Beam transfer considerations for LAGUNA

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LAGUNA-LBNO General Meeting in Hamburg

25-27 February 2013

DESY Hamburg

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- 400 GeV extraction from SPS
- TT20 switch and 400 GeV beamline
- 4 GeV H- injection for HP-PS
- Extraction System HP-PS: basic considerations
- Conclusion

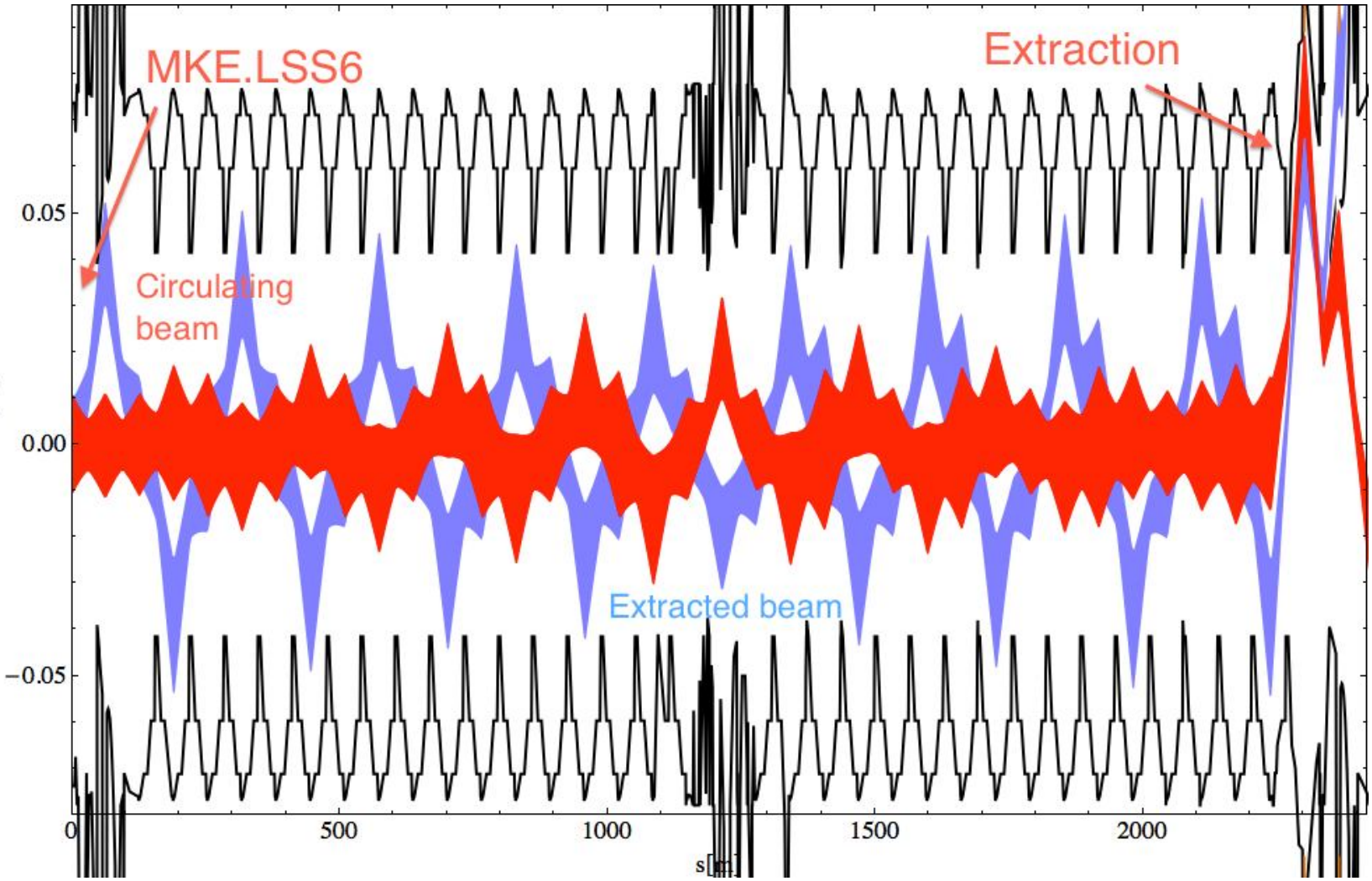
400 GeV extraction from SPS

Non-local extraction over 2.2 km of SPS

SIMULATION: IDEAL CASE

Aperture limitations

TT20



Extraction tests LSS6->LSS2

Machine settings:

