Beam Energy Measurements for Mott Run II : Dry run for Bubble ?

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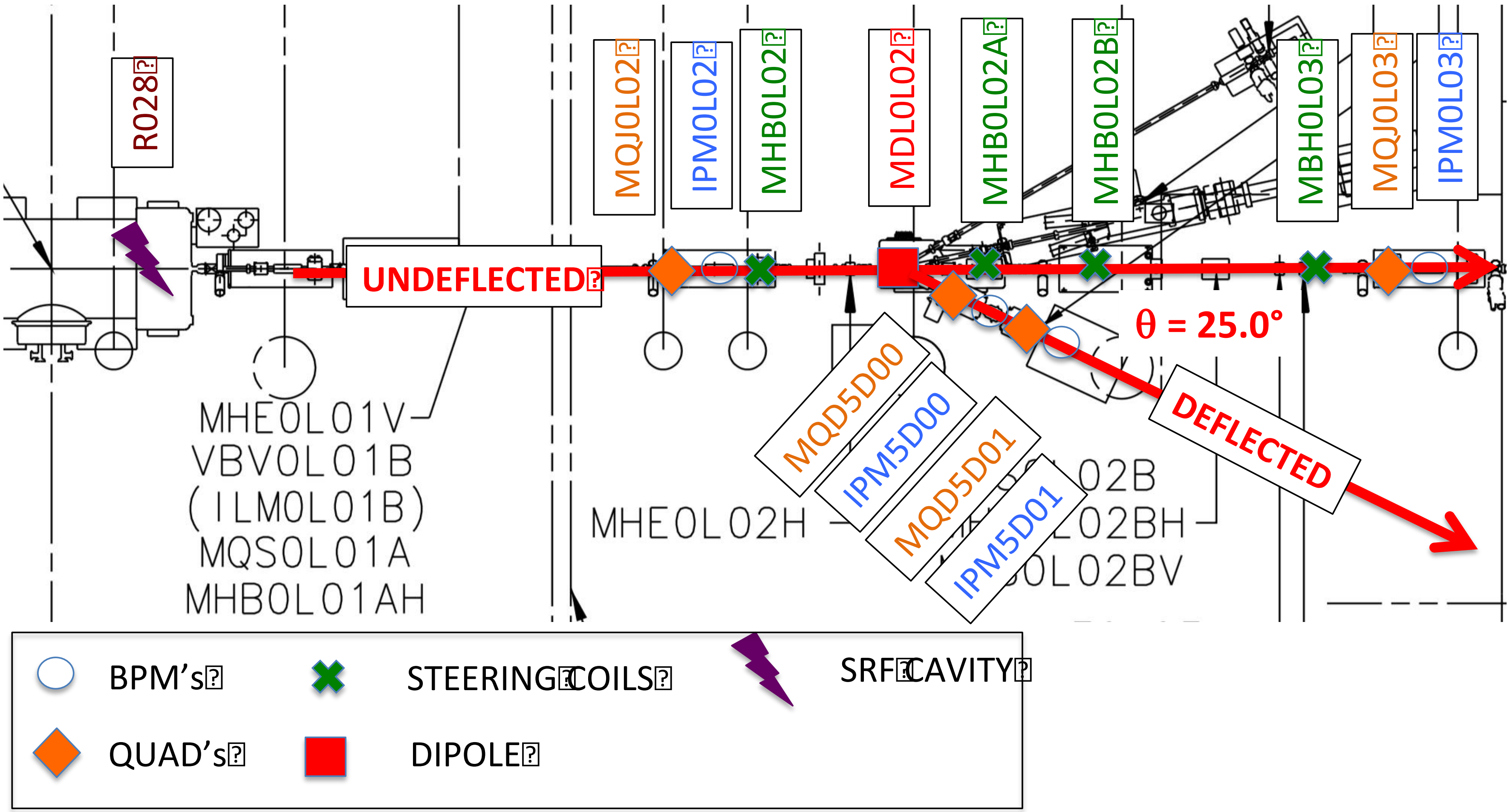
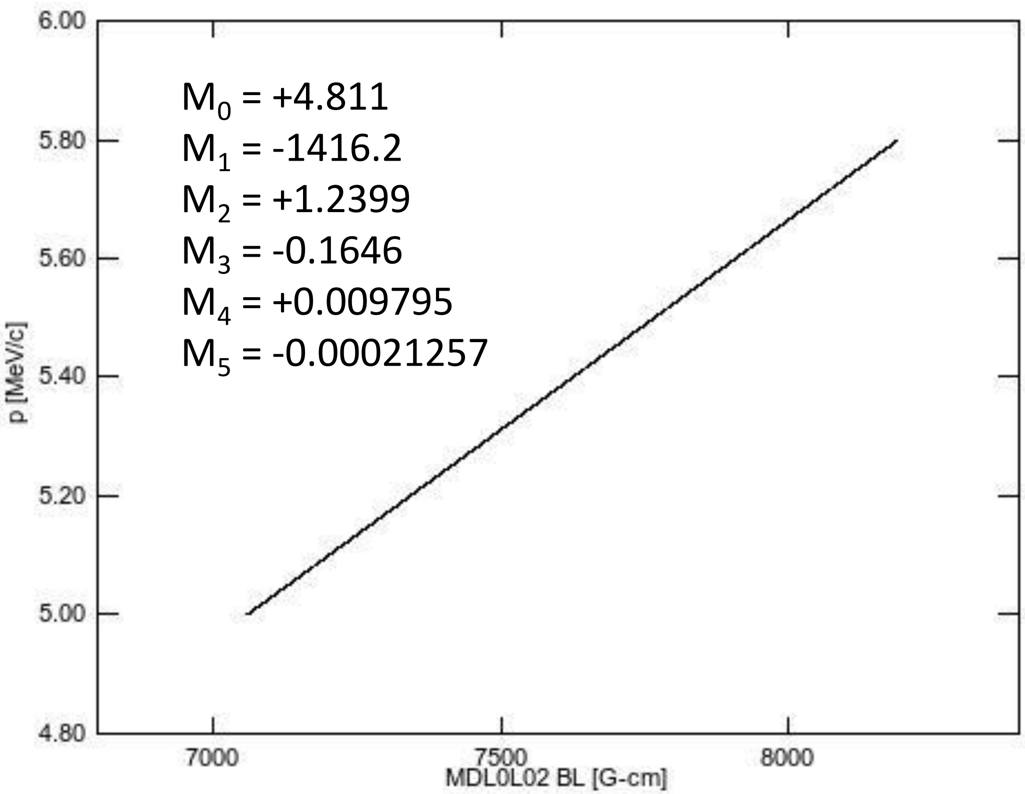
- Oct 2015 studied Mott analyzing power vs. beam energy.
- Varied beam kinetic energy 4.5-5.3 MeV in 0.2 MeV steps.
- Record cavity gradient, Bubble dipole, steering coils, beam positions.



