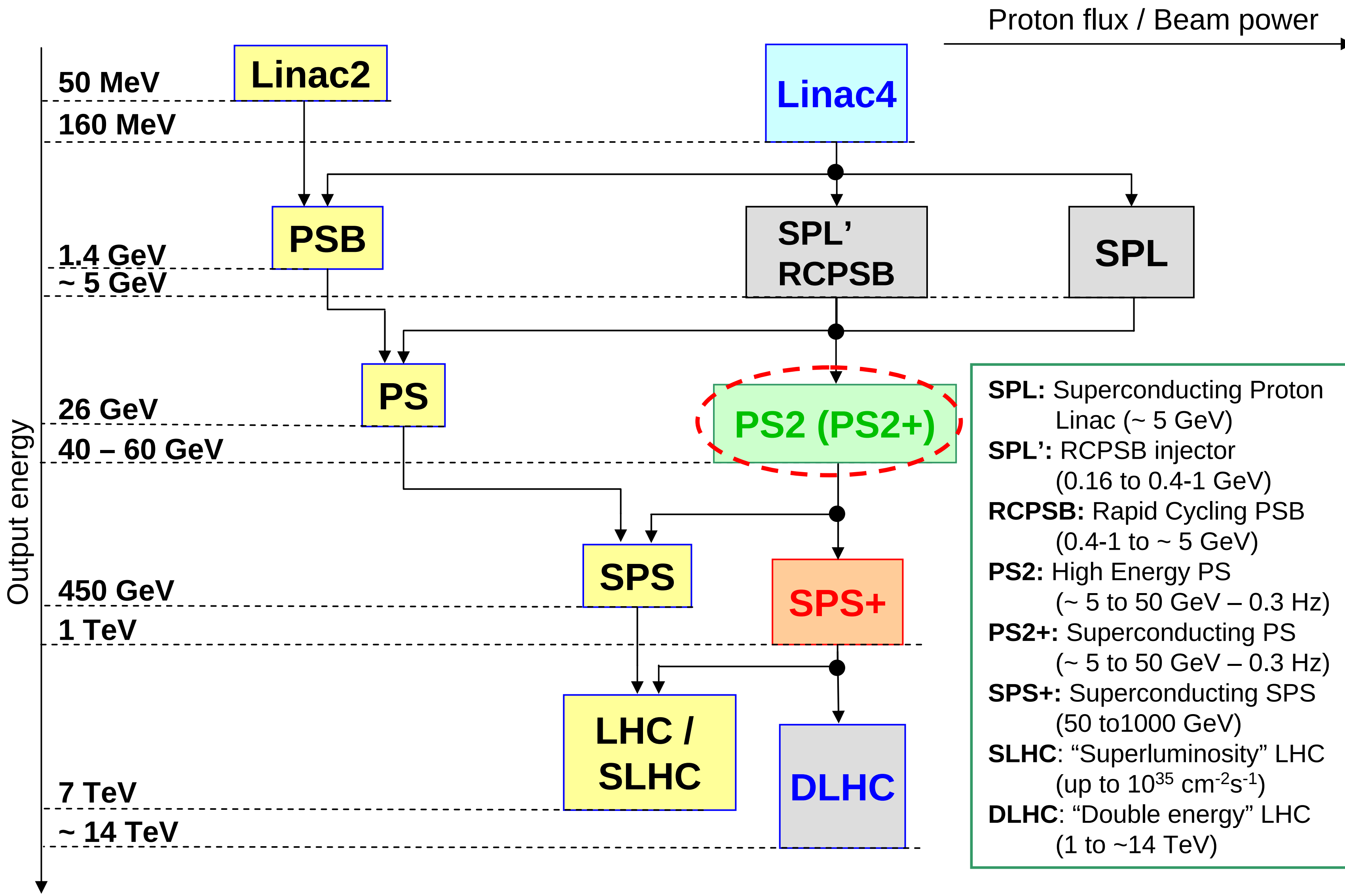
LIS section meeting

PS2 design status

Y. Papaphilippou

April 30th, 2007

Upgrade of the injector chain (R. Garoby, PAF)