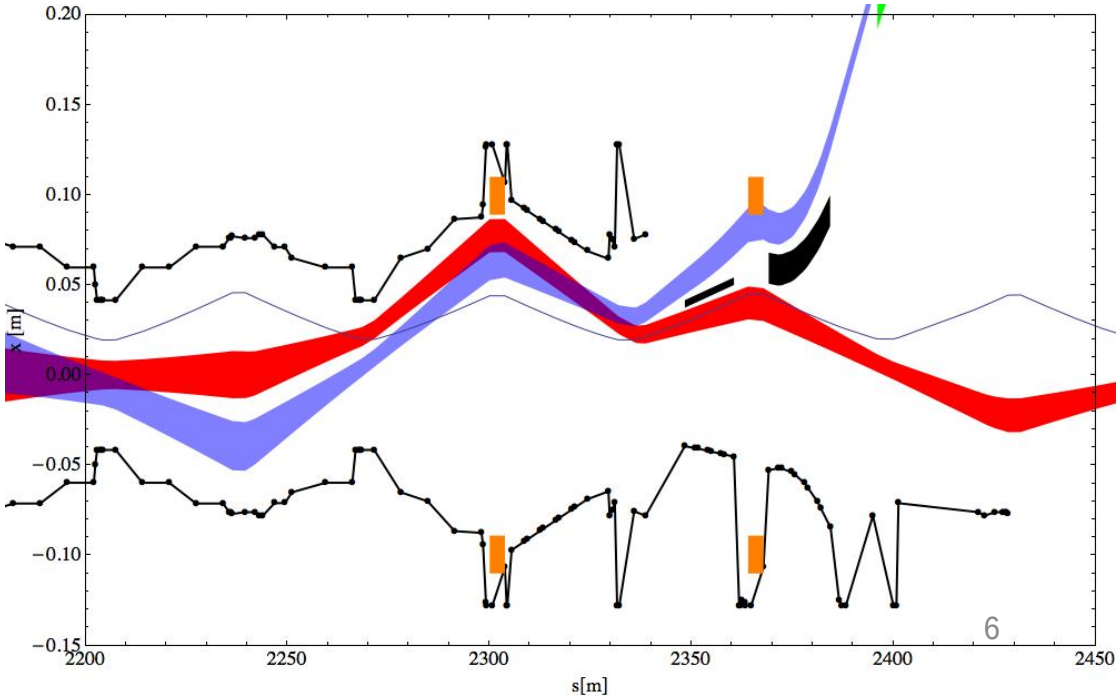
- Carried out on 22 October 2012
- HiRadMat cycle at 440 GeV (due to interlock constraints)
- New SPS tune of 26.87 to get good kicker-septum phase advance
- 6.5 μm emittance, 1-2e11 p+ in a single INDIV bunch
- LSS2 electrostatic septum ZS retracted

Beam into TT20 at first attempt

(using reference values)

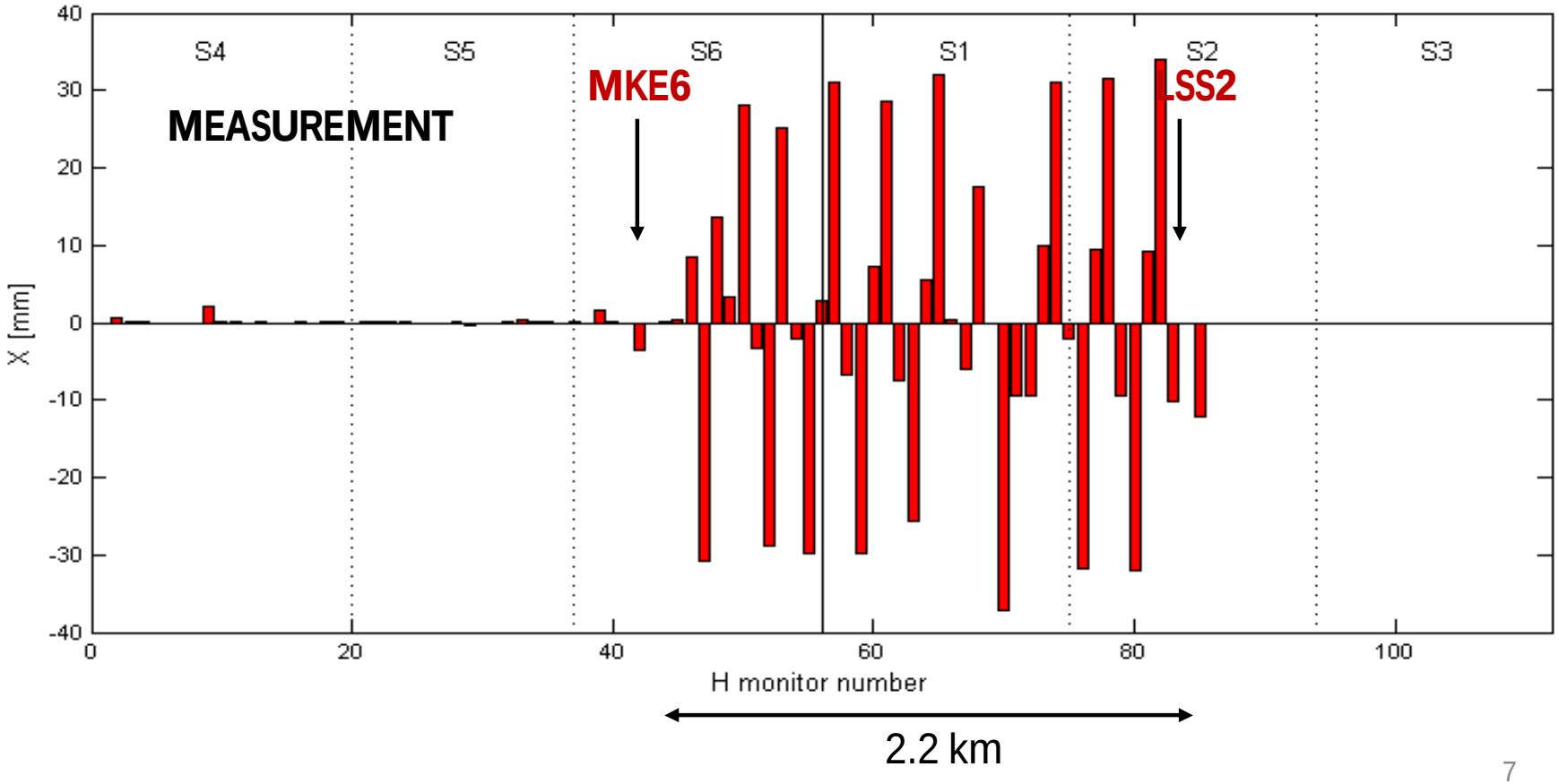
- MKE (LSS6) on at 32.28 kV (HiRadMat nominal values)
- MST on at 0.2 mrad
- MSE on at 1.9 mrad