- J. Benesh, *"A detailed examination of the MDL field map and the TOSCA model of this "5 MeV" dipole"*, JLab-TN-15-017.

- TN provides model for ideal operation with $\delta P/P = 0.1\%$

$$BL = M_0 + M_1\,P + M_2\,P^2 + M_3\,P^3 + M_4\,P^4 + M_5\,P^5$$

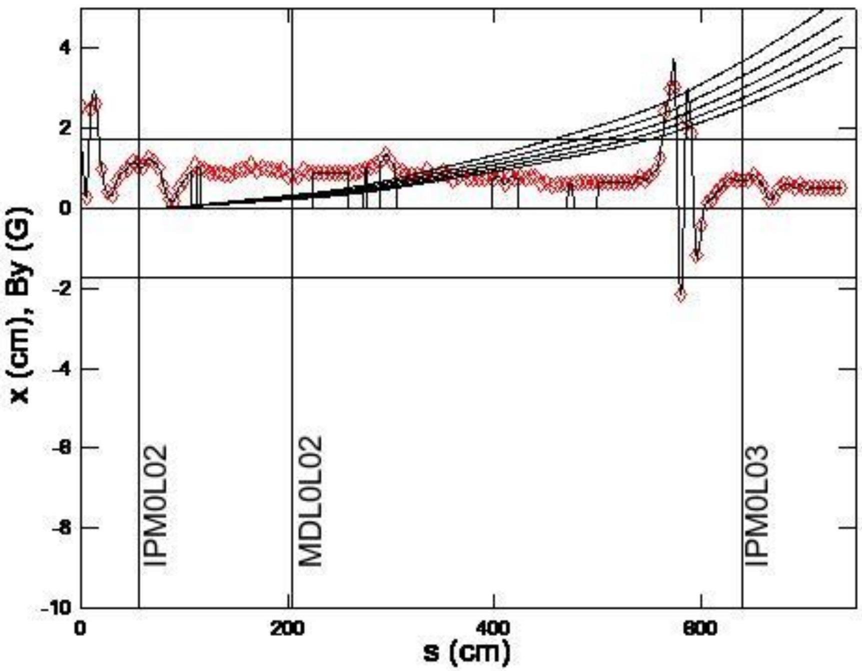


R028	*MDL0L02*	*P*	*dP*
MV/m	*G-cm*	*MeV/c*	*MeV/c*
3.35	7109.57	5.035	0.005
3.74	7384.34	5.229	0.005
4.12	7646.01	5.415	0.005
4.5	7927.59	5.614	0.006
4.89	8185	5.797	0.006

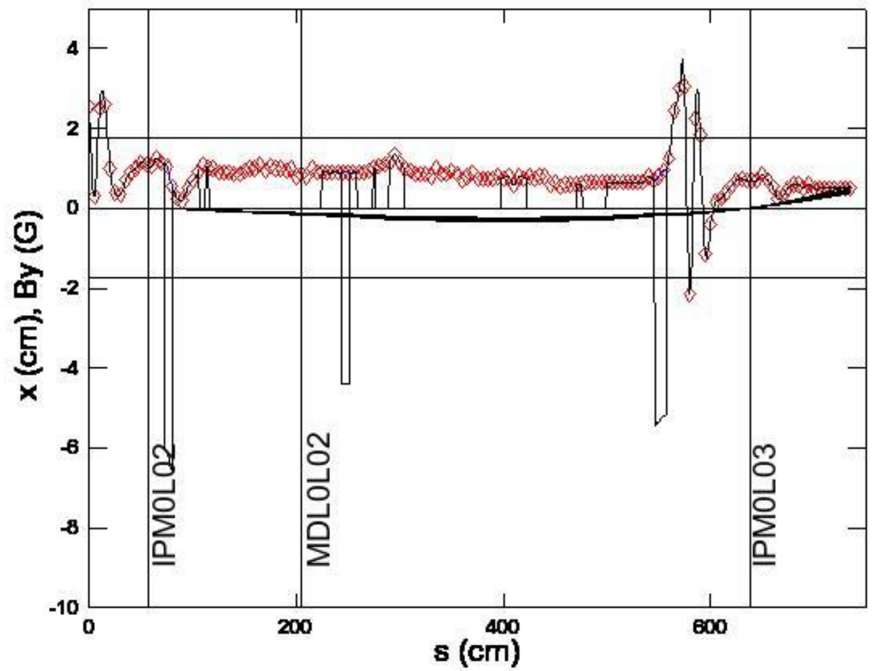
- Magnetic fields other than dipole play important role:
  - Stray B_y field (red points) from Earth and Ion Pumps
  - Distributed mu-metal helps shield beam from stray field
  - Steering coils provide distributed point-correction

- Constructed simple model to track fields
  - Plots show trajectories for 4.5-6.5 MeV/c in 0.5 MeV/c increments
  - Without steering coils beam is “lost” to pipe wall x=1.75cm
  - With steering coils orbit is realistic and quasi-independent of momentum

With Stray. Without Mu-Metal, Steering Coils



With Stray, Mu-Metal, Steering Coils



- Record SRF gradient, steering coils, Bubble dipole and beam positions.