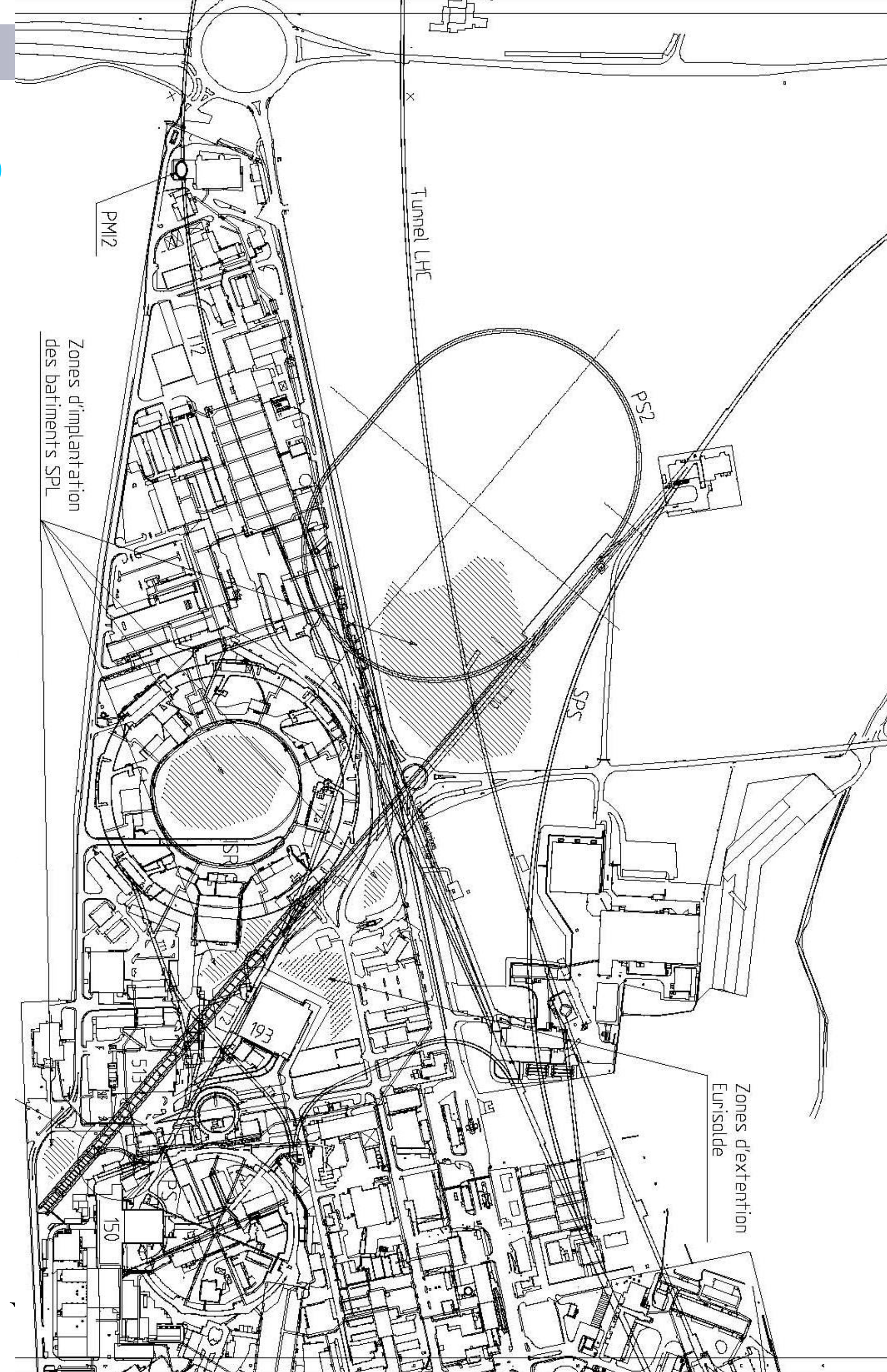


Physics benefits (R. Garoby, PAF)