SIMULATION : ZOOM to LSS2



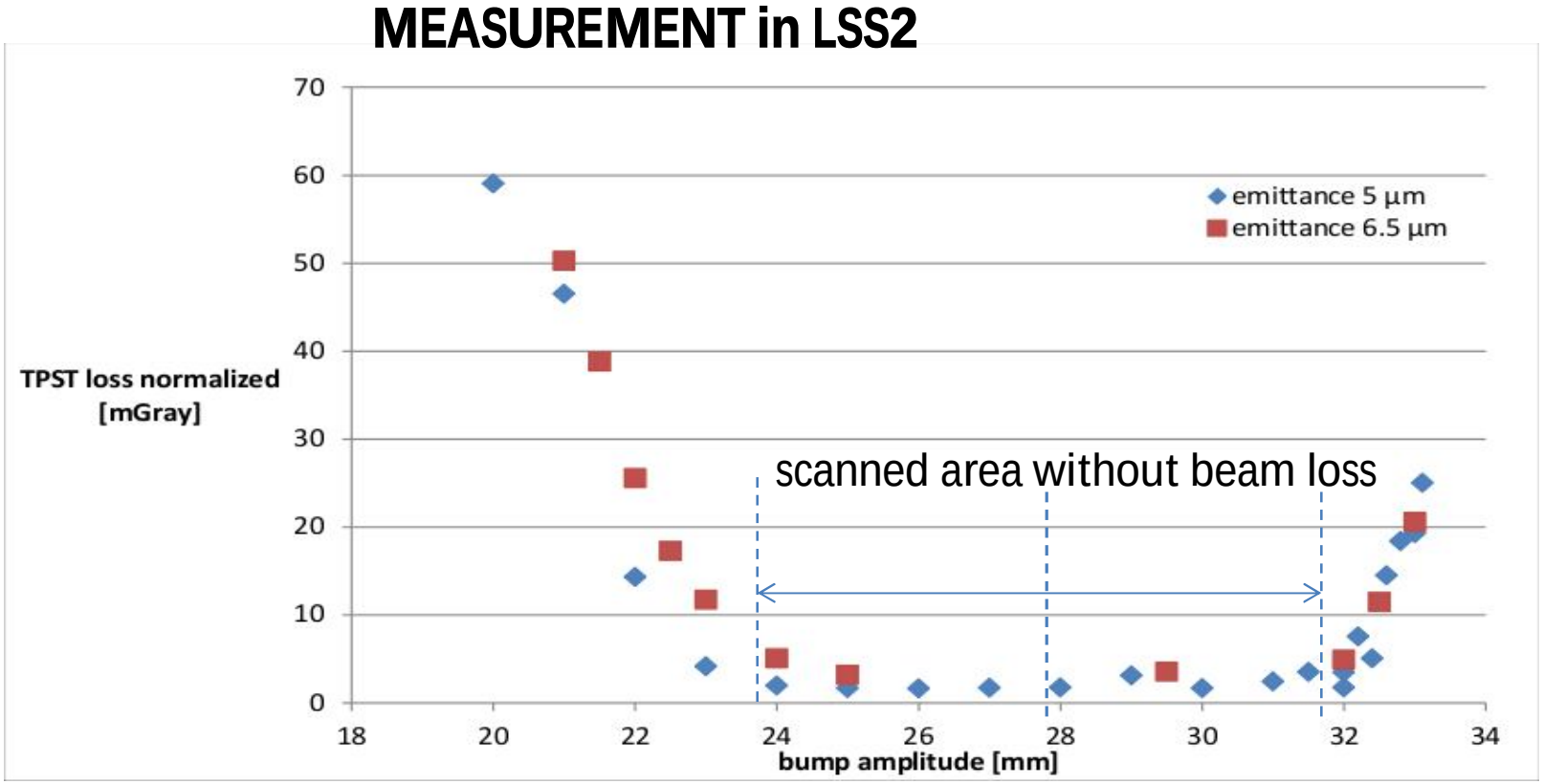
Beam extraction

- Last turn in SPS captured with multiturn application



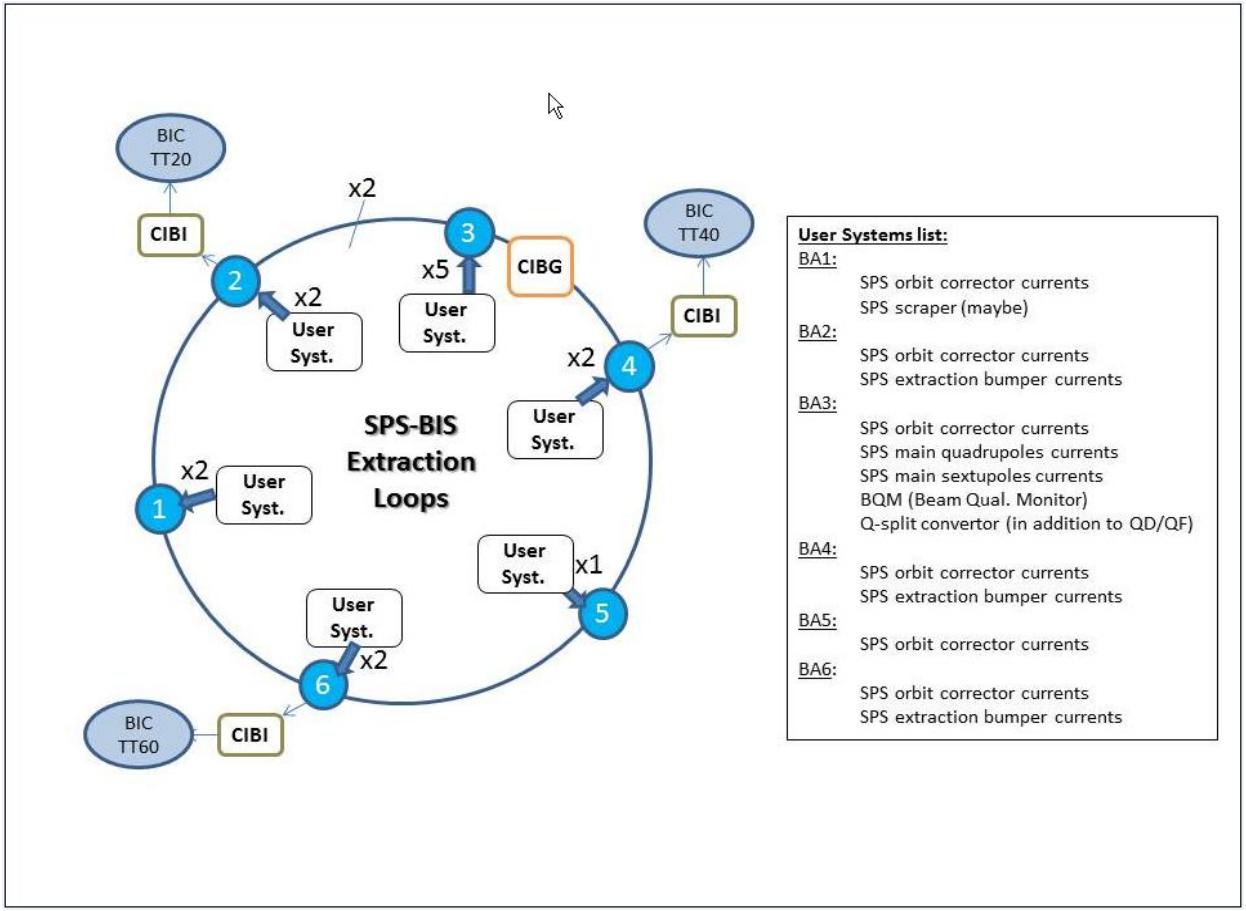
Apertures

