1.4 GeV protons on molten Pb primary target
* REXTRAP/EBIS: trap, bunch and charge breed ions to $4 \leq A/q \leq 5$
* REX-Linac: Mass separator RFQ, IHS, 7-gap and 9-gap



Experimental Set-up

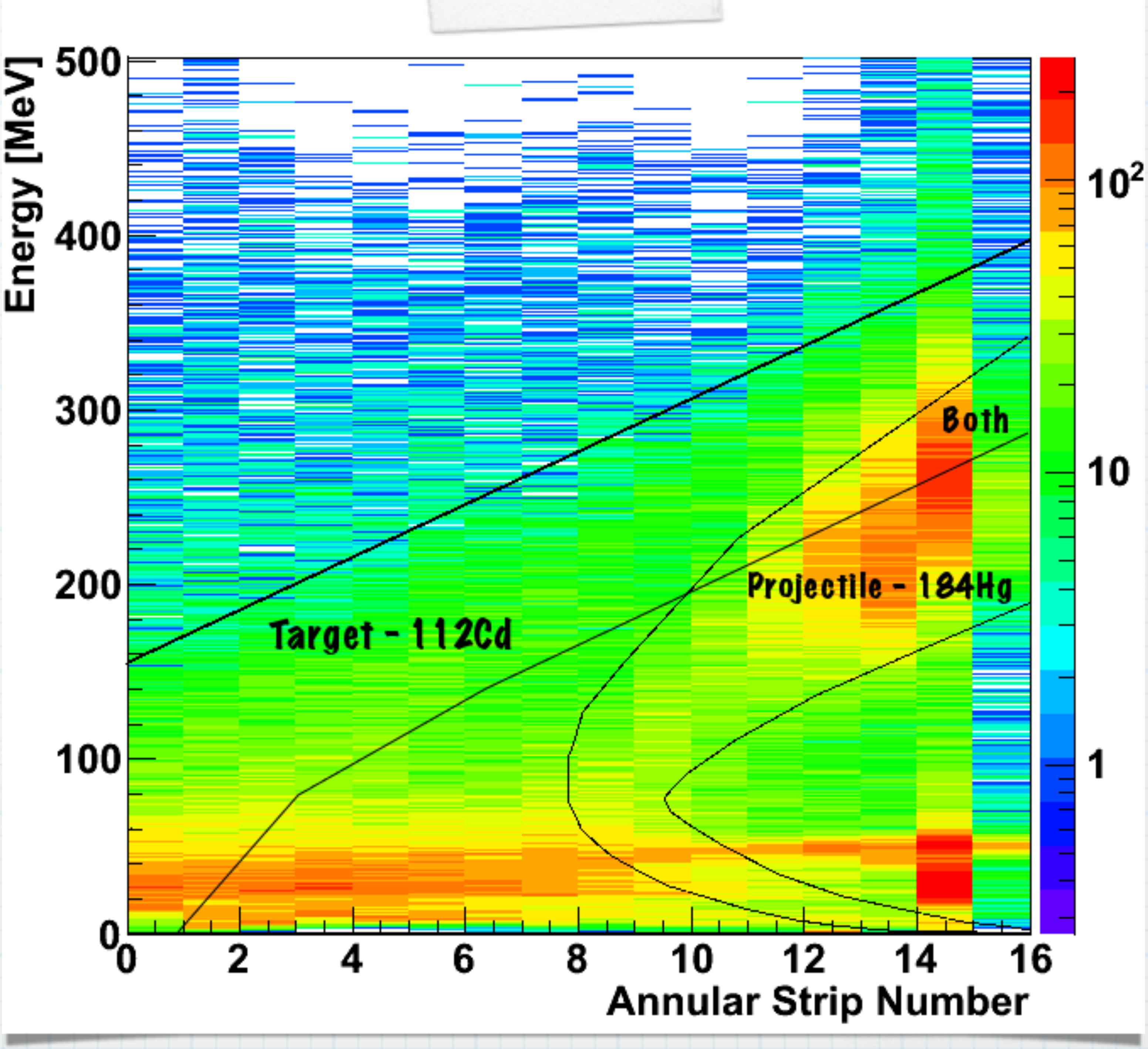
- MINIBALL - 8 triple cluster Ge detectors, 6-fold segmentation
- $\varepsilon > 7\%$ at 1.3 MeV FWHM ≈ 7keV
- DSSSD gives θ , φ

  and energy loss information
- Kinematic reconstruction, gating and Doppler correction



Analysis • Kinematics

* Inverse kinematics reaction $^{112}Cd(^{184}Hg, ^{184}Hg)^{112}Cd$
* Identify products in Energy vs. Angle plot
* Gates on projectile define coincident γ -rays
* Coincident target particle kinematically reconstructed for Doppler correction