STAGE	1	2	3	4
DESCRIPTION (*new accelerator*)	*Linac4* PSB PS SPS	*Linac4* PSB *PS2 or PS2+* (& PS) SPS	*Linac4* *SPL* *PS2 or PS2+* SPS	*Linac4* *SPL* *PS2 or PS2+* *SPS+*
Performance of LHC injectors (SLHC)	+ Ultimate beam from PS	++ Ultimate beam from SPS	++ Maximum SPS performance	+++ Highest performance LHC injector
Higher energy LHC	-	-	-	+++
β beam	-	-	++ (γ ~100)	++ (γ ~200)
ν Factory	-	-	+++ (~5 GeV prod. beam)	+++ (~5 GeV prod. beam)
k, μ	-	~150 kW beam at 50 GeV	~400 kW beam at 50 GeV	~400 kW beam at 50 GeV
EURISOL	-	-	+++	+++

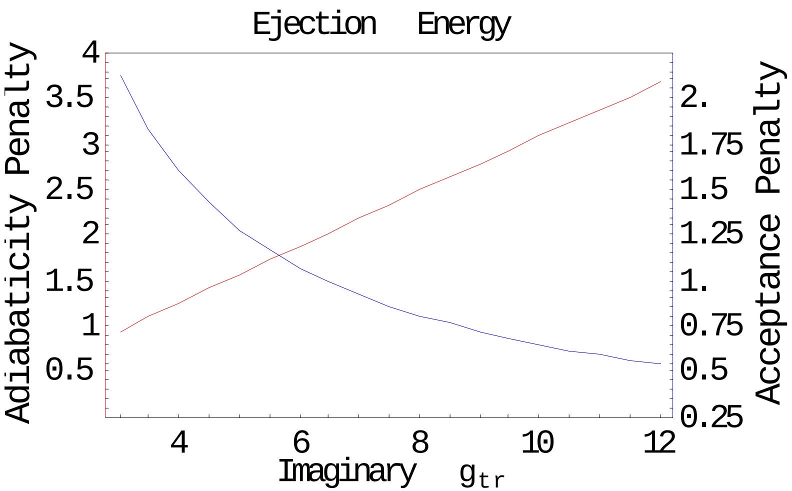
Main parameters (M. Benedikt)

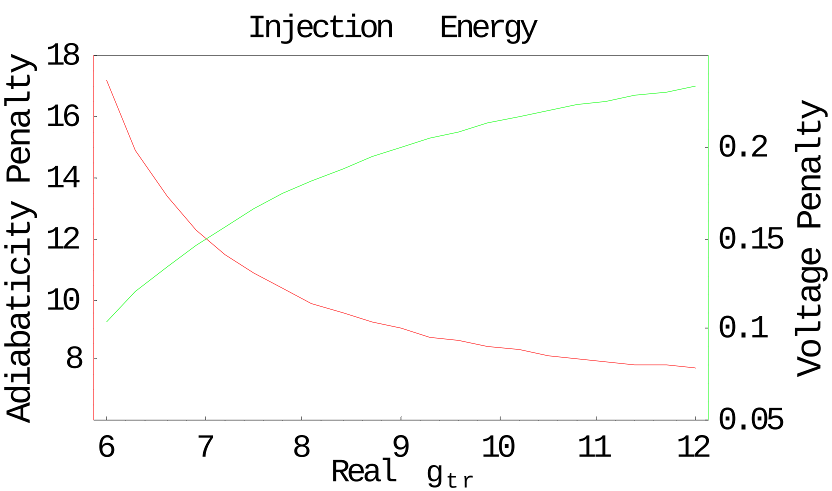
- Goal: achieve double LHC ultimate bunch intensity with a 20% loss margin, i.e. 4.1×10^{11} protons per LHC bunch
- Minimum circumference of $2C_{PS}$=1257m for extraction energy of 50 GeV and normal conducting magnet technology (1.8 T maximum bending field)
- Injection energy can be constrained by incoherent space-charge tune-shift considerations and scaling from PS:
  - $\beta\gamma^2_{PS2} = (2 \times 1.2) \times \beta\gamma^2_{PS} \times (C_{PS2} / C_{PS}) > 4.8 \times \beta\gamma^2_{PS}$
  - The condition is satisfied for energies of 4GeV and above



RF considerations (S. Hancock)