- No losses seen in arcs 61 and 12, nor in LSS1



SPS interlocking

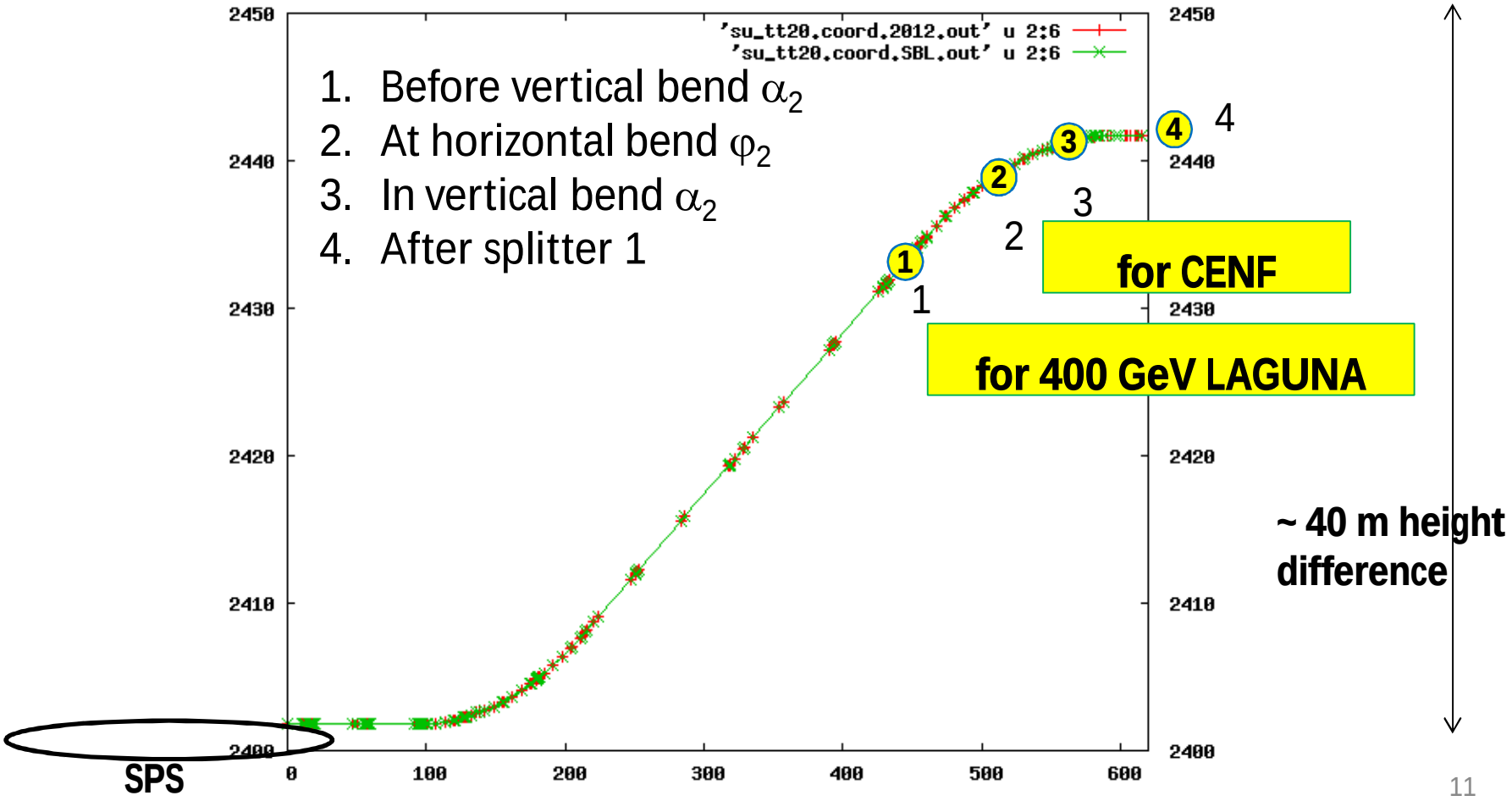
- Crucial to control overall machine parameters
- New 'extraction loop' required (as for CENF)