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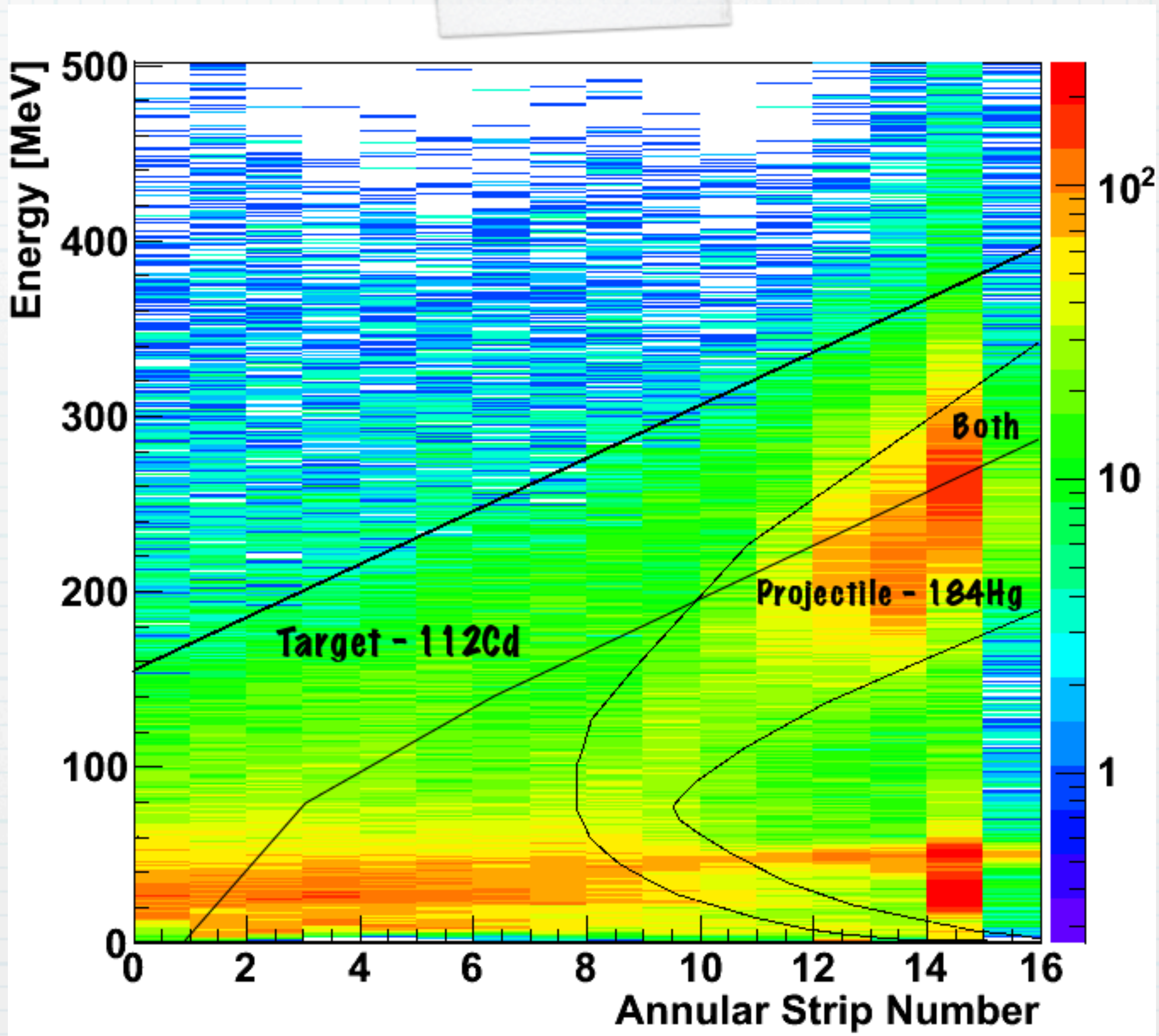
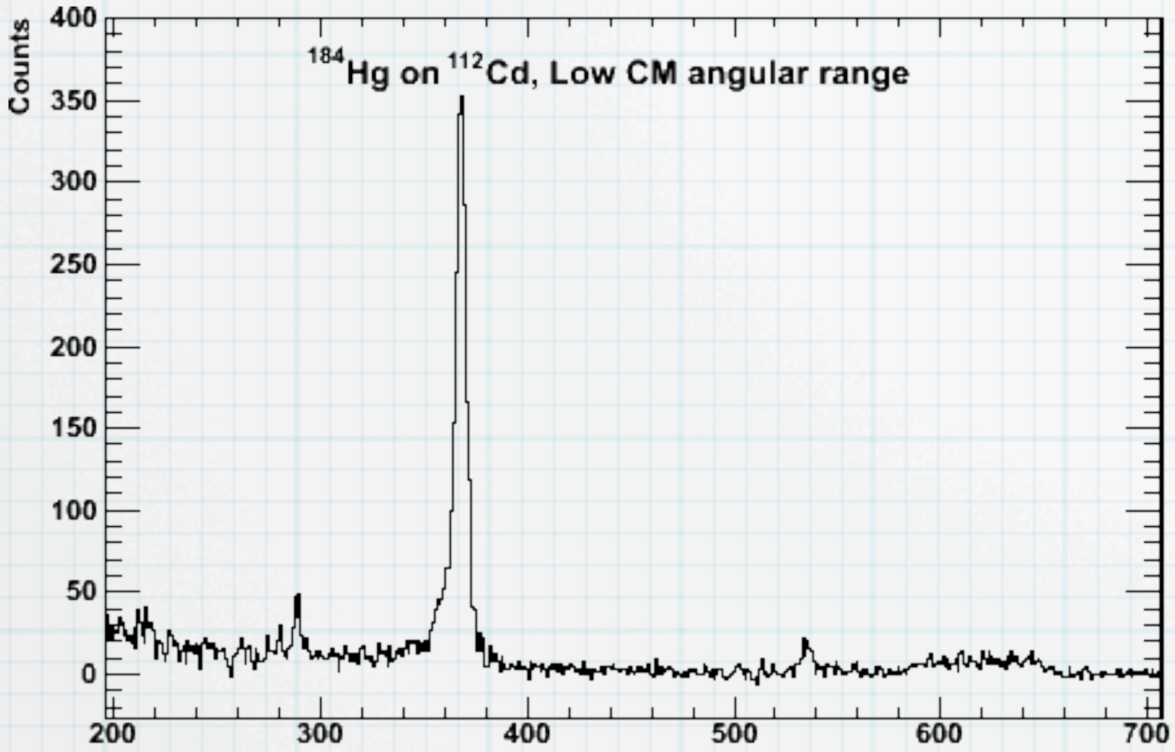
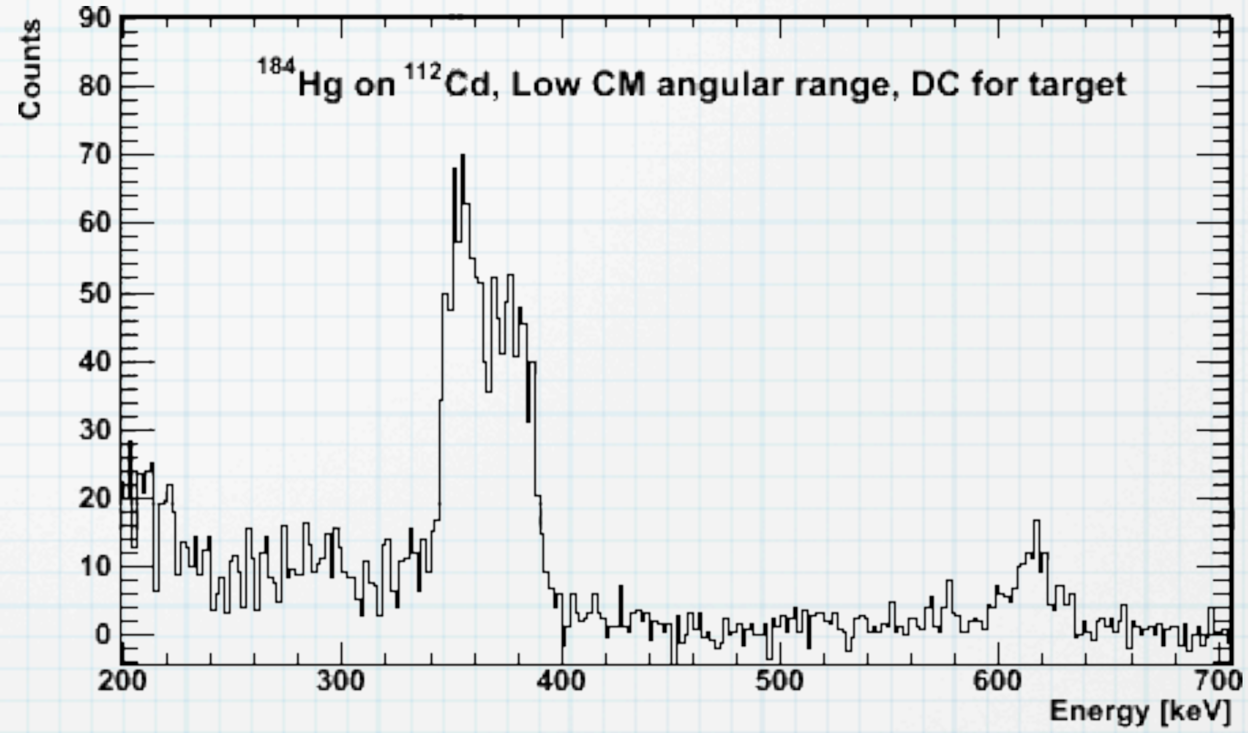
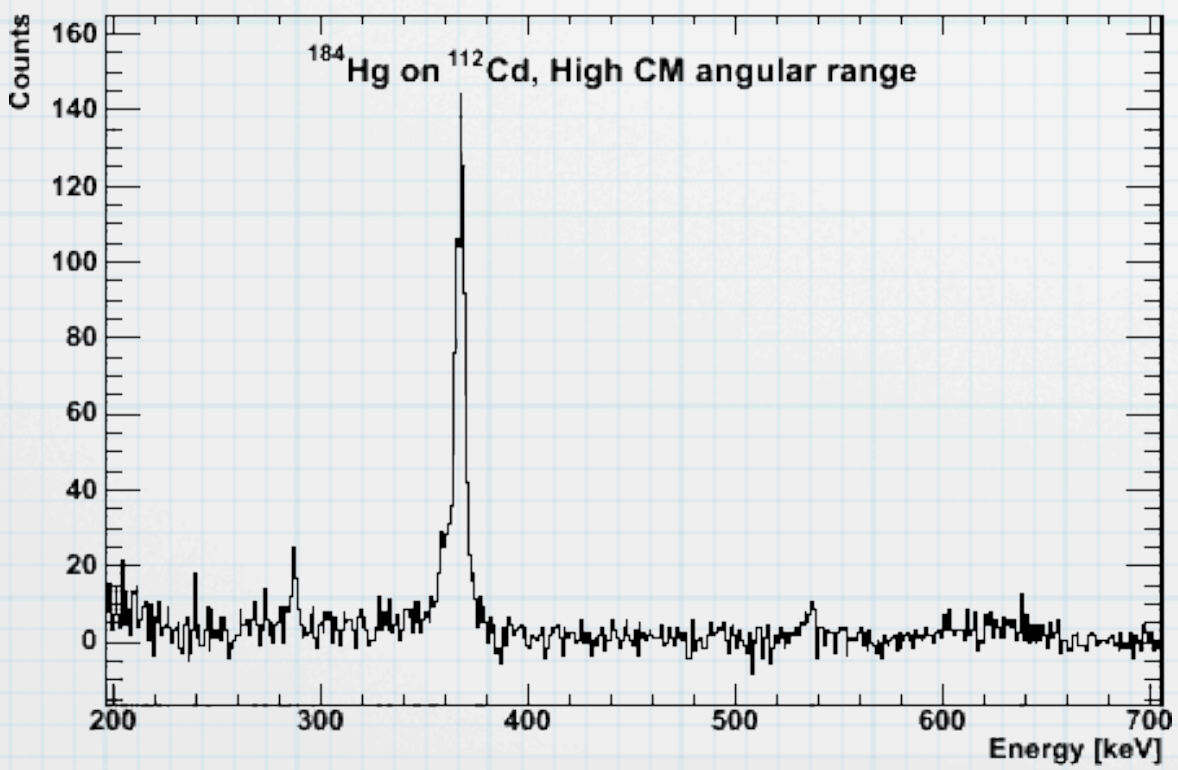
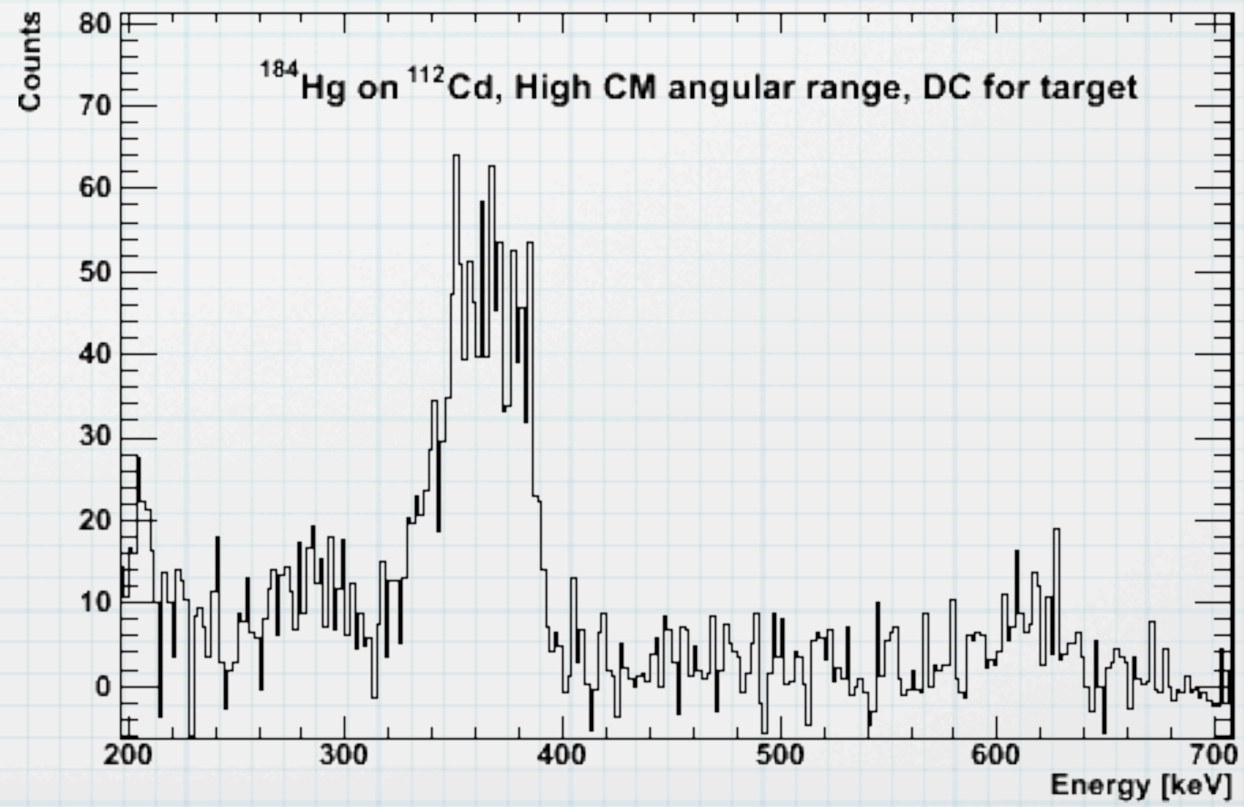