- RF manipulations are instrumental for good performance of present PS
- RF requirements were considered as **basic input** for lattice design: adiabaticity (synchrotron frequency) + longitudinal acceptance (RF Voltage) on γ_t.
- RF cavities of RF similar to PS (10 MHz (400 kV), 20, 40, 80 MHz systems for LHC) with gymnastics at low and high energy
  - Ideal γ_t around 6i
- PS2 RF with SPL as injection (40 MHz, system only, ~1.5 MV)
  - Injection of any bunch pattern up to 40 MHz with SPL chopping.
  - No gymnastics at low energy, bunch shortening (adiabatic or non ad.) at high energy
  - γ_t between 6 and 10 (real or imaginary)





RF constraints on the PS2 size (R. Garoby)

- Circumference of PS2 and SPS are multiples of bunch spacing

$$C_{SPS} = h_{SPS} \cdot d_b$$

$$C_{PS2} = h_{PS2} \cdot d_b$$

- For the following bunch spacing the largest common divider is 154=2x7x11

Time interval (ns)	h_{SPS}	
2.5	9240	8x3x5x7x11
5	4620	4x3x5x7x11
10	2310	2x3x5x7x11
12.5	3080	8x3x7x11
15	1540	4x5x7x11
25	924	4x3x7x11
50	462	2x3x7x11
75	308	4x7x11

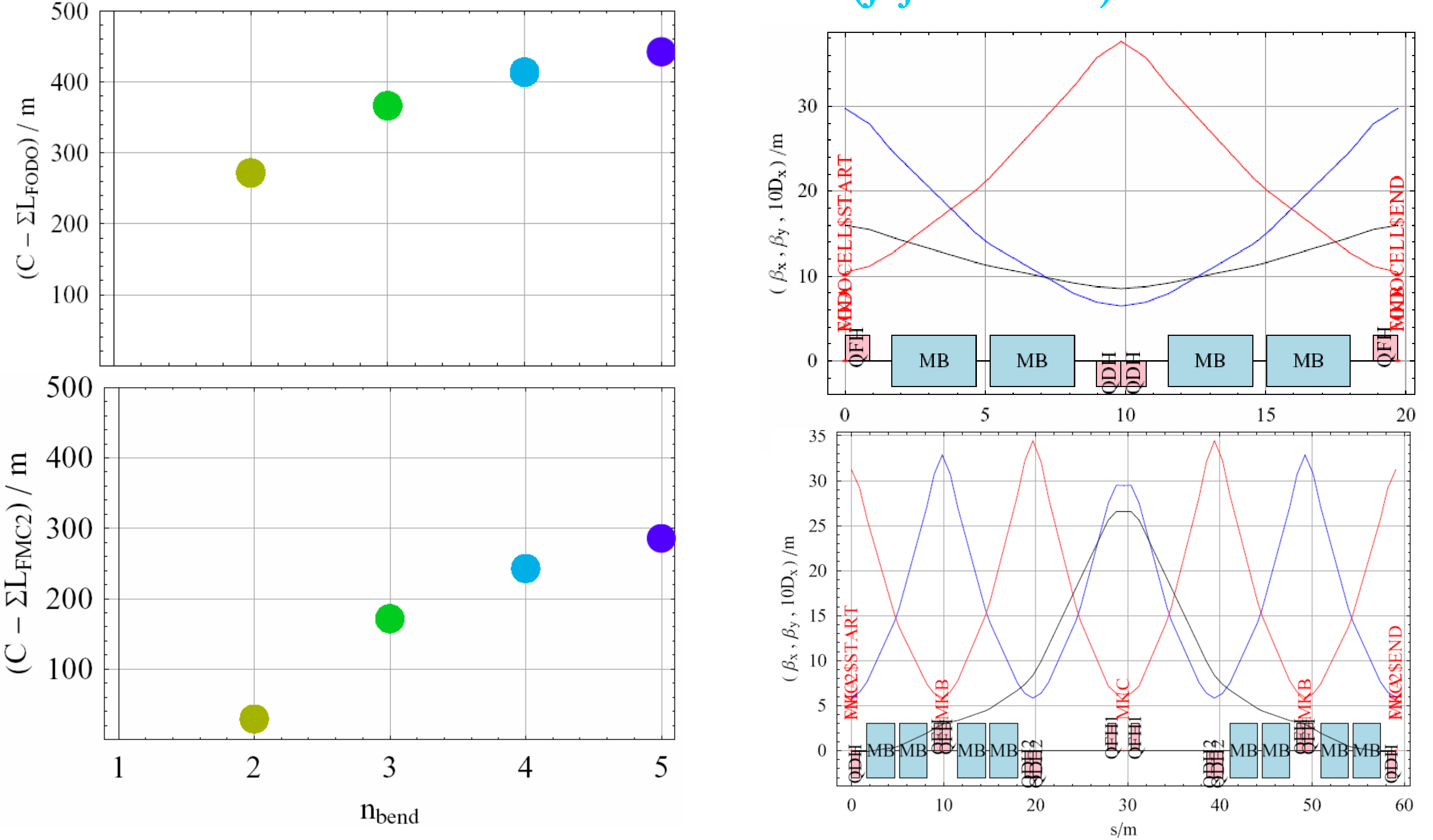
C_{SPS}/C_{PS2}			h_{PS2} (75 ns)	h_{PS2} (50 ns)	Comment
154/14	11	11	4x7	2x3x7	PS size
154/22	7	7	4x11	2x3x11	
154/28	**11/2**	**5.5**	**8x7**	**4x3x7**	2 x PS
154/30	**77/15**	**5.1333..**	**4x3x5**	**2x9x5**	
154/31		4.9677..	2x31	3x31	
154/32	**77/16**	**4.8125**	**64**	**32x3**	
154/33	**14/3**	**4.6666..**	**2x3x11**	**9x11**	
154/34	**77/17**	**4.5294..**	**4x17**	**2x3x17**	
154/35	22/5	4.4	2x5x7	3x5x7	
154/36	**77/18**	**4.2777..**	**8x9**	**4x27**	
154/37		4.1621..	2x37	3x37	
154/38	77/19	4.0526	4x19	2x3x19	
154/39		3.9487..	2x39	3x39	

