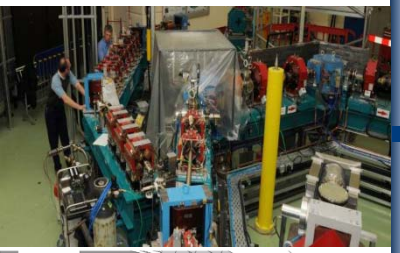
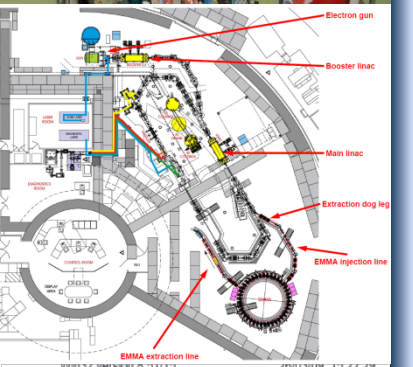
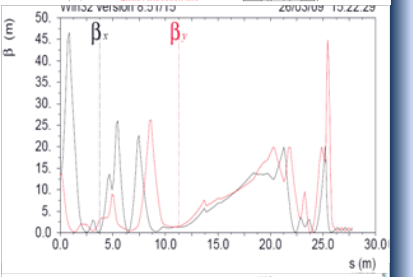
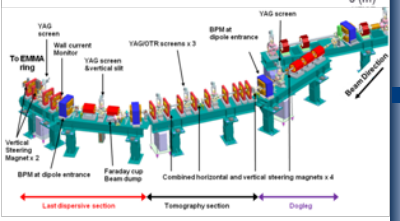
The Cockcroft Institute
of Accelerator Science and Technology









Science & Technology Facilities Council
Daresbury Laboratory

UNIVERSITY OF LIVERPOOL

Modification of the EMMA Injection Line to act as a Full-Energy Electron Beam Diagnostic for ALICE

David Holder

The Cockcroft Institute

and the University of Liverpool Department of Physics.