Analysis • Spectra



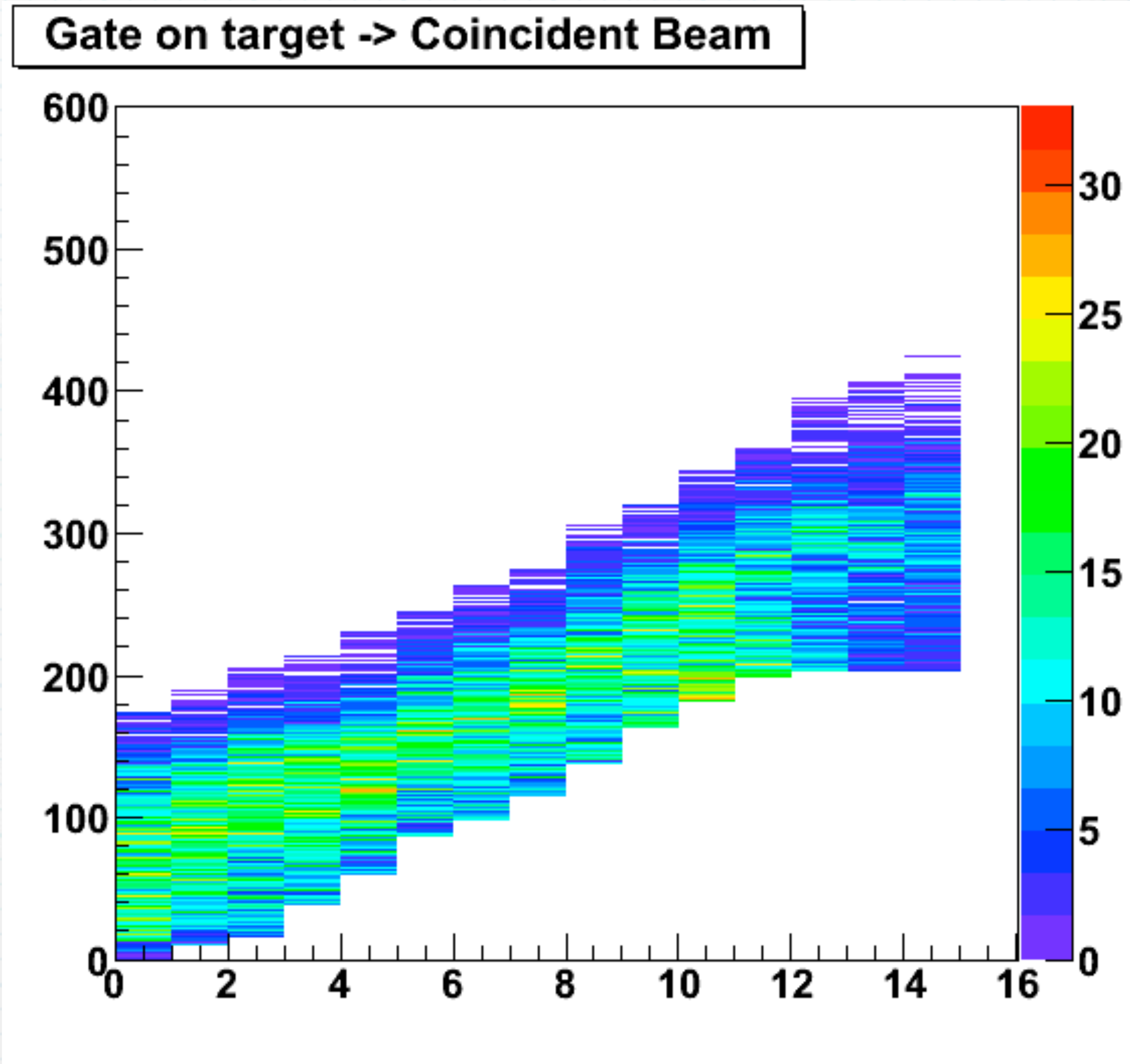






Analysis - 2 Particle

* 2 particles required in opposite quadrants
* Energy gate on target -> beam
* 3 distinct angular ranges
* Better Doppler correction



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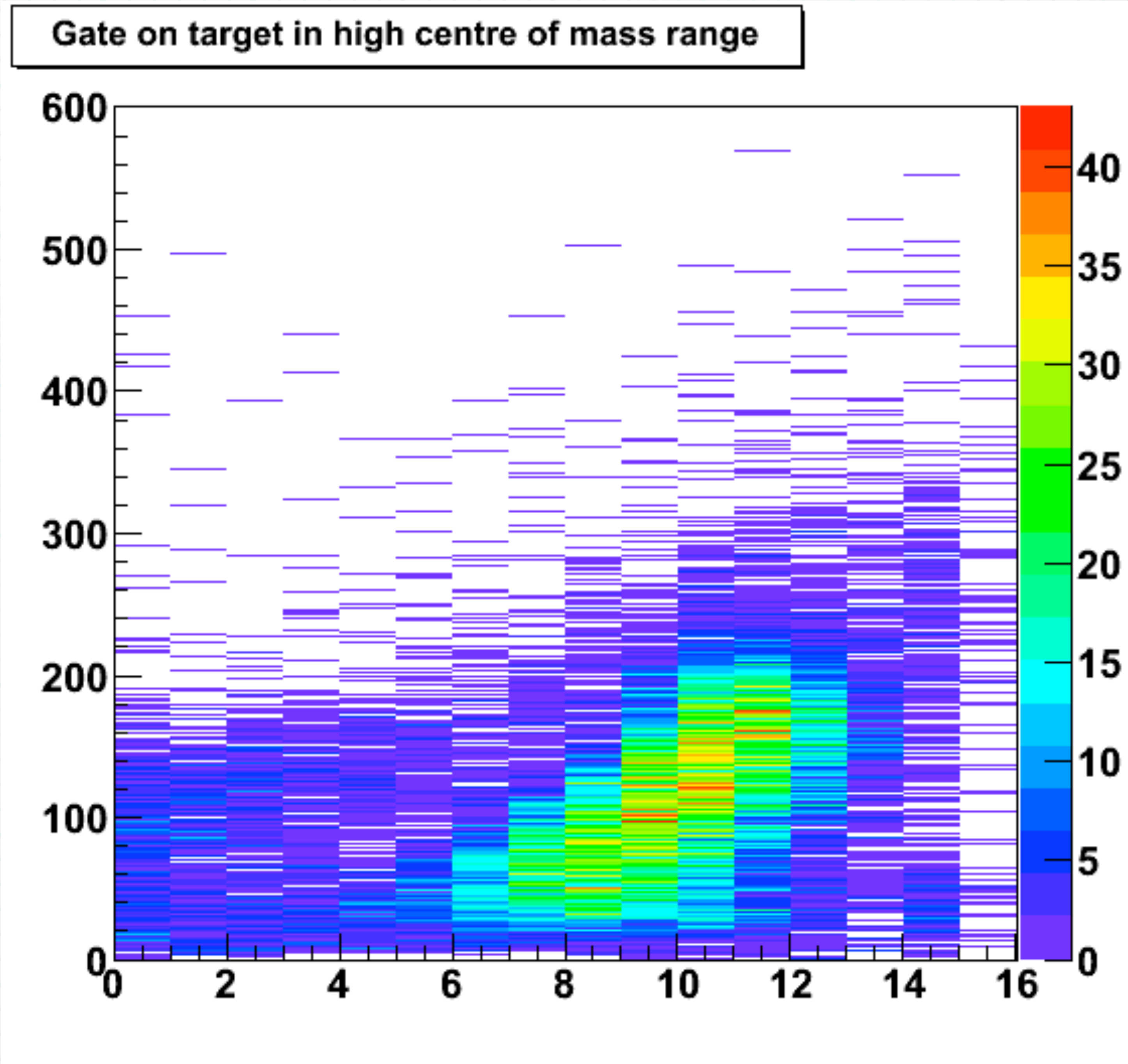

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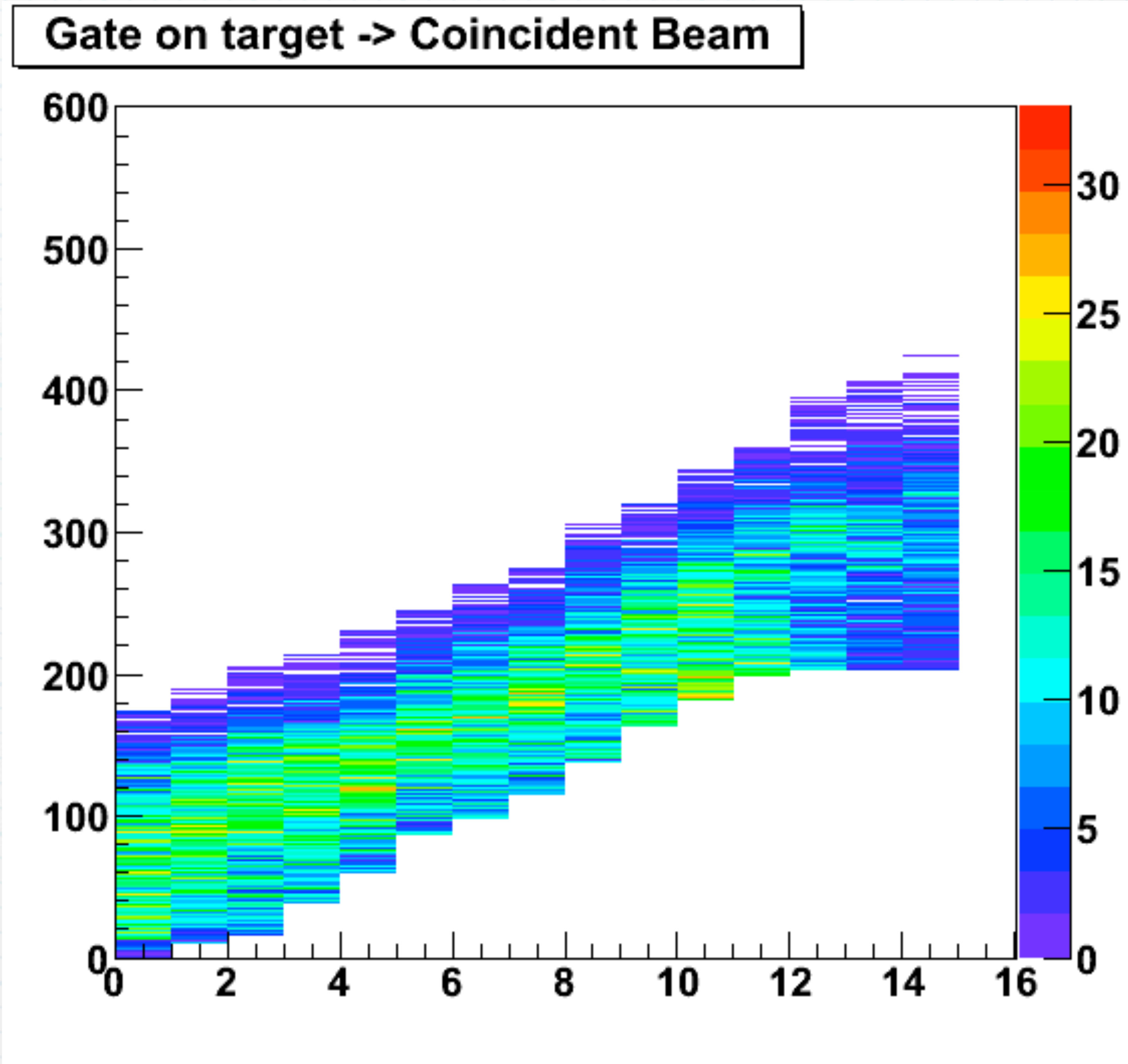