Lattice considerations (J. Jowett et al.)

- Arc modules treated:
  - FODO, FMC with FODO, Doublet, Triplet, FMC2 (=FMC with DOFO), FMC module with FODO, missing dipole
  - Varying number of bends, phase advances, etc
  - Matched for unequal vertical and horizontal phase
  - Tunability, “neck-tie diagrams”.
  - More realistic drift spaces for sextupoles, BPMs, etc.,
- Preliminary conclusions
  - FODO remains straightforward choice
  - Triplet or Doublet can achieve lower (real) γt.
  - FMC2 could has narrower tuning range in phases and large optical functions

	$(2C_{PS}-\Sigma L_{cell})$/m	γ_t(PS2)	K_{QF} /m^{-2}	K_{QD} /m^{-2}	K_{QF1} /m^{-2}	K_{QD2} /m^{-2}	$\int\lvert K_1\rvert ds$ /m	max β_x/m	max β_y/m	max D_x/m
FODOoptics[2,90,90]	272.	13.1	0.0873	−0.087			15.3	32.8	32.8	1.7
FODOoptics[3,90,90]	367.	9.15	0.0633	−0.0628			7.35	44.7	44.5	3.46
TripletROModule[200,3,90,90]	210.	9.12	0.104	−0.0982			20.2	25.6	48.1	2.87
TripletROModule[200,4,90,90]	297.	7.17	0.0929	−0.0885			13.6	32.	56.8	4.68
DoubletModule[200,2,90,90]	302.	14.3	0.156	−0.156			27.3	27.4	27.3	1.49
DoubletModule[200,3,90,90]	387.	9.93	0.13	−0.13			15.1	36.4	36.1	3.01
DoubletModule[200,4,90,90]	429.	7.63	0.114	−0.113			9.92	45.1	44.5	5.02
FMC2module[200,3,90,90,0.5]	172.	9.99 *i*	0.0633	−0.0628	0.174	−0.113	17.2	63.2	89.6	5.21
FMC2module[200,4,90,90,0.5]	243.	7.19 *i*	0.0496	−0.0489	0.143	−0.092	10.4	83.9	123.	8.89
FMC2module[200,4,90,90,1.5]	143.	15.4 *i*	0.0496	−0.0489	0.0837	−0.0649	7.91	62.7	81.3	9.16

Lattice considerations II (J. Jowett et al.)