TT20 switch and 400 GeV beamline

An example: switch from TT20

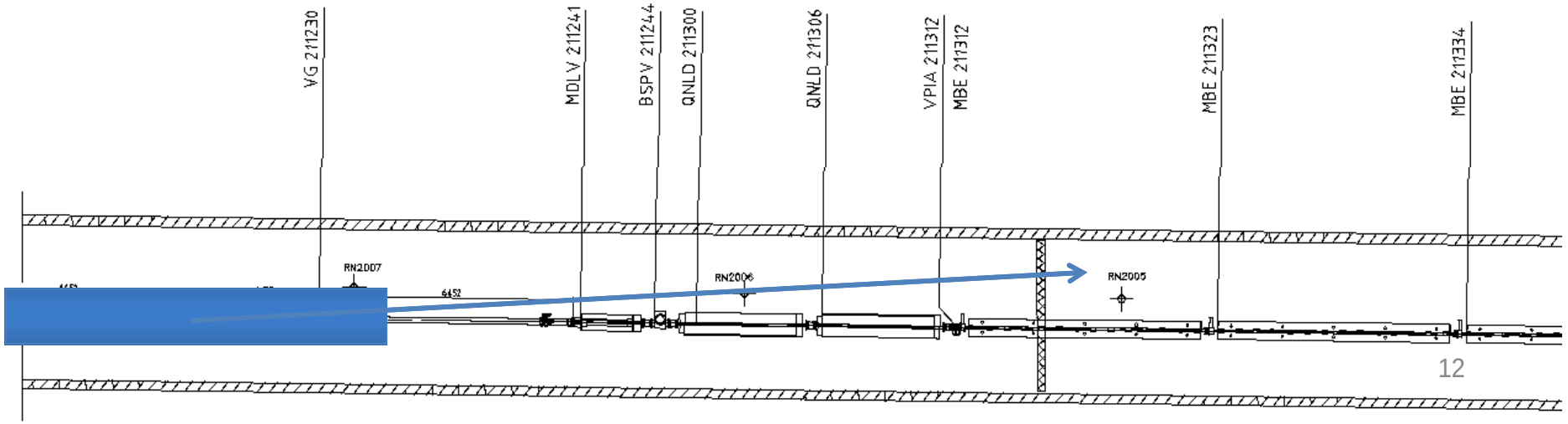
- 4 switch locations were investigated
  - Note: Option 2 chosen for CENF (≤100 GeV)



Option 1: Switch before vertical bend a_2

Considerations:

- Only realistic option for 400 GeV (long drift needed)
- 6x MBS-like switch magnets
- Minimal changes on existing TT20 systems
- Junction cavern exactly under 'decheterie' (integration issue)



Option 1: Before vertical bend α_2

Beamline arc cells

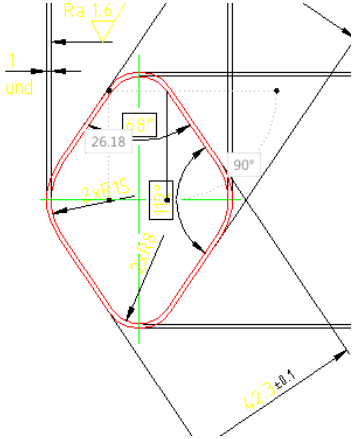
- Take as starting point arcs for CNGS
- Minimum bending radius ~960 m (400 Gev)
- Assumptions
  - Emittance hor: 12 μm
  - Emittance vert: 8 μm

  } Somewhat pessimistic
  - Orbit H/V: +/-4$\sqrt{(\beta/\beta_{max})}$ mm,
  - Mechanical/alignment: 0 mm — Somewhat optimistic
  - Dp/p (half): 1.35e-3 — Somewhat pessimistic
  - Beta-beating: 20% on β

CNGS TT41 magnet parameters

Quads QTG:

- 50x40 mm aperture
- 2.2 m length
- 34 T/m gradient
- About 20 magnets (+10 ‘others’)