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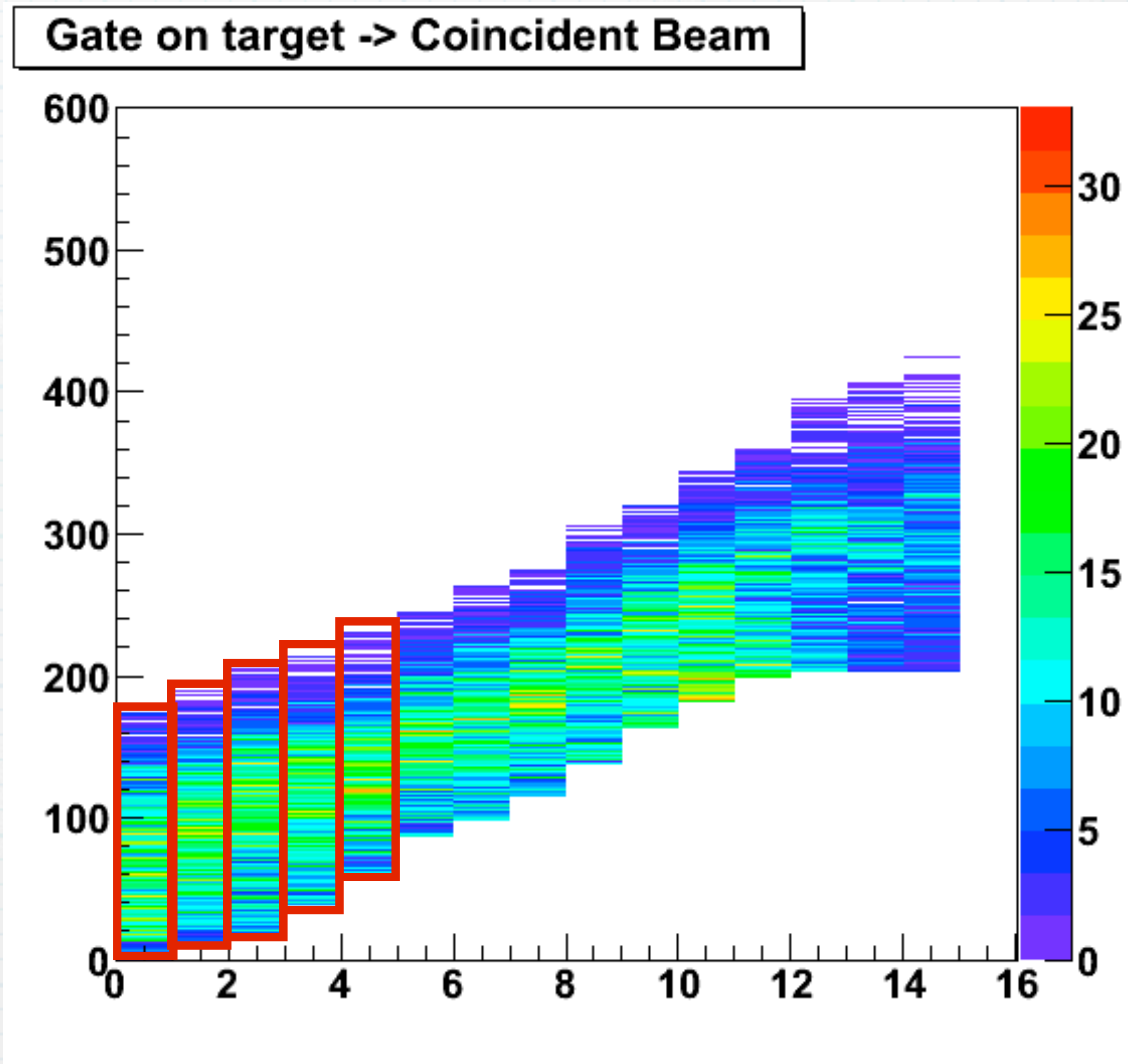

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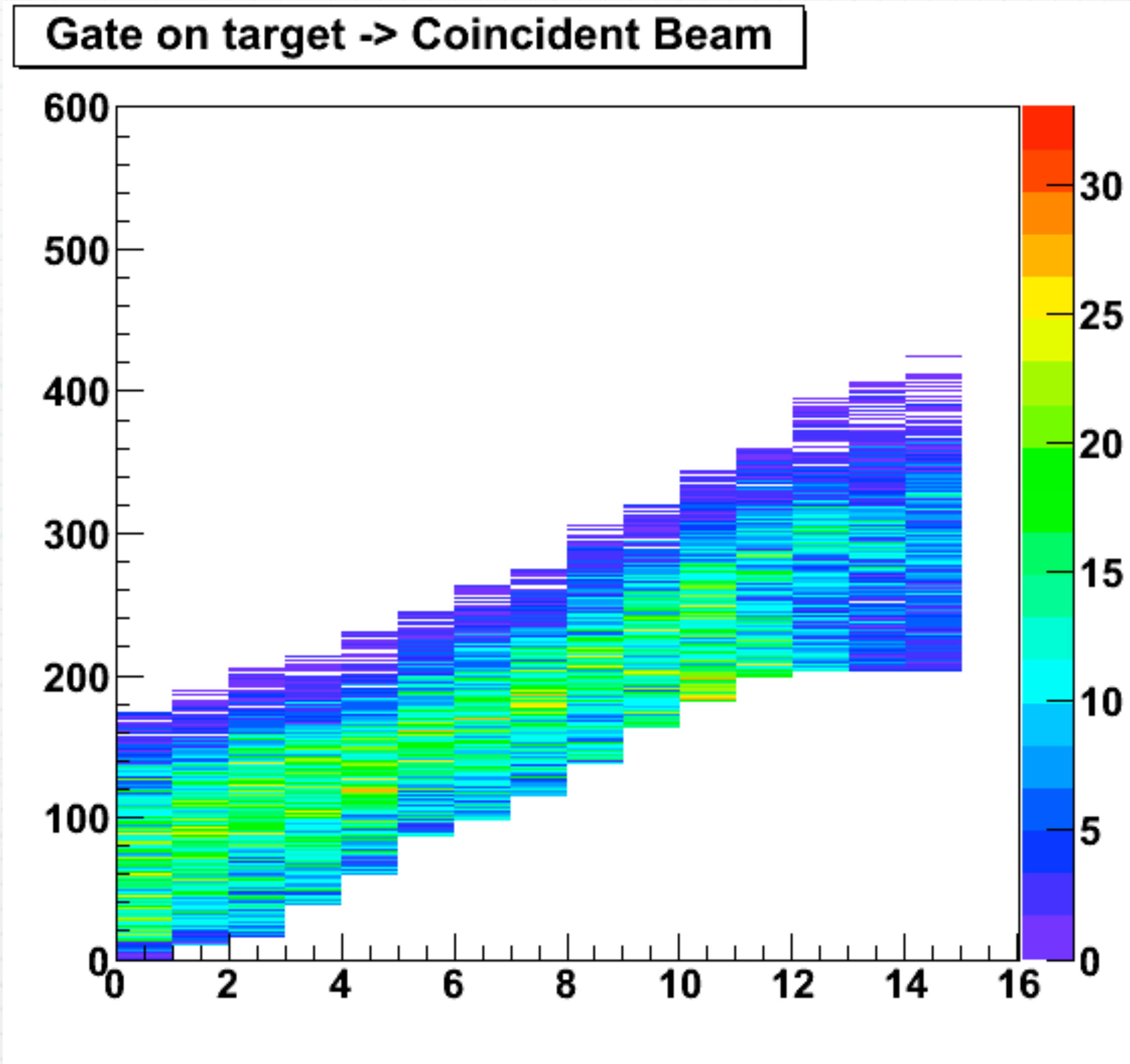