For more info see G:\Users\j\jowett\Public\LookHere\MB\PS2\PS2Optics.nb

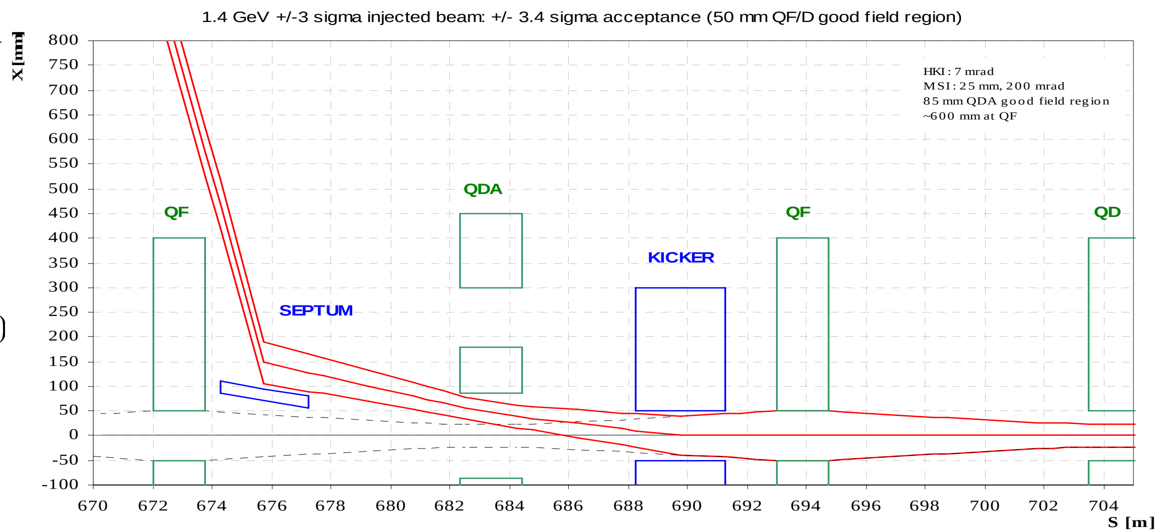
Lattice considerations III (W. Bartmann)

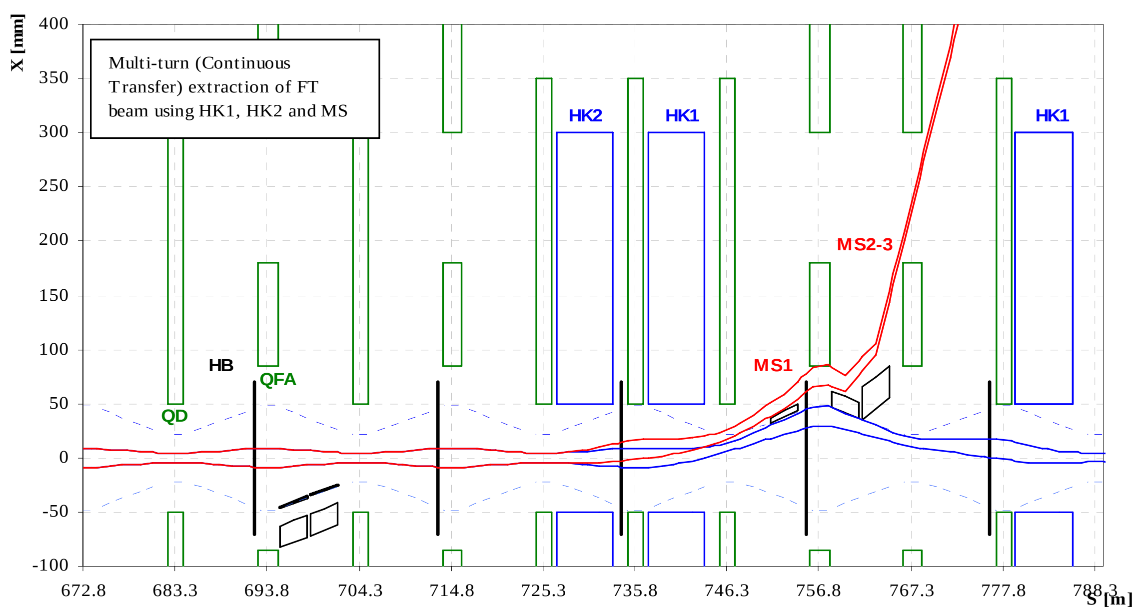
	# arc cells	C [m]	ℓ_d [m]	n_d	L_{cell} [m]	SS_{total} [m]	free drift betw. 2 quads [m]	E_{kin} (1256.6m) [GeV]
FODO (4)	26	1253	3.00	200	19.6	235	8.3	50.8
FODO (6)	18	1259	2.94	204	26.2	315	11.6	50.5
FODO (6)	21	1273	2.50	240	23.6	283	10.3	49.7
Doublet (4)	26	1391	3.00	200	21.7	261	15.9	44.2
Doublet (6)	18	1363	2.94	204	28.4	341	22.5	45.0
Doublet (6)	20	1380	2.63	228	26.5	318	20.7	44.3
Triplet (6)	18	1536	2.94	204	32.0	384	22.5	37.4