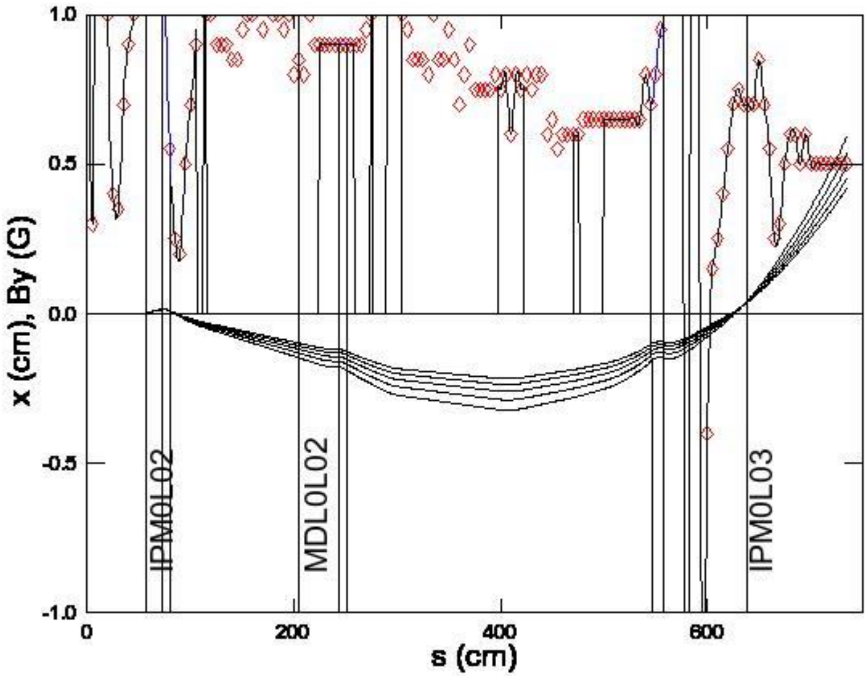
Conditions for individual measurements						*Undeflected*			*Deflected*		
R028	*MBH0L01*	*MHB0L02*	*MHB0L02A*	*MHB0L02B*	*MBH0L03*	*MDL0L02*	*IPM0L02.XPOS*	*IPM0L03.XPOS*	*MDL0L02*	*IPM5D00.XPOS*	*IPM5D01.XPOS*
MV/m	*mA*	*mA*	*mA*	*mA*	*mA*	*G-cm*	*mm*	*mm*	*G-cm*	*mm*	*mm*
3.35	-325.00	-292.00	-214.54	-0.03	-342.83	0.00	0.03	0.22	7109.57	0.00	3.50
3.74	-327.00	-293.00	-214.54	-0.03	-342.83	0.00	0.08	0.17	7384.34	0.01	3.67
4.12	-329.00	-292.00	-214.54	-0.03	-342.83	0.00	0.06	0.15	7646.01	0.00	4.06
4.50	-332.00	-286.00	-214.54	-0.03	-342.83	0.00	-0.02	0.00	7927.59	0.00	3.89
4.89	-333.00	-287.00	-214.54	-0.03	-342.83	0.00	0.05	0.21	8185.00	0.03	3.85

- Convert recorded beam positions (*.XPOS*) to absolute survey positions (*.XCOR*).
  - Assumed calibration of beam position monitor to quadrupole σ = 0.50 mm
  - Assumed survey of quadrupole to absolute coordinates σ=0.25 mm