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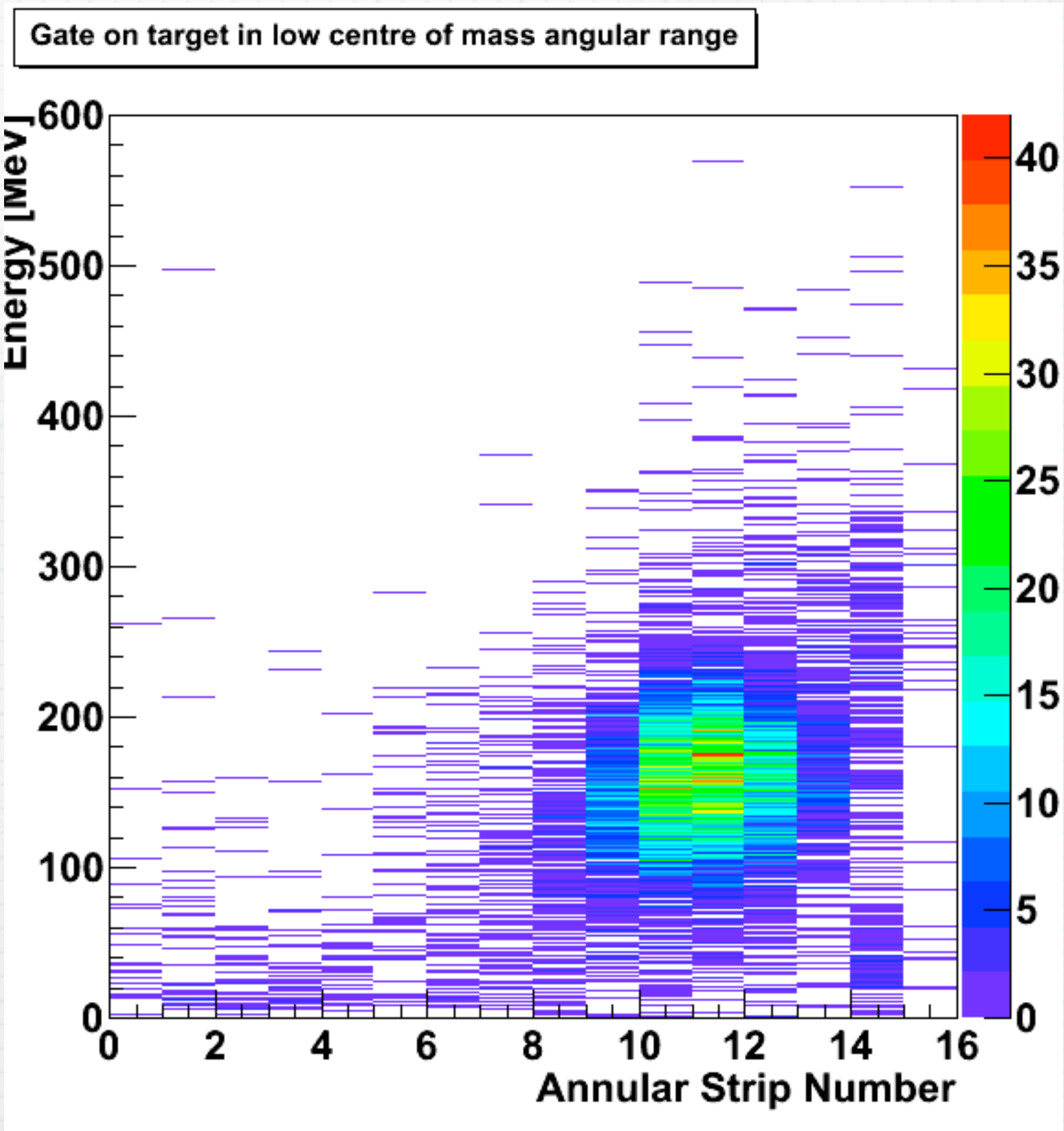
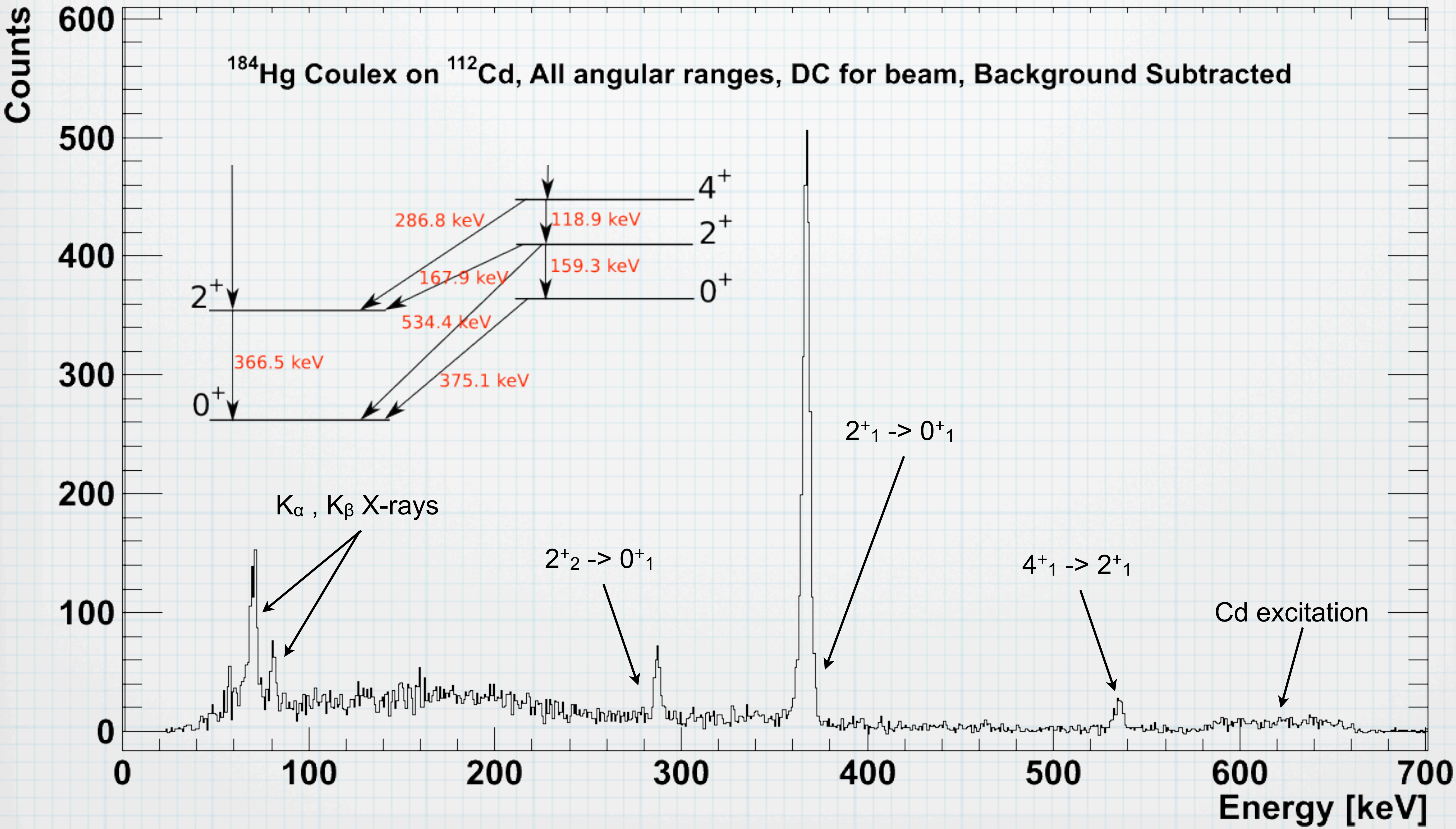
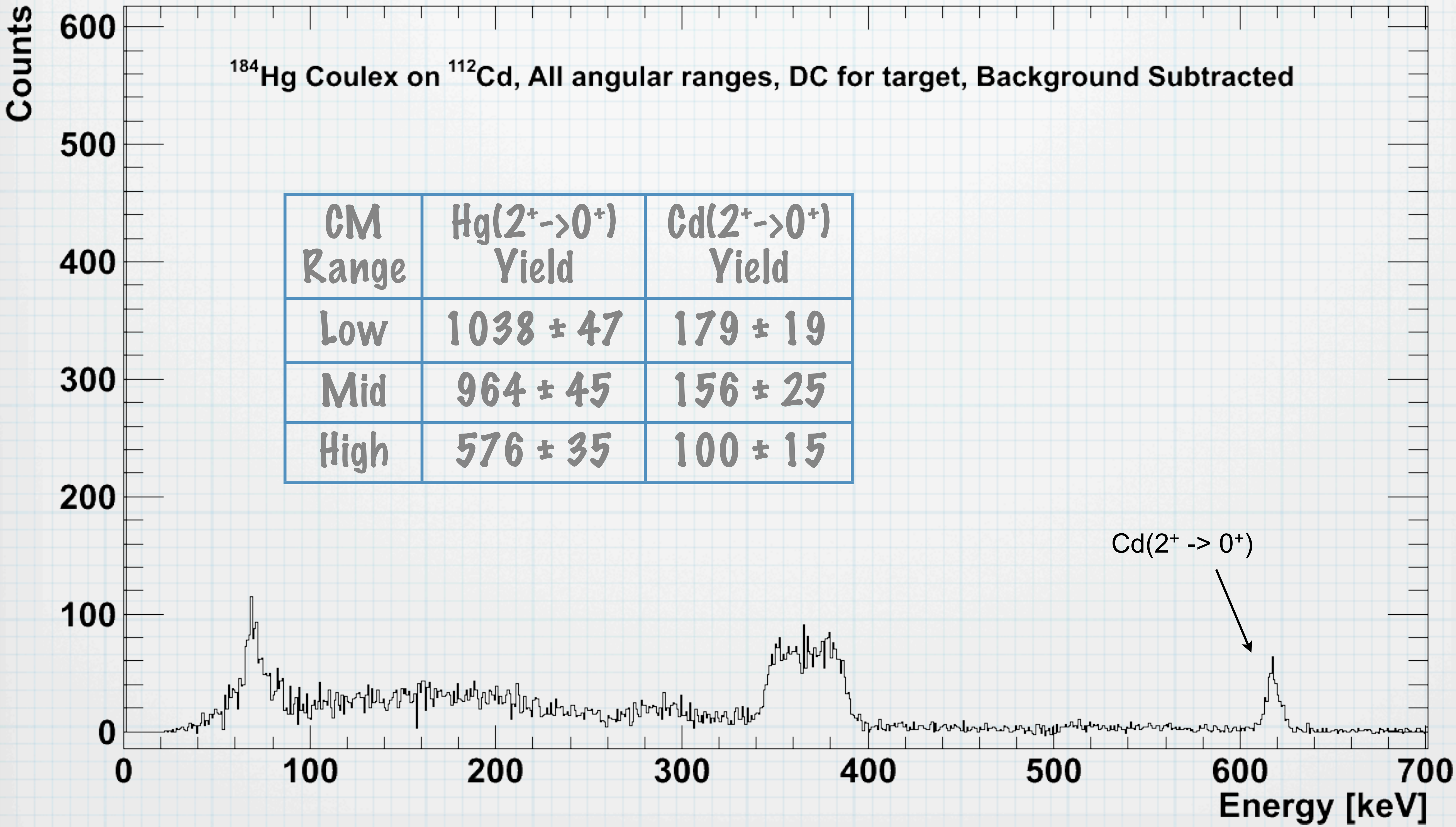


Analysis • p-p-γ



Analysis • Spectra



CM Range	Hg(2⁺->0⁺) Yield	Cd(2⁺->0⁺) Yield
Low	1038 ± 47	179 ± 19
Mid	964 ± 45	156 ± 25
High	576 ± 35	100 ± 15

Analysis - Minimisation

- GOSIA least squares fit Fortran code
- Error analysis yet to be performed
- Preliminary ^{184}Hg matrix elements:

  $\langle 2^+_1 \| E(2) \| 0^+_{g.s} \rangle = 1.57$ eb

  $\tau = 23.6$ ps => 30(7)ps Rudd et. al.

- $E0(2^+_2 \rightarrow 2^+_1)$ transition to be understood
- $E0(0^+_2 \rightarrow 0^+_{g.s})$ transition is negligible

CALCULATED LIFETIMES

LEVEL	LIFETIME(PSEC)	EXP	ERROR
2	-.1000E+01		
3	0.2355E+02	0.3000E+02	0.7000E+11
4	0.1068E+04	0.9000E+03	0.3000E+13
5	0.1248E+03		
6	0.2288E+02	0.3280E+02	0.3400E+11
7	0.1018E+02	0.8100E+01	0.3100E+11
8	0.7449E+00		
9	0.5479E-01		

MATRIX ELEMENTS

MULTIPOLARITY=2

INDEX	NF	NS	ME	RED. TRANS. PROB.
1	1	3	1.57219	0.49436
2	1	5	0.19856	0.00789
3	3	3	0.51657	**********
4	3	4	0.22870	0.05230
5	3	5	0.87943	0.15468
6	3	6	-3.69149	1.51412
7	3	8	2.21473	0.54500
8	4	6	-0.25174	0.00704
9	5	5	-0.36546	**********
10	5	6	5.12651	2.92012
11	5	8	-0.35359	0.01389
12	6	6	-1.80823	**********
13	6	7	4.62143	1.64289
14	6	8	0.56963	0.03605
15	6	9	2.90912	0.65100
16	7	7	-1.84570	**********
17	7	8	0.37800	0.01588
18	7	9	-0.16572	0.00211
19	8	8	1.61731	**********
20	8	9	-4.97438	1.90342
21	9	9	1.77290	**********