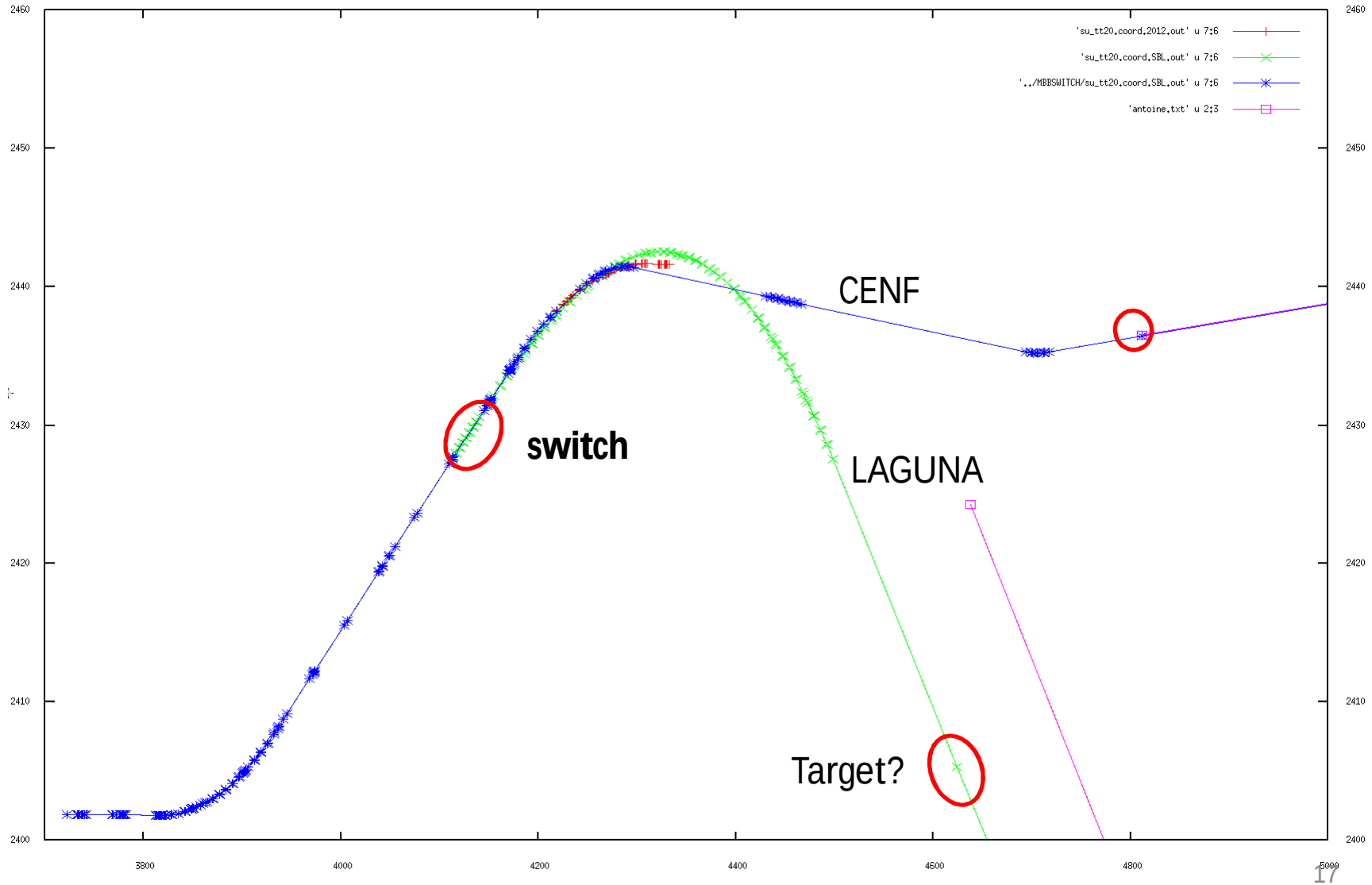
Bends MBG:

- 6.92/6.32 m (total/magn) length
- GFR : +/-37 mm, +/- 17 mm
- 1.91 T: 35.7 mrad bending at 100 GeV
- and 9 mrad at 400 GeV
- About 75 magnets