25th June 2009

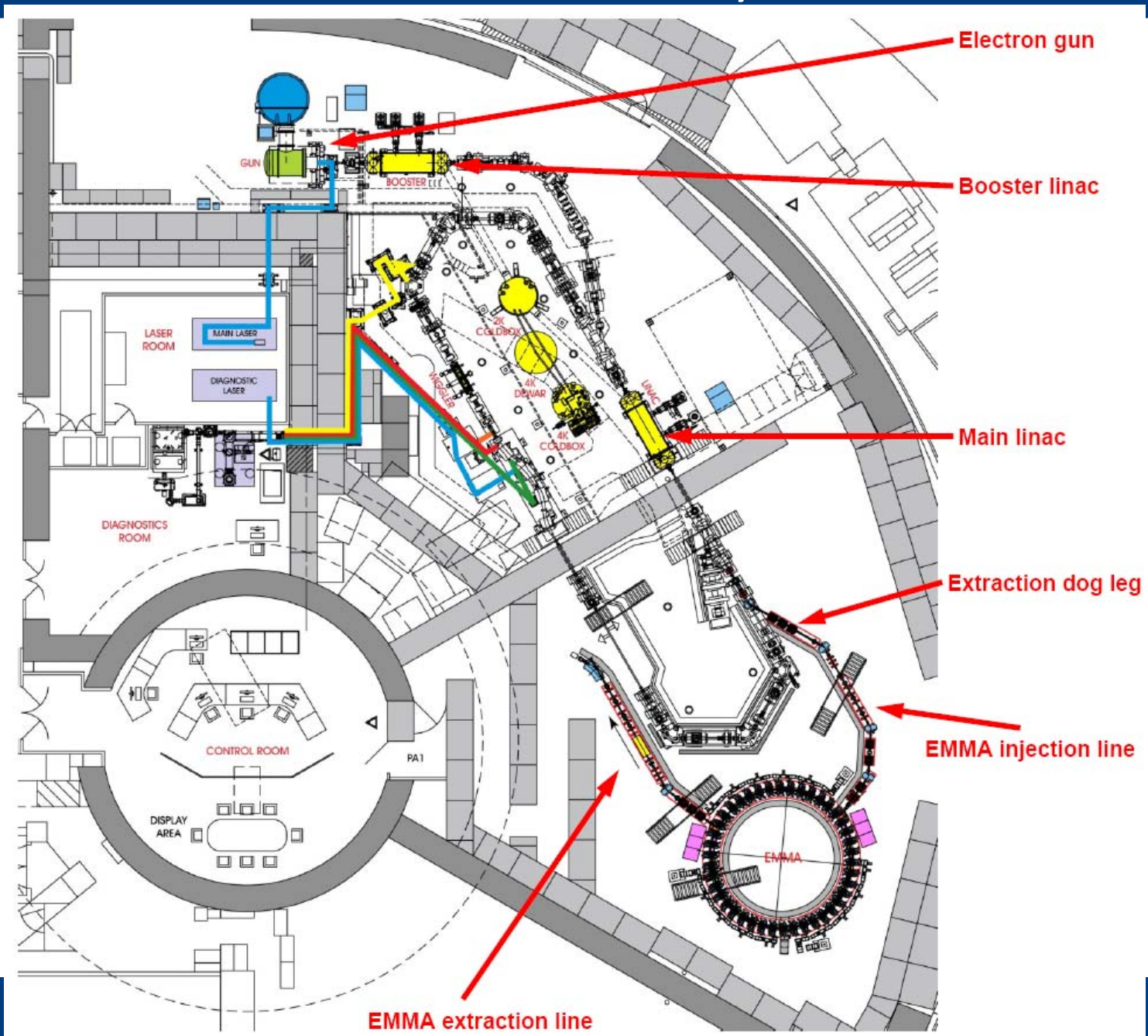
ASTeC

Accelerator Science and Technology Centre

Outline of Project

- Step 1: Assessment as to whether this modification is technically and financially viable;
- Step 2: Specification of the changes required;
- Step 3: Calculation of the magnet settings required for the successful propagation of the electron beam down the modified line in the presence of space charge.