MULTIPOLARITY=7

INDEX	NF	NS	ME	RED. TRANS. PROB.
22	2	4	0.05877	0.00345
23	3	5	0.26490	0.01403

********* END OF EXECUTION **********

Summary and Future Work

* Preliminary matrix elements shown (^{184}Hg)
* Initial indication of oblate/prolate
* Investigate $2_2^+ \rightarrow 2_1^+$ E0/M1/E2 effect
* Error bars expected to span 0 when calculated
* Lifetime measurements planned at Argonne
* E0 SAGE proposal accepted at JYFL
* Branching ratios, lifetimes and δ values

  add data points to fit

IS452 Collaborators - Coulex of $^{182, 184, 186, 188}Hg$

A. Petts[1], N. Bree[2], P.A. Butler[1], P. Van Duppen[2], A. Andreyev[2], B. Bastin[2], A. Blazhev[3], B. Bruyneel[3], M. Carpenter[4], J. Cederkäll[5], E. Clement[6], T.E. Cocolios[2], J. Dirkin[2], J. Eberth[3], L. Fraile[5], C. Fransen[3], L.P. Gaffney[1], T. Grahn[1], M. Guttormsen[7], K. Hadynska[8], R.-D. Herzberg[1], M. Huyse[2], D.G. Jenkins[9], R. Julin[10], S. Knapen[2], Th. Kröll[11], R. Krücken[11], A.C. Larsen[7], P. Marley[9], P.J. Napiorkowski[8], J. Pakarinen[1], N. Patronis[2], P.J. Peura[10], E. Piselli[6], P. Reiter[3], M. Scheck[1], S. Siem[7], I. Stefanescu[2], J. Van de Walle[6], D. Voulot[6], N. Warr[3], D. Weissharr[3], F. Wenanders[6], M. Zielinska[9]

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11 Physik-Department E12, TU München, 85748 Garching, Germany

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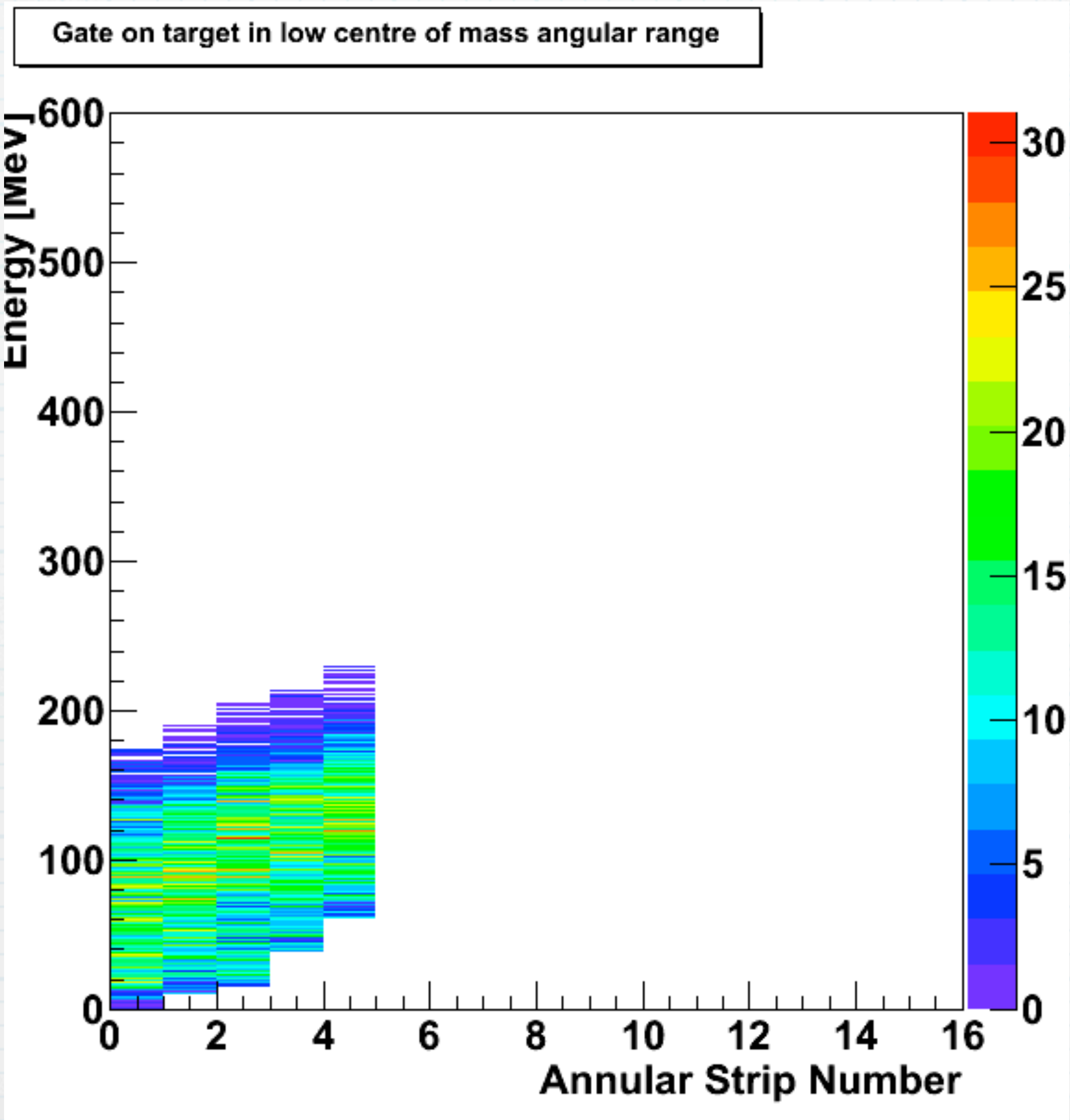

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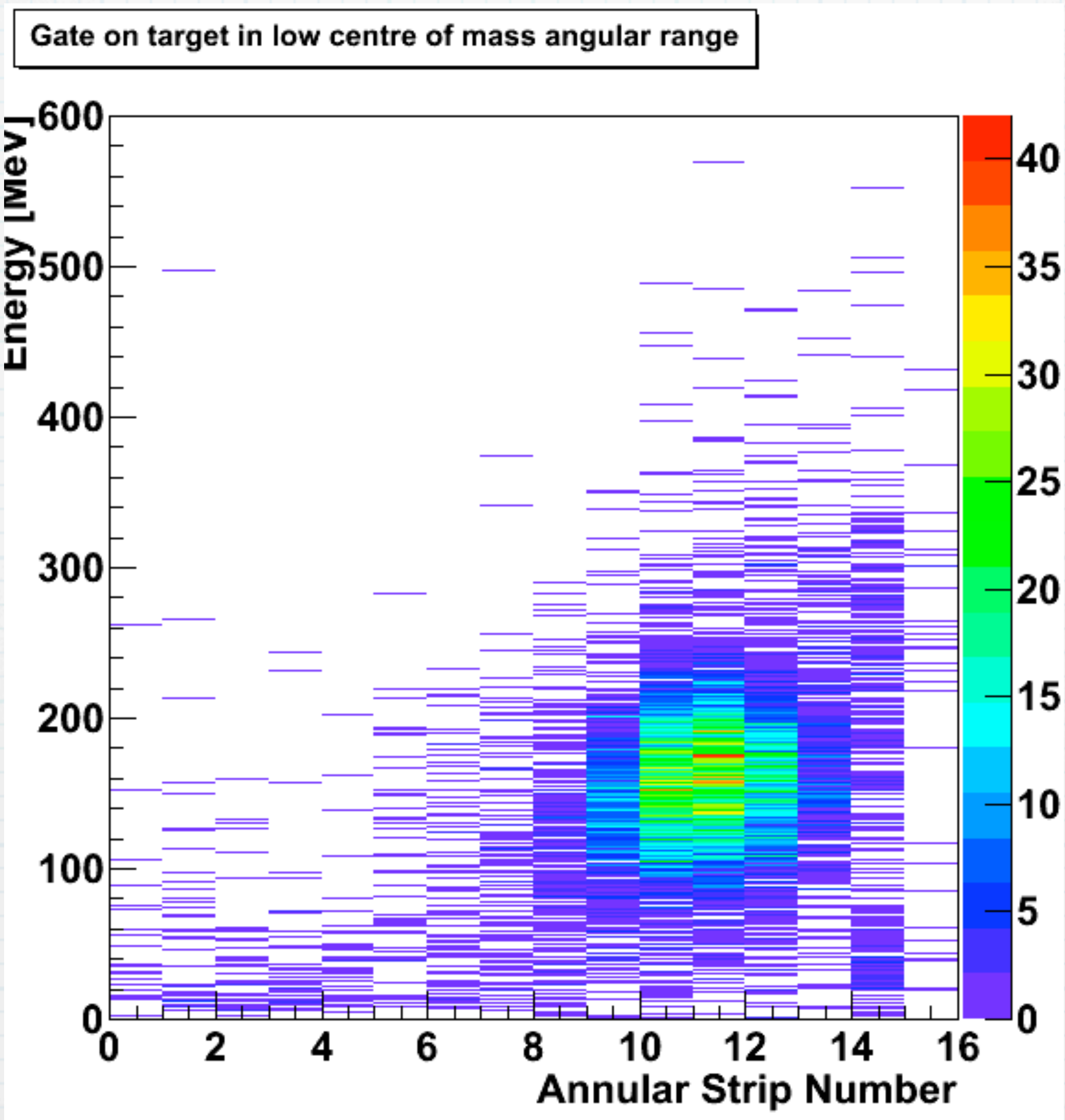