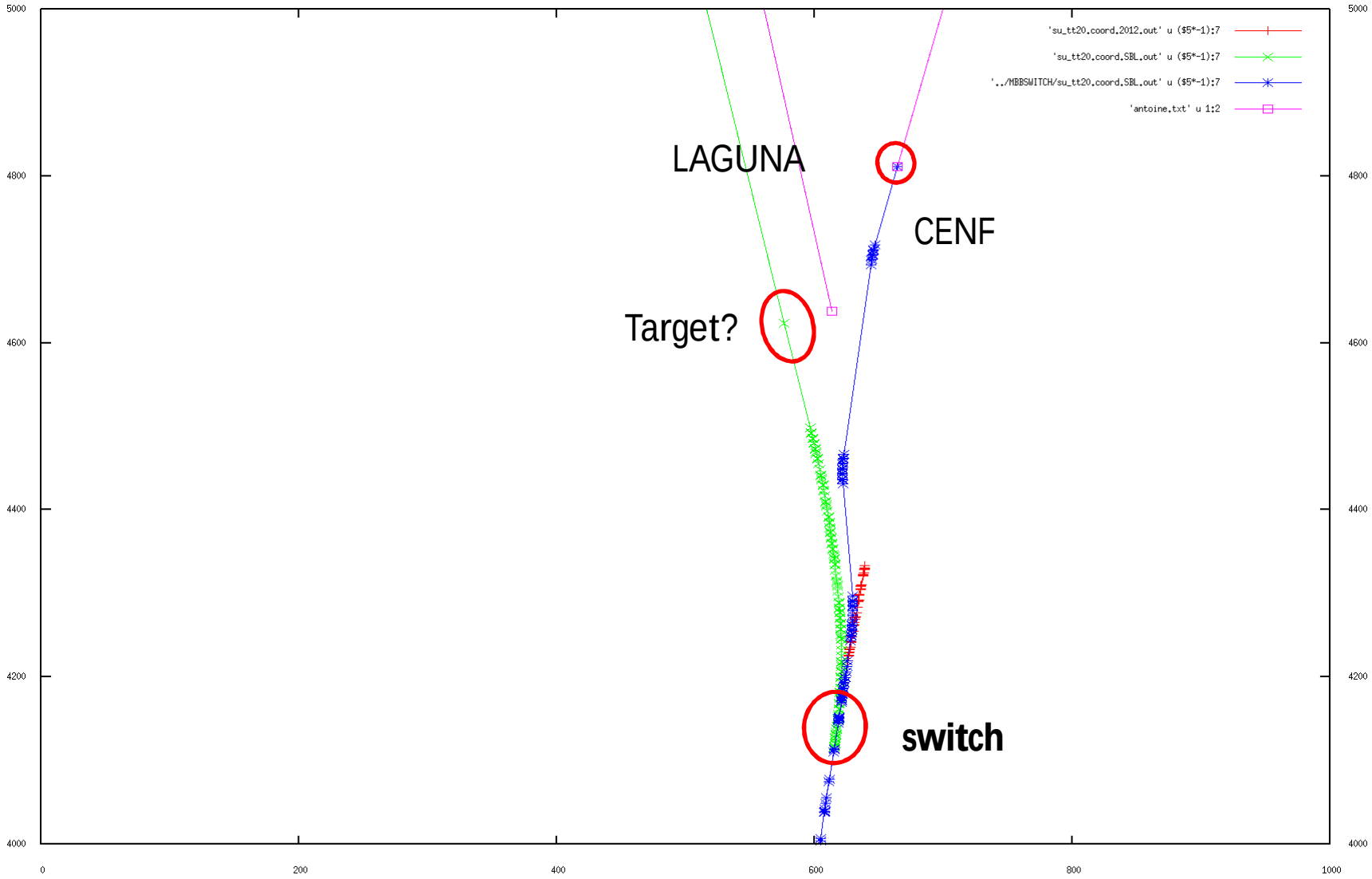
LAGUNA switch and beamline geometry

- Switch on TT20 upslope
- Assume 8x new MBS magnets at 1.65 T
- Assume 44x CNGS main dipoles at 1.85 T (one powering family but tilted with 2 different angles)