ALICE & EMMA Layout



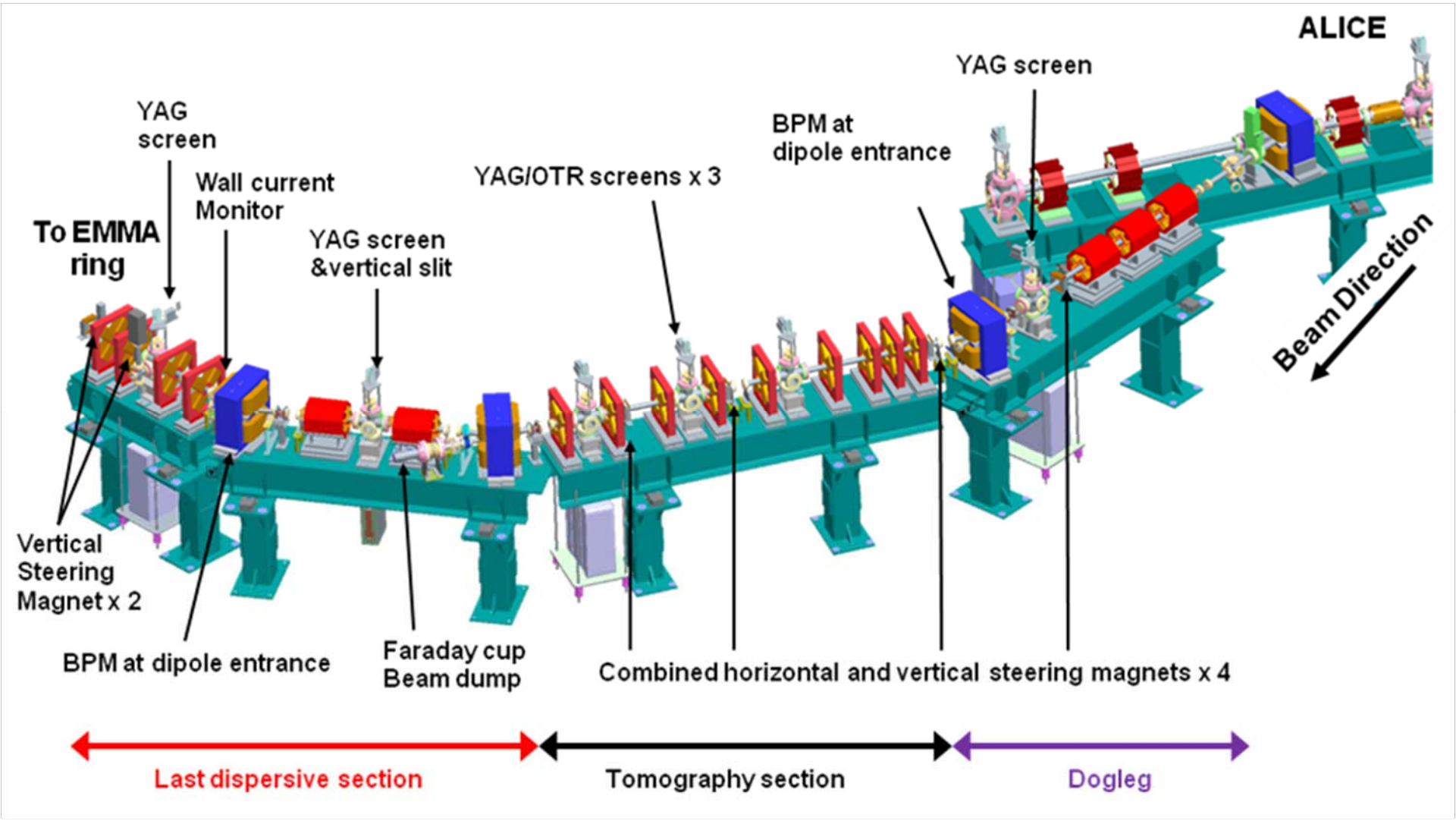
ALICE Status

- Gun voltage 230 kV (c.f. 350 kV nominal – limited by Stanford ceramic);
- Injector energy 4.8 MeV (correct ratio to full energy must be maintained);
- Full energy 20.8 MeV (limited by SCRF cavity performance);
- Energy recovery demonstrated;
- Coherent terahertz radiation obtained;
- Cryosystem problems currently.

ALICE & EMMA Parameters

	ALICE	EMMA	
Nominal gun energy	**350**		keV
Actual gun energy	**230**		keV
Nominal injector energy	**8.35**		MeV
Actual injector energy	**4.8**		MeV
Nominal circulating beam energy	**35**		MeV
Actual circulating beam energy	**20.8**		MeV
Injection energy		**10 to 20**	MeV
Nominal bunch charge	**80**		pC
Bunch charge		**1 to 32**	pC

Layout of EMMA Injection Line



Nominal 20 MeV Magnet Parameters Rescaled for 35 MeV

Magnet type	K1 (m^{-2})	Gradient (T/m)	Field (T)	Voltage (V)	Current (A)	I density (A/mm^2)
		20 MeV				
F dipole		-	0.173	16.8	6.0	0.8
G dipole		-	0.190	14.0	5.3	0.7
G quadrupole	20	1.4	-	1.0	66	
H quadrupole	124	8.5	-	8.5	5.6	1.4
		35 MeV				
F dipole		-	0.303	**29.4**	**10.5**	1.4
G dipole		-	0.333	**24.4**	**9.3**	1.2
G quadrupole	20	2.4	-	1.7	**115**	
H quadrupole	124	14.7	-	14.9	9.9	2.5

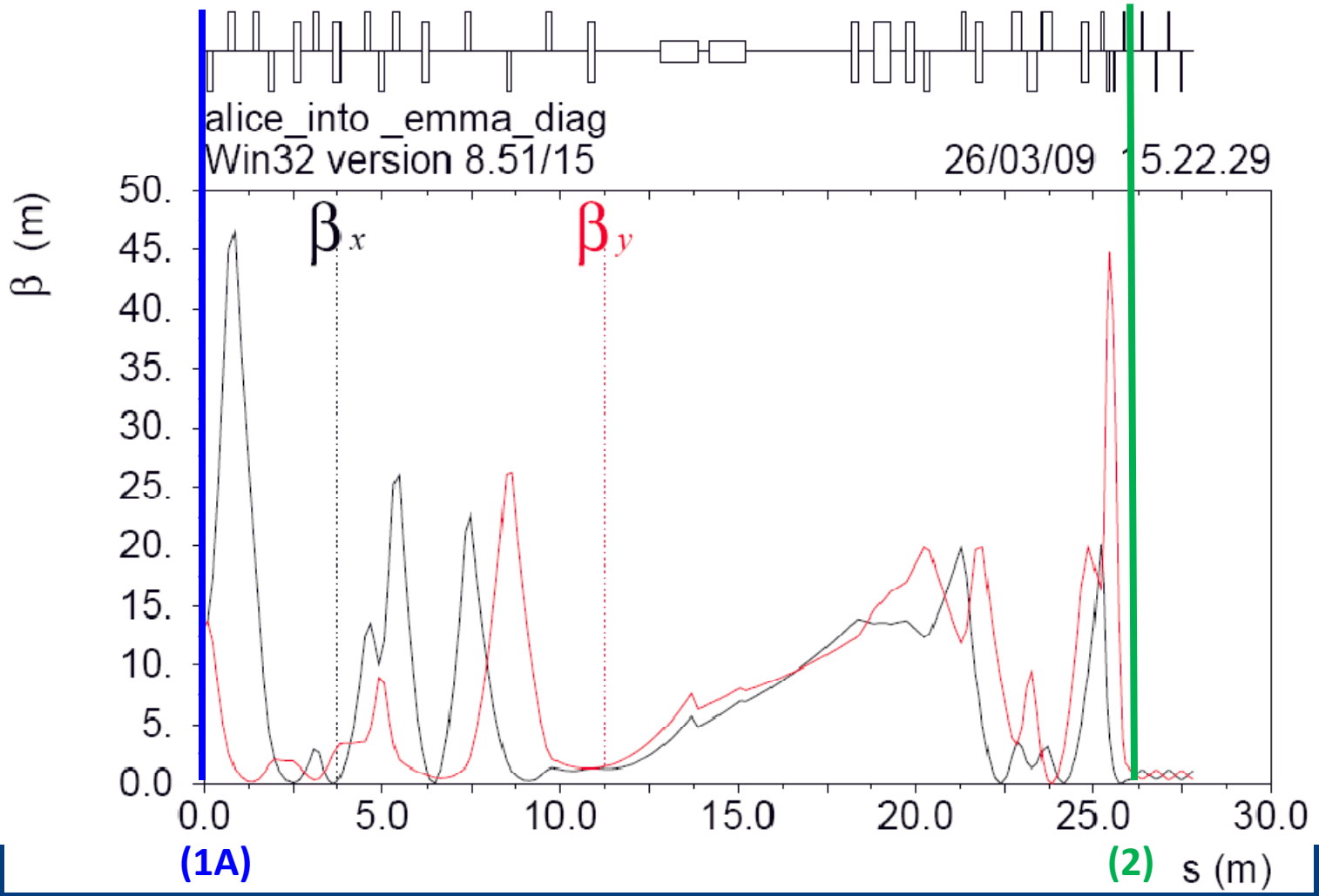
	Existing power supply:	**Rating** (V)	(A)	**Max I** (A)
F dipole	Needs up-rating	20	10	6.7
G dipole	Needs up-rating	20	10	6.7
G quadrupole	Needs up-rating			66
H quadrupole	OK	20	10	9.9