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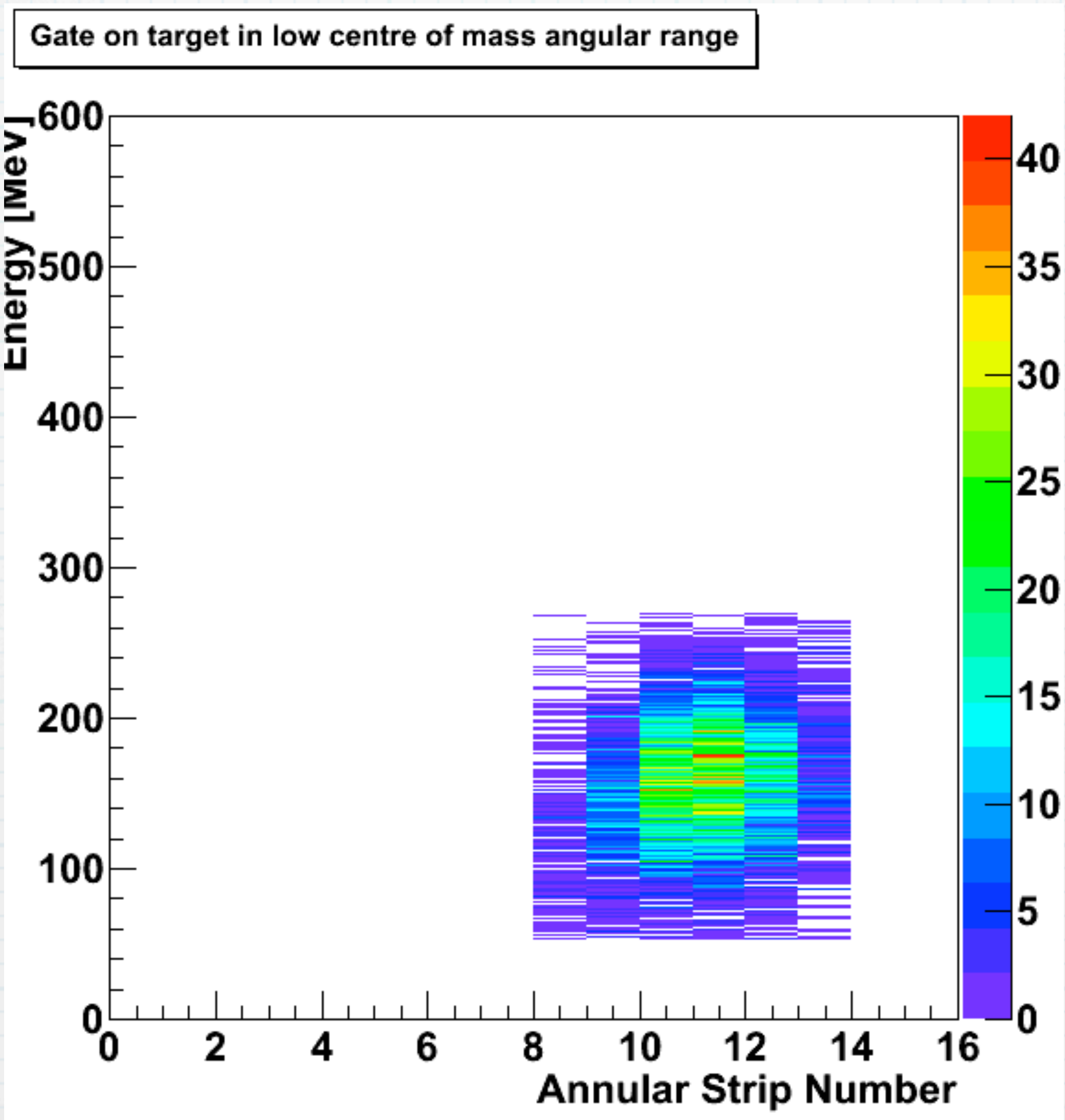

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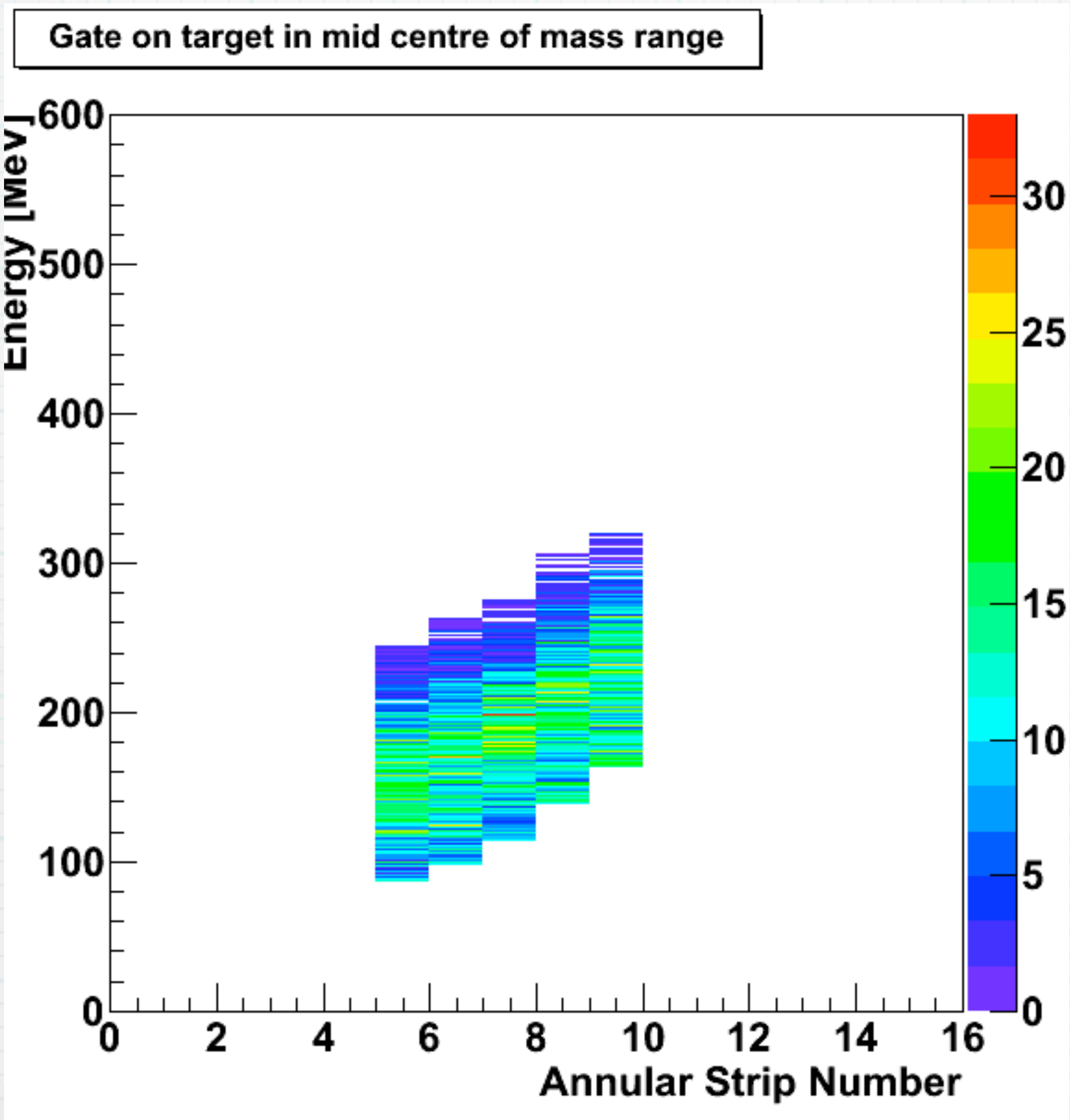

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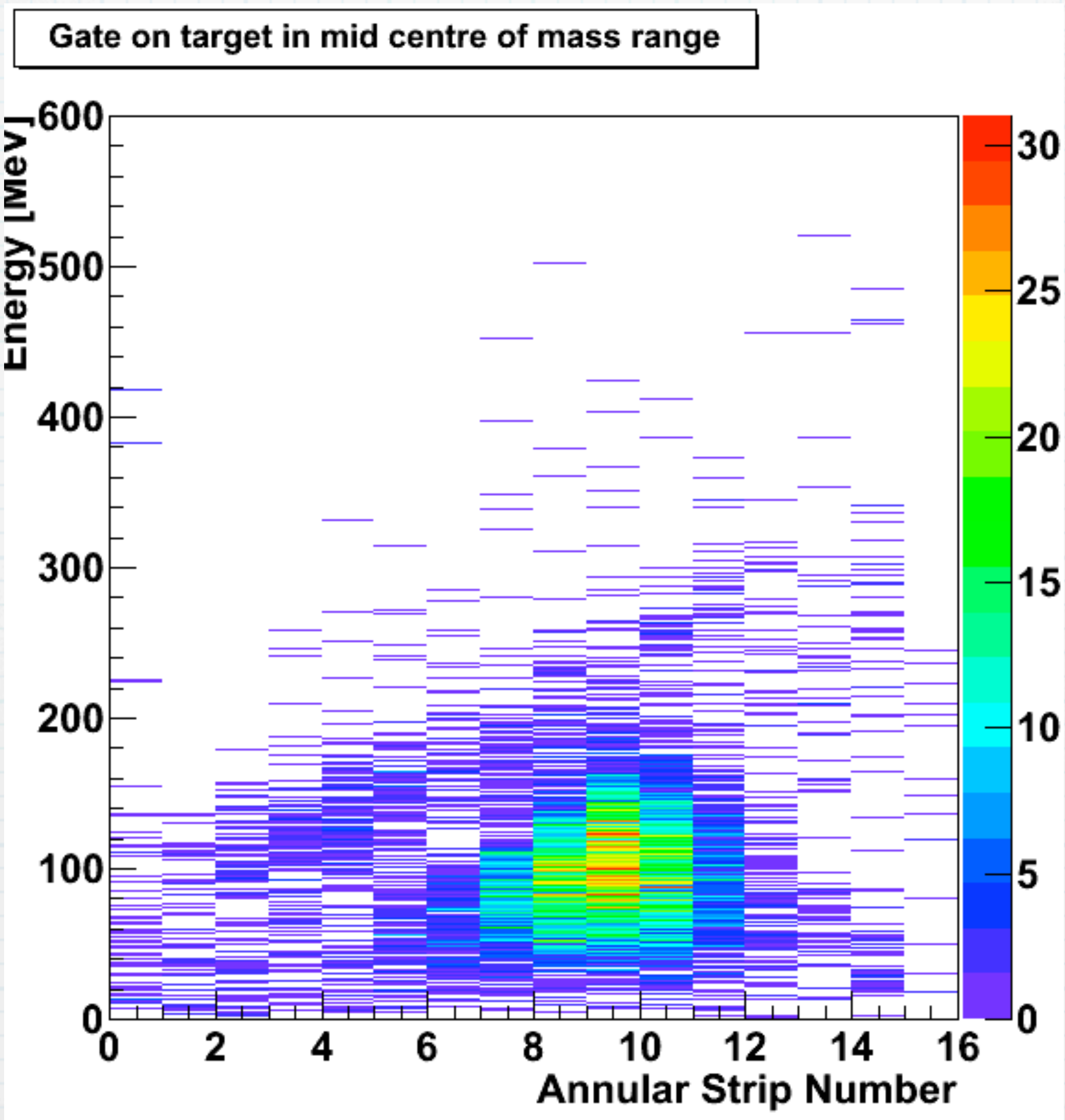