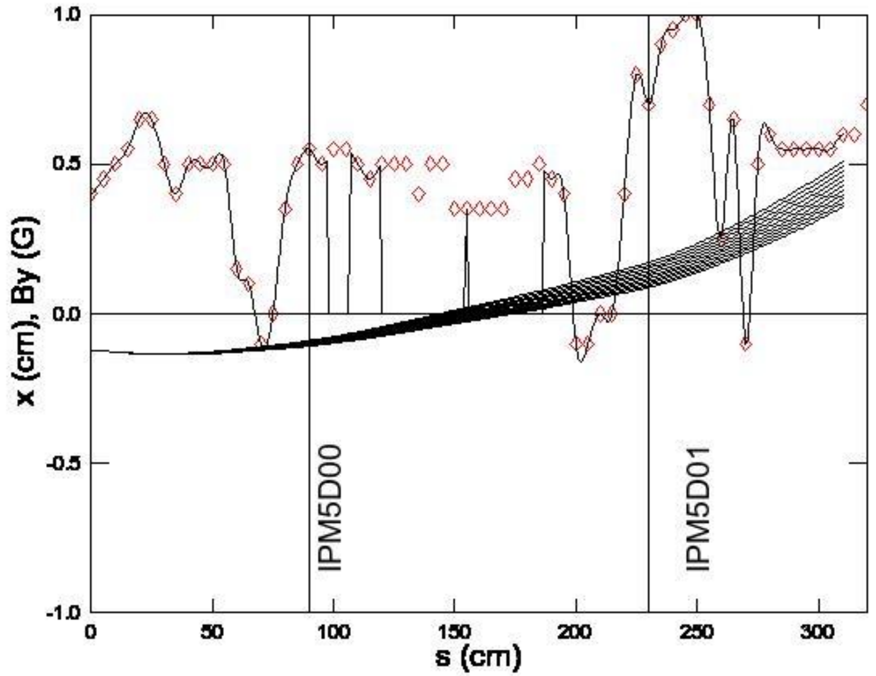
Constant	*Undeflected*						*Deflected*					
R028	*IPM0L02.XPOS*	*MQJ0L02.XOFF*	*IPM0L02.XCOR*	*IPM0L03.XPOS*	*MQJ0L03A.XOFF*	*IPM0L03.XCOR*	*IPM5D00.XPOS*	*MQD5D00.XOFF*	*IPM5D00.XCOR*	*IPM5D01.XPOS*	*MQD5D01.XOFF*	*IPM5D01.XCOR*
MV/m	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*
3.35	0.03	-0.01	0.04	0.22	-0.24	0.46	0.00	-0.27	0.27	3.50	-0.22	3.72
3.74	0.08	-0.01	0.09	0.17	-0.24	0.41	0.01	-0.27	0.28	3.67	-0.22	3.89
4.12	0.06	-0.01	0.07	0.15	-0.24	0.39	0.00	-0.27	0.27	4.06	-0.22	4.28
4.50	-0.02	-0.01	-0.01	0.00	-0.24	0.24	0.00	-0.27	0.27	3.89	-0.22	4.11
4.89	0.05	-0.01	0.06	0.21	-0.24	0.45	0.03	-0.27	0.30	3.85	-0.22	4.07

- Model trajectories using beam positions and propagate uncertainties
  - Use 0L BPM’s to constrain orbit and predict beam (X,X’) at dipole MDL0L02
  - Use (X,X’) at dipole and 5D BPM’s to determine how much θ <> 25.0°
  - Correct Jay’s model calculation proportionally : $P_{TOSCA}(25.0°)\bullet[25.0°/(25.0°+\theta)]$

Model of Undeflected 0L beam line



Model of Deflected 5D beam line



- Model predicts dipole deflected beam in excess of 25.0° by <θ>:

$$\langle\theta\rangle = 1.311 \pm 0.267\ mrad = 0.0751° \pm 0.015°$$

- Error budget for Mott Run II

Contribution	*Value*
TOSCA Model (Ref [4])	0.10%
Magnet Power Supply Calibration	0.01%
Model Correction	0.06%
Total	**0.12%**

- Summary for Mott Run II

Conditions		*Momentum*			*Kinetic Energy*	
R028	*MDL0L02*	*TOSCA*	*Corrected*		*Final*	
GSET	*BL*	P_T	P_C	δP_C	*T*	δT
MV/m	*G-cm*	*MeV/c*	*MeV/c*	*MeV/c*	*MeV*	*MeV*
3.350	7109.570	5.035	5.020	0.006	4.535	0.006
3.740	7384.340	5.229	5.213	0.006	4.727	0.006
4.120	7646.010	5.415	5.399	0.006	4.912	0.006
4.500	7927.590	5.614	5.597	0.007	5.109	0.007
4.890	8185.000	5.797	5.780	0.007	5.291	0.007

- Recommendations for Bubble
  - Shielding helpful, but probably not global solution => still need model
  - Improve beam position monitoring around (0L) or further from (5D) dipole
  - Greatest “bang for effort” systematic study of model for non-ideal orbits