MAD Modelling

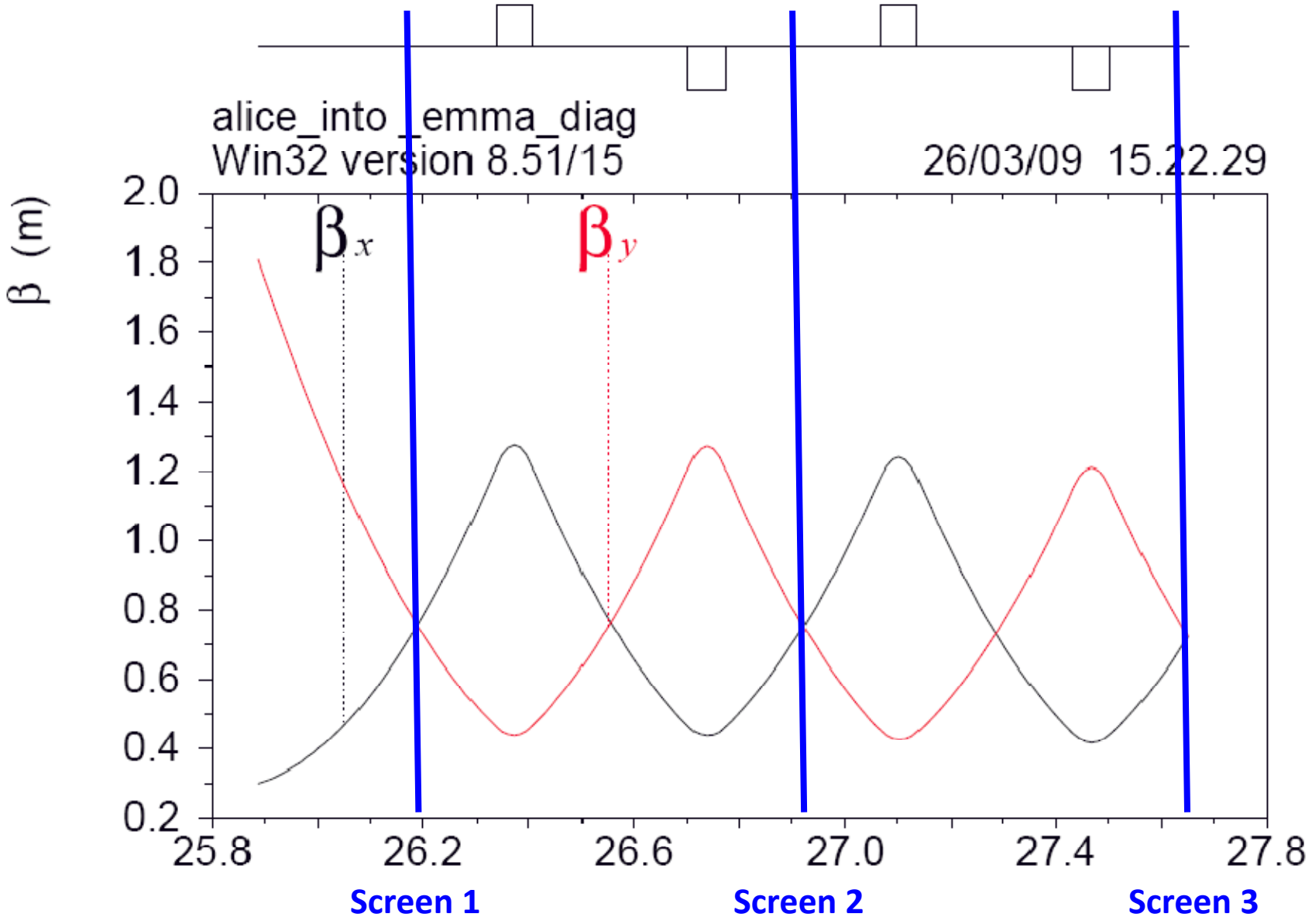
- Standard ALICE lattice 8.5 tuning from the exit of the booster module to the new extraction dipole;
- Zero dispersion in the extraction dog leg;
- Beta functions between main linac and start of the matching section <20 m;
- Matched to specific Twiss parameters at the first screen of the tomography diagnostic;
- Quadrupole gradients must not exceed the limit set by the new magnet power supplies.