- Within a certain cell type, circumference remains almost the constant
- Doublet and Triplet cells provide larger free drift than FODO cell
- The FODO structure has the largest bending power per cell

Injection / Extraction (B. Goddard et al.)

- Hypothesis: racetrack machine with long SS parallel to TT10
  - Injection from TT10 (or new injection line)
  - Extraction towards SPS point 1
- Injection requirements
  - H^- @ 4 GeV with ~ 100 turns (500 μs)
  - Fast bunch-to-bucket injection from PS, RCS or LEIR (ions directly)
- Extraction requirements
  - Fast towards SPS for LHC type beams
  - Five turn continuous (MTE) towards SPS for fixed target physics.
  - Slow extraction and fast extraction for PS2 physics
- Single extraction channel for all extractions
  - Presently study of transfer line towards SPS (for FODO PS2) and separation for PS2 exp. areas.





Constraints for MTE on PS2 (M. Giovannozzi and YP)

- Non-linear elements
  - Two pairs of sextupoles/octupoles separated by 2π, installed in a dispersion-free region to avoid chromatic effects. Place them in the RF region for flexibility in the choice of phase advances and avoid interference with extraction bumps
  - Minimum β_y and maximum β_x for optimal strength and minimal non-linear coupling. Taking into consideration that in the actual PS the optics functions near their location are **$(\beta_x,\beta_y)= (22,12)$m**, an optics with **$\beta_x>30$m** and **$\beta_y < 10$m** is ideal.
  - Scaling from the actual PS, and assuming the same β functions, the maximum integrated strength needed @ 50GeV is around **175 $T.m^{-1}$** for the sextupoles and **4715 $T.m^{-2}$** for the octupole. Strengths can be scaled by reducing diameter, increasing length, number of elements, or horizontal beta, to achieve reasonable pole tip field. Similar scaling for 75GeV
  - Additional sextupole/octupoles in different phase advances for cancelling any non-linear effect produced by the MTE elements and the fine tuning of beamlets' properties
- Slow bump
  - Outside of the nonlinear elements to avoid feed-down and special care in the multi-pole errors of the elements inside the bump
  - Four independently powered magnets enough to create required bump, but special care to the aperture. Pulsed quadrupoles similar to the QKE elements 2π apart may be needed to enhance the kick provided by the bump/kickers and special tuning of the optics at extraction
- Extraction kicker:
  - Its phase should be chosen such that the central core can be kicked into the island that is used for extracting the previous four turns

Remarks

- Racetrack option not yet fully justified (space constraints for injection from old PS)
  - A 3-fold (J-PARC) or 4-fold symmetric lattice may be an interesting option (separate straight sections for collimation)
- Transition energy constrained by RF choices
  - Severely limits lattice flexibility
  - Lattice should be optimised for beam losses
- Injection systems designed based on the optics of a missing dipole FODO cell
  - Larger flexibility for independently tuned straight sections
- Analysis between normal-conducting vs super-conducting option to be finalised
- Some work done on experimental facilities
- Still the study in the level of brainstorming
  - More info in https://paf-ps2.web.cern.ch/paf-ps2/