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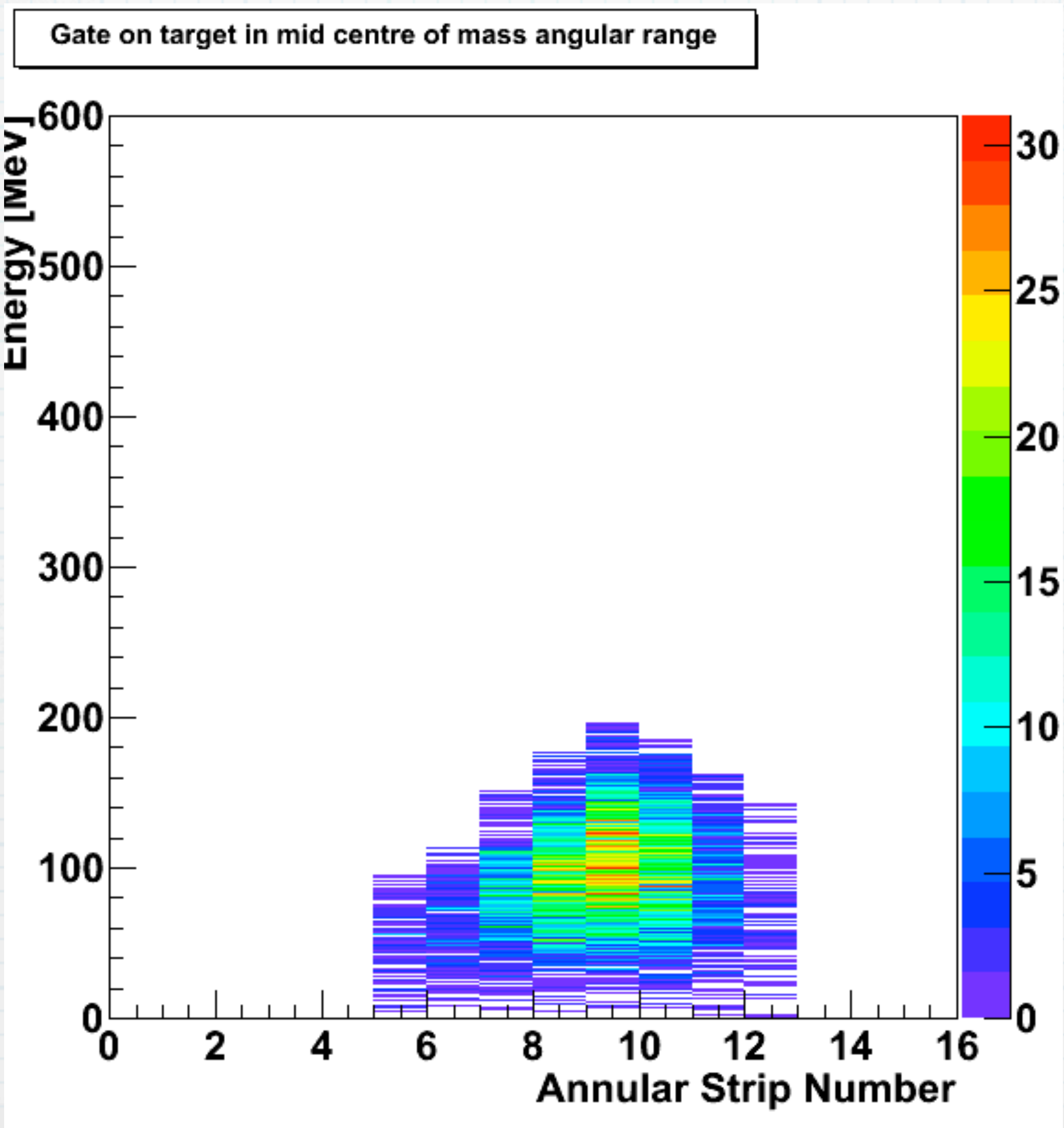

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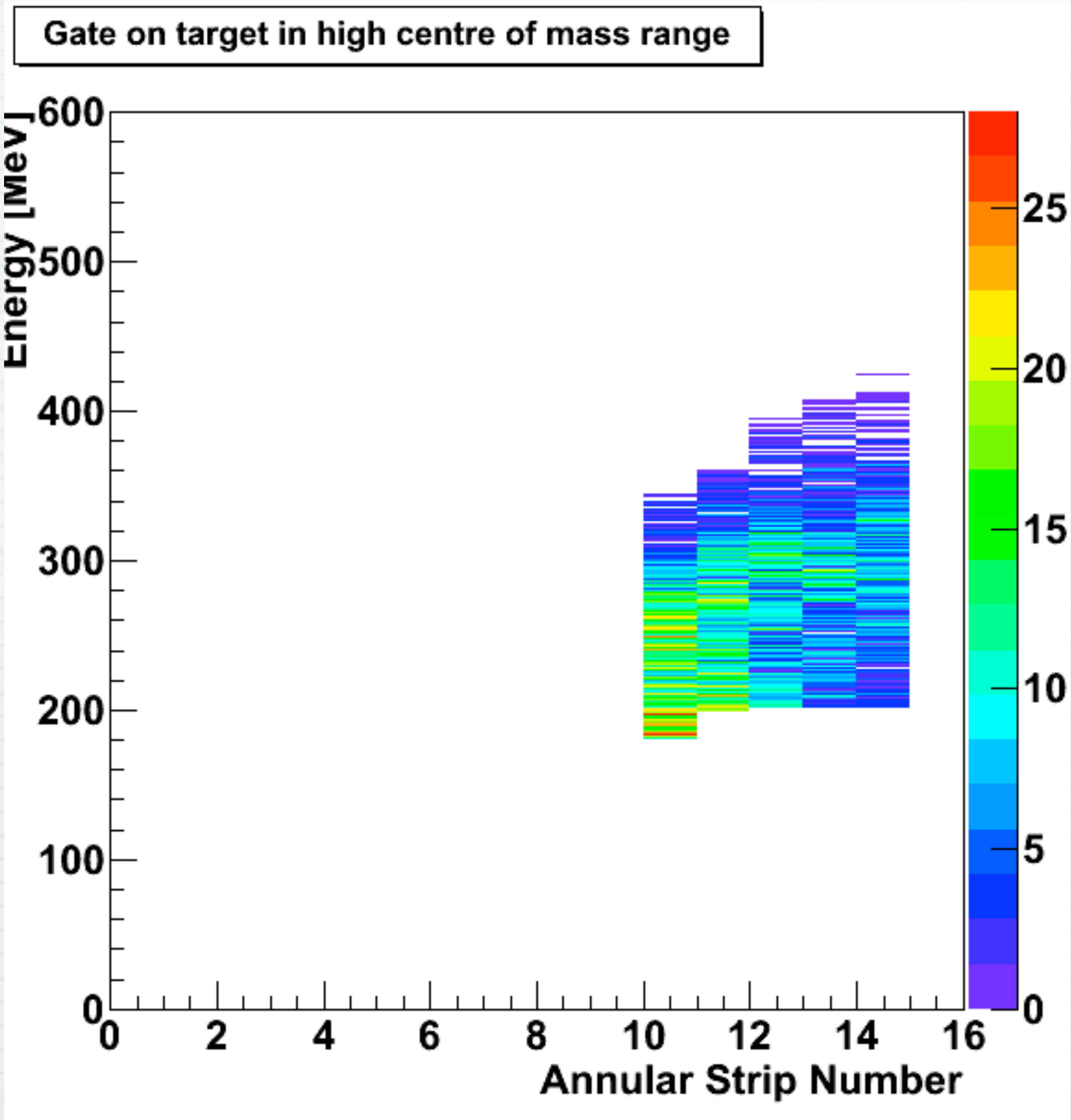

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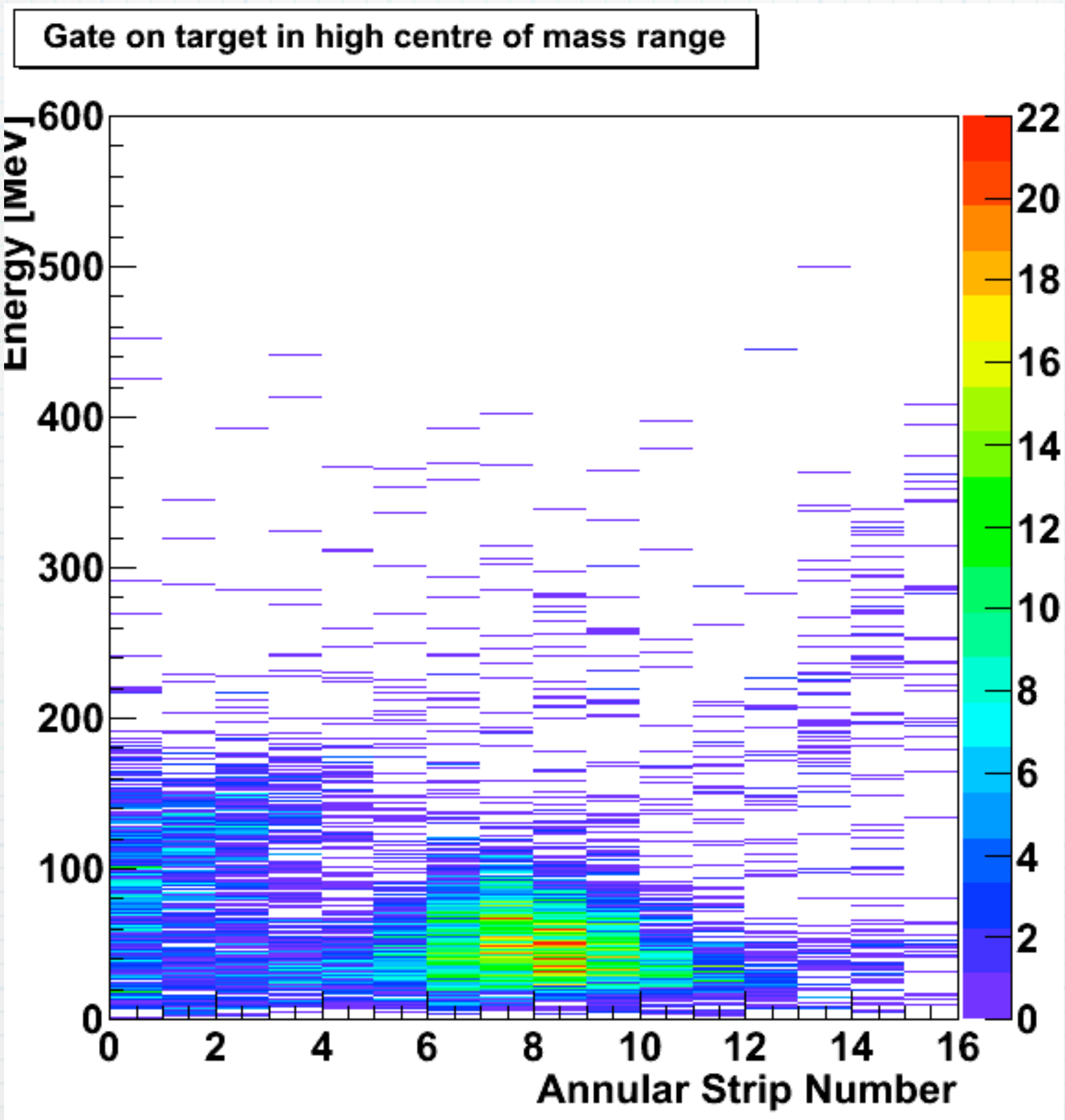

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