MAD Modelling

	α_x	α_y	β_x (m)	B_y (m)
(1A) ALICE booster exit	-2.2	-2.2	13.4	13.4
(2) Tomography section entrance	-1.235	1.235	0.7439	0.7439



MAD Modelling – Tomography Section

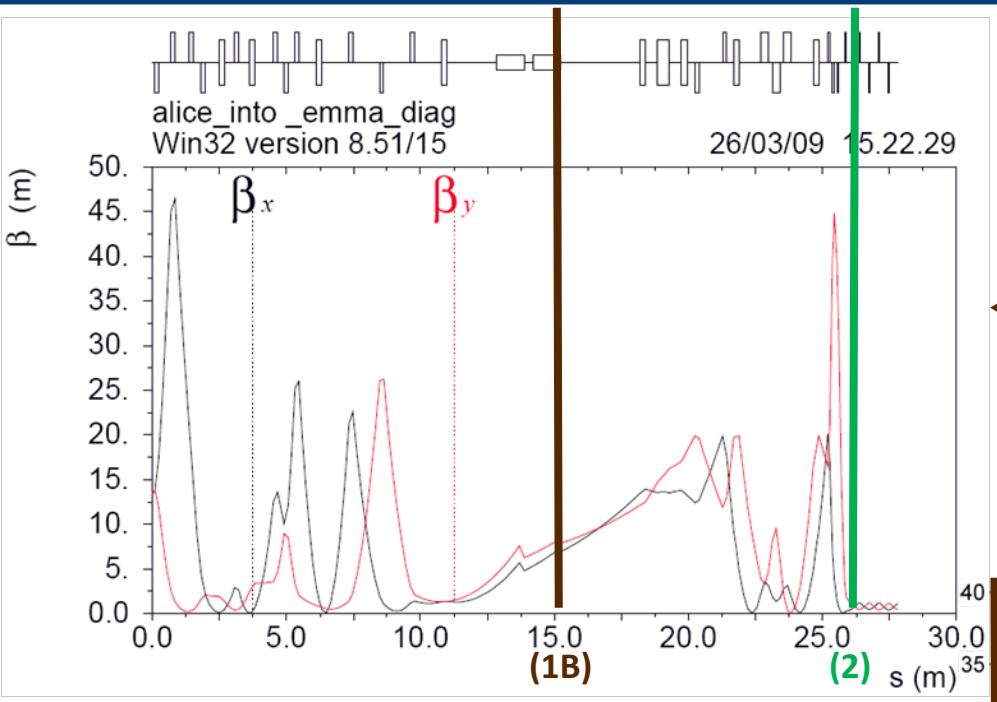


GPT Modelling

- Twiss parameters at the exit of the main linac determined by MAD result;
- No changes in the extraction dog leg (to maintain zero dispersion here);
- Matched to the same Twiss parameters at the first screen of the tomography diagnostic.

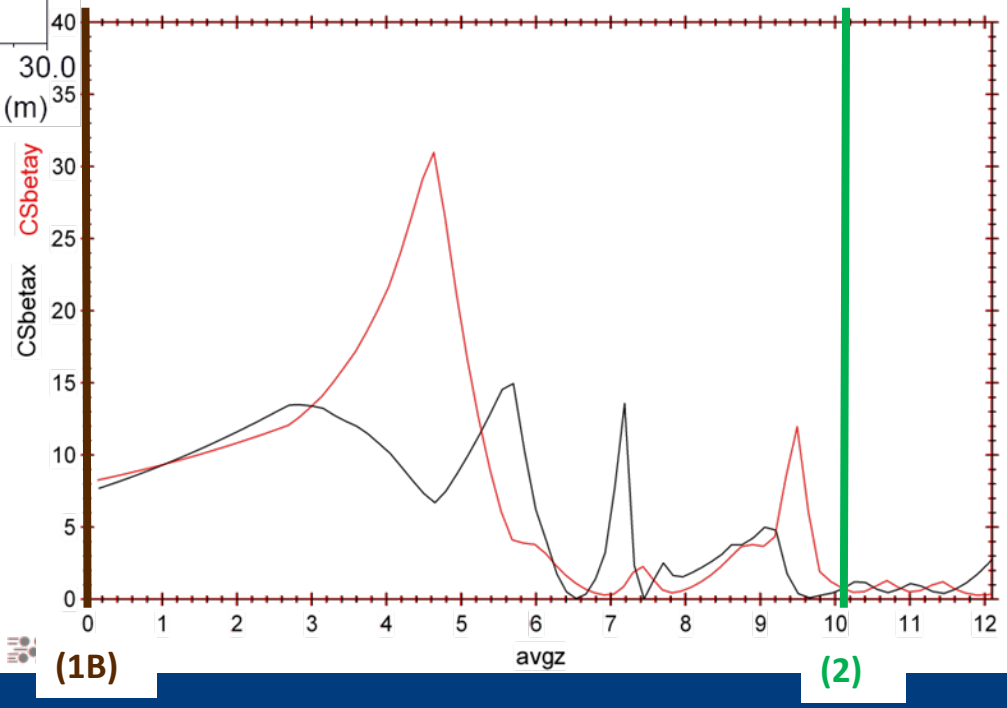
	α_x	α_y	β_x (m)	B_y (m)	**Normalised emittance**
(1B) ALICE linac exit	-0.863	-0.553	7.644	8.333	3
(2) Tomography section entrance	-1.235	1.235	0.7439	0.7439	(mm.mrad)

GPT Modelling

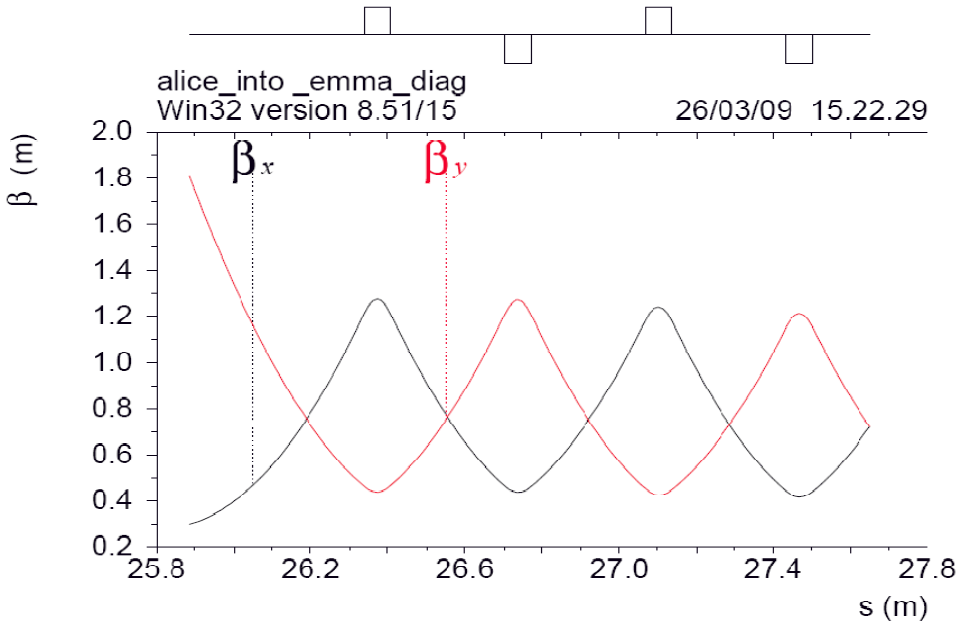


MAD

GPT

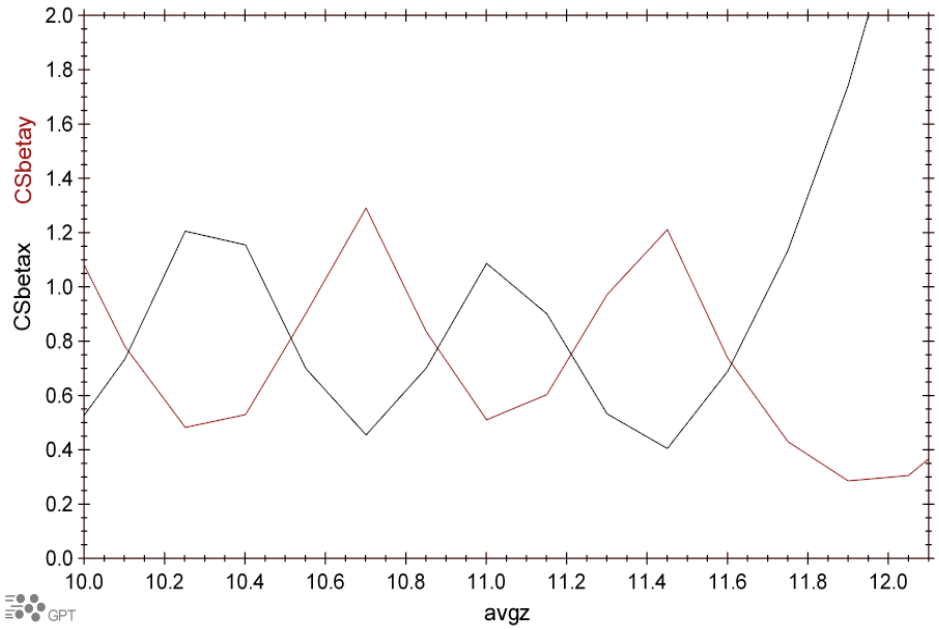


GPT Modelling – Tomography Section

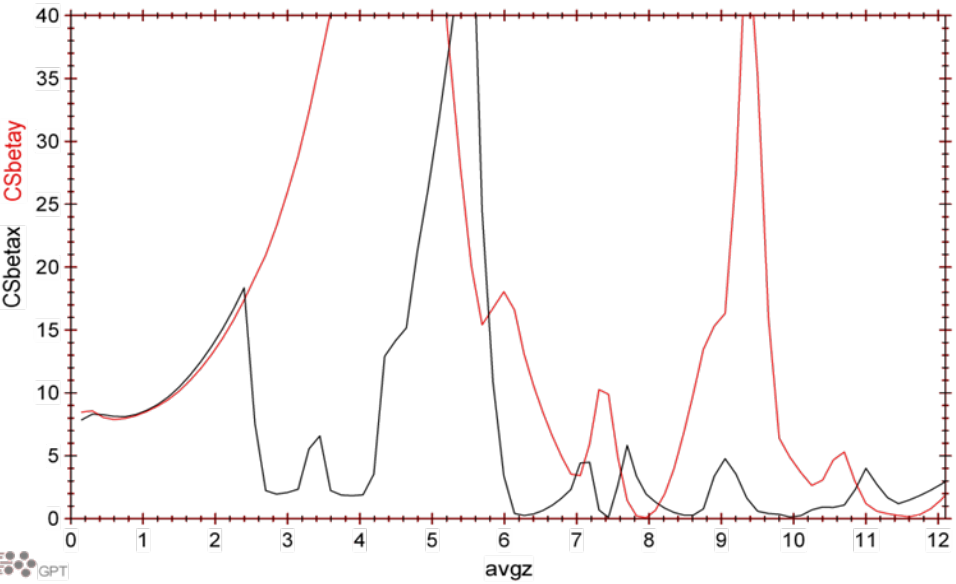


MAD

GPT

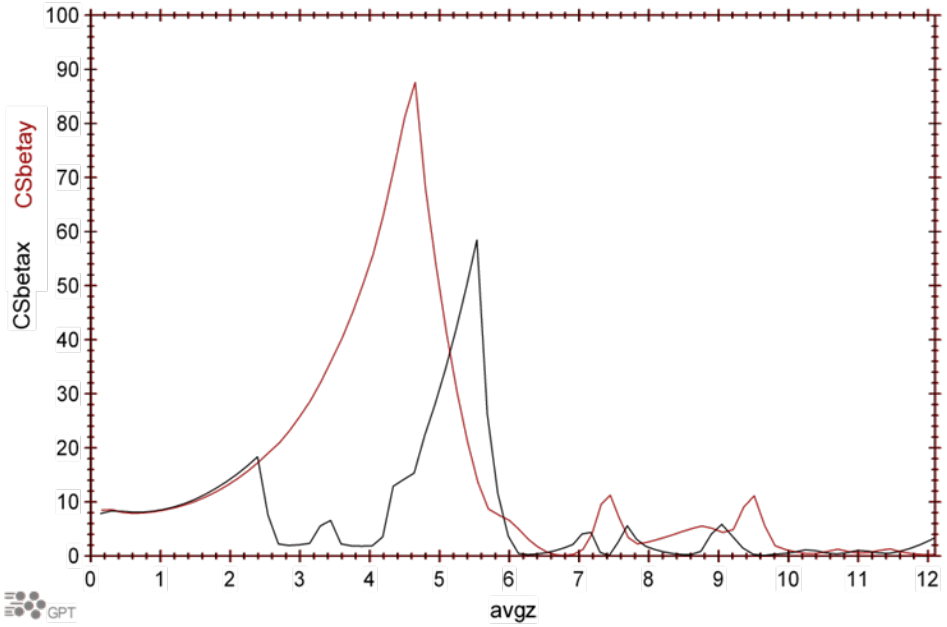


GPT Modelling with Space Charge Compensation



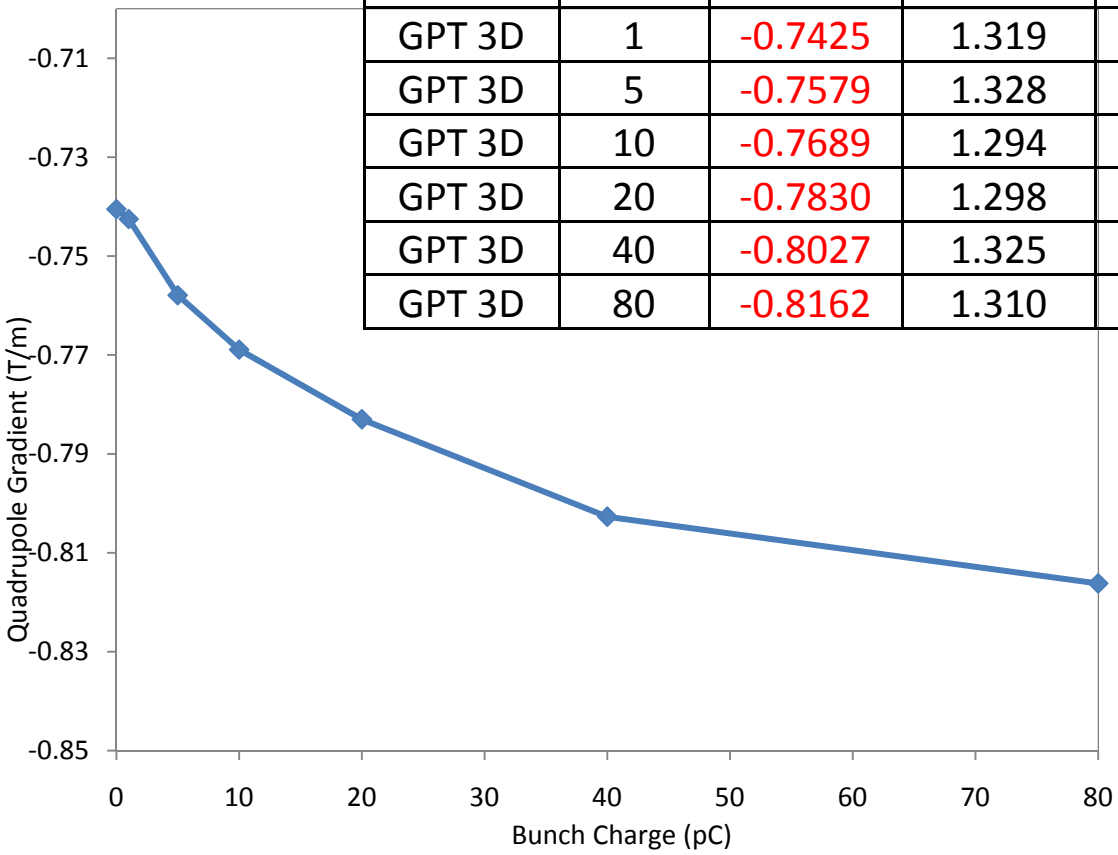
80 pC, no space charge compensation

80 pC, with space charge compensation



GPT Modelling with Space Charge Compensation

Space charge method	Bunch charge	ST1-QUAD-01	ST1-QUAD-02	EMI-QUAD-04	EMI-QUAD-05	EMI-QUAD-06	EMI-QUAD-07
		B	B	B	B	B	B
	(pC)	(T/m)	(T/m)	(T/m)	(T/m)	(T/m)	(T/m)
MAD	-	-0.3113	0.9673	7.148	-5.318	-3.496	16.04
GPT 3D	0	-0.7405	1.314	5.132	-1.055	-5.779	7.118
GPT 3D	1	-0.7425	1.319	5.140	-1.013	-5.781	7.012
GPT 3D	5	-0.7579	1.328	5.259	-0.980	-5.812	6.972
GPT 3D	10	-0.7689	1.294	5.501	-0.912	-5.869	6.900
GPT 3D	20	-0.7830	1.298	5.527	-0.894	-5.857	6.898
GPT 3D	40	-0.8027	1.325	5.547	-0.875	-5.838	6.904
GPT 3D	80	-0.8162	1.310	5.695	-0.816	-5.844	6.872



Conclusion

- Feasibility of converting the EMMA injection line into a useful diagnostic for measuring the properties of the full-energy ALICE beam was assessed;
- Hardware changes specified:
  - No changes to any of the existing magnets;
  - Increased the current & voltage limit of magnet power supplies;
  - Add OTR screens in parallel to the existing YAG screens;
- Effect of space charge at 35 MeV/80 pC calculated and corrected for.

The end…