Vertical plane 400 GeV

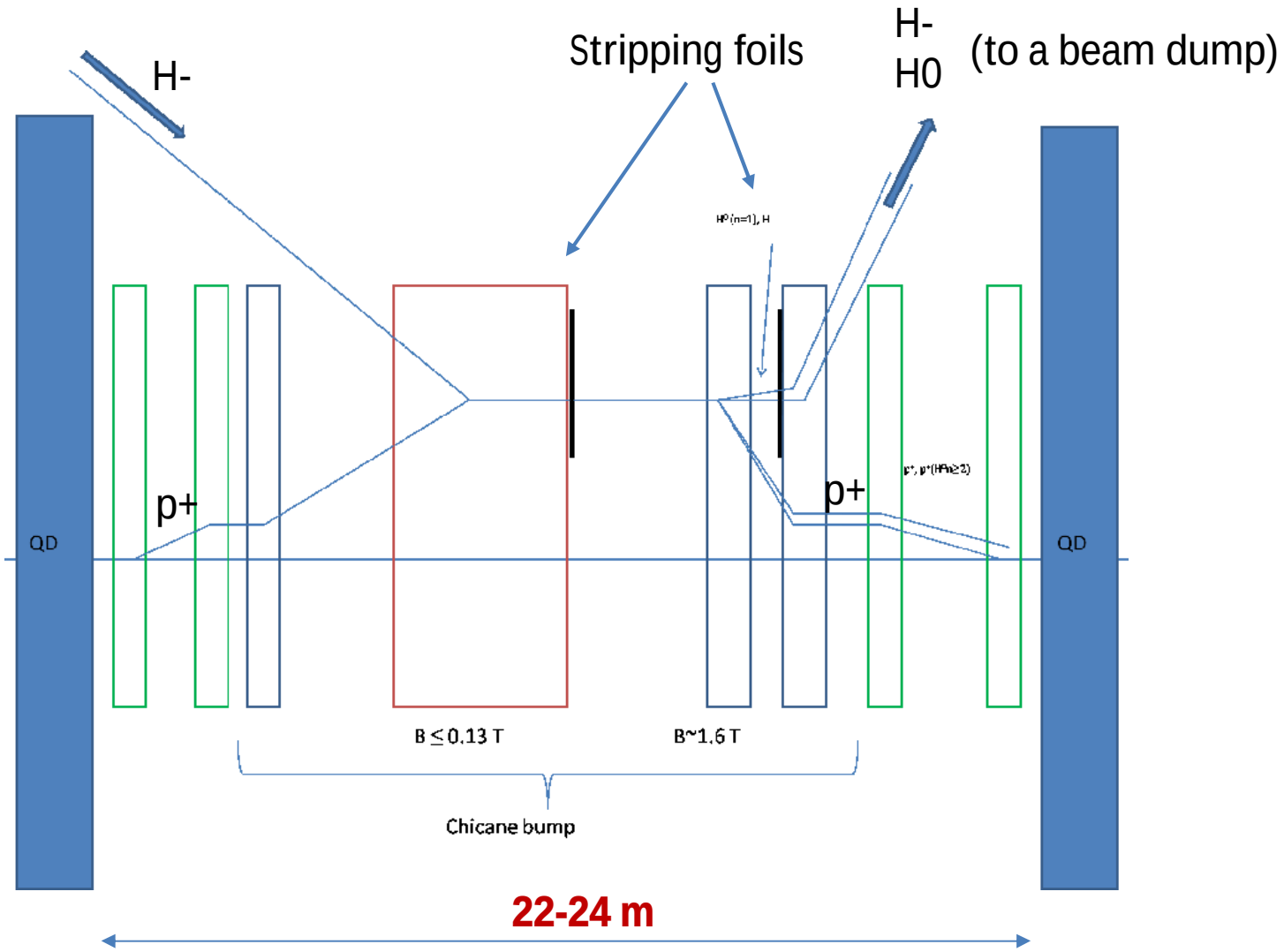


Horizontal plane 400 GeV

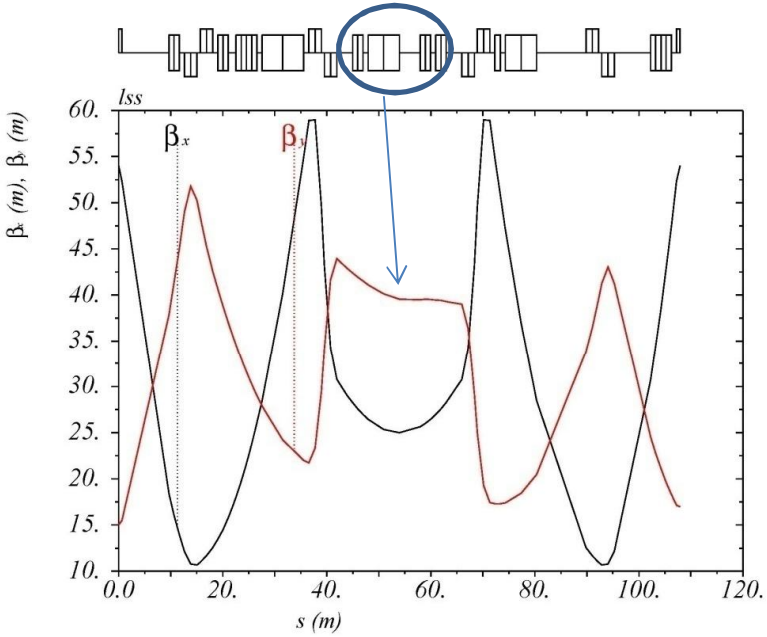


4 GeV H- injection for HP-PS

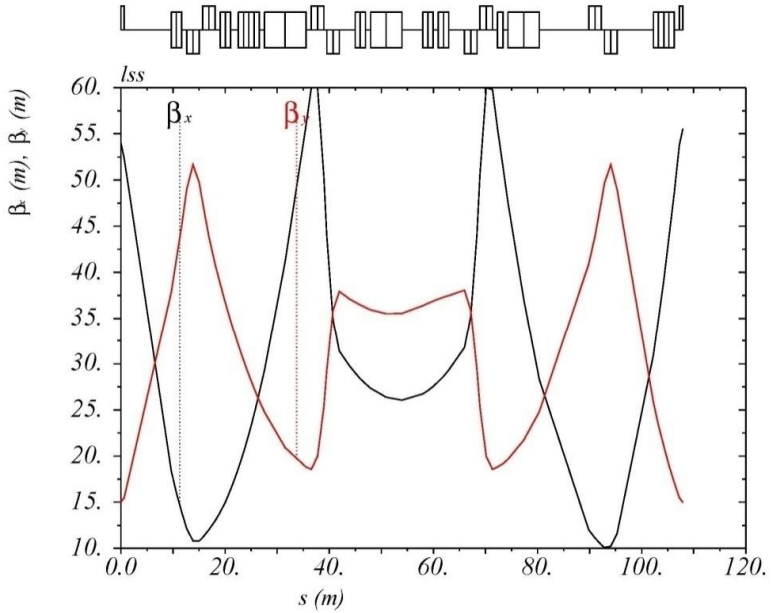
Injection drift layout



PS2 Optics perturbation by H- chicane



Effect of the vertical focussing from the chicane magnets



Compensation by separate powering of the quadrupoles

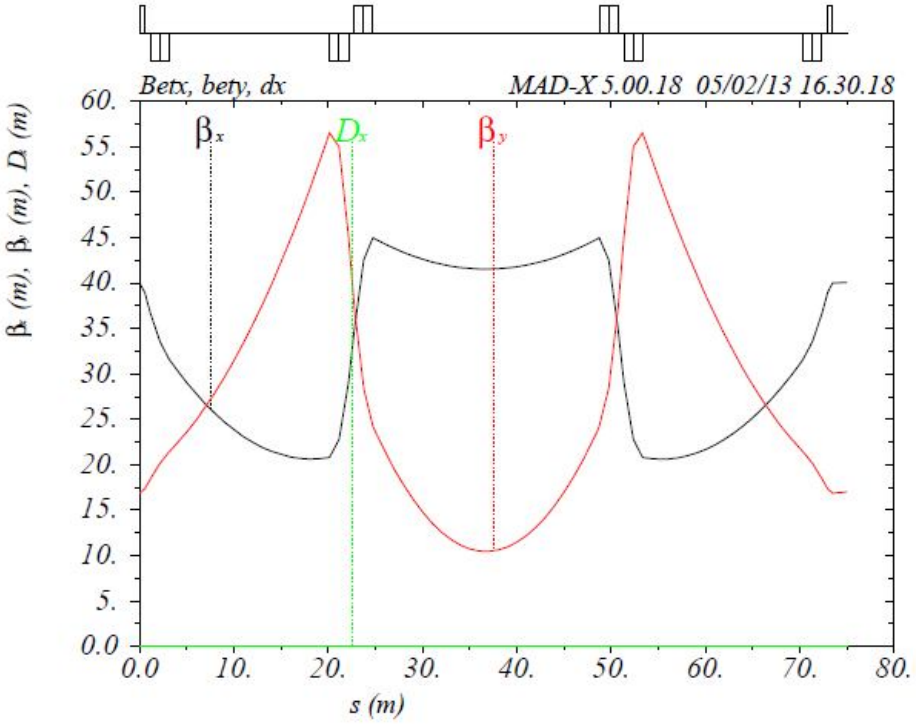
Injection: H- multi-turn, 4.0 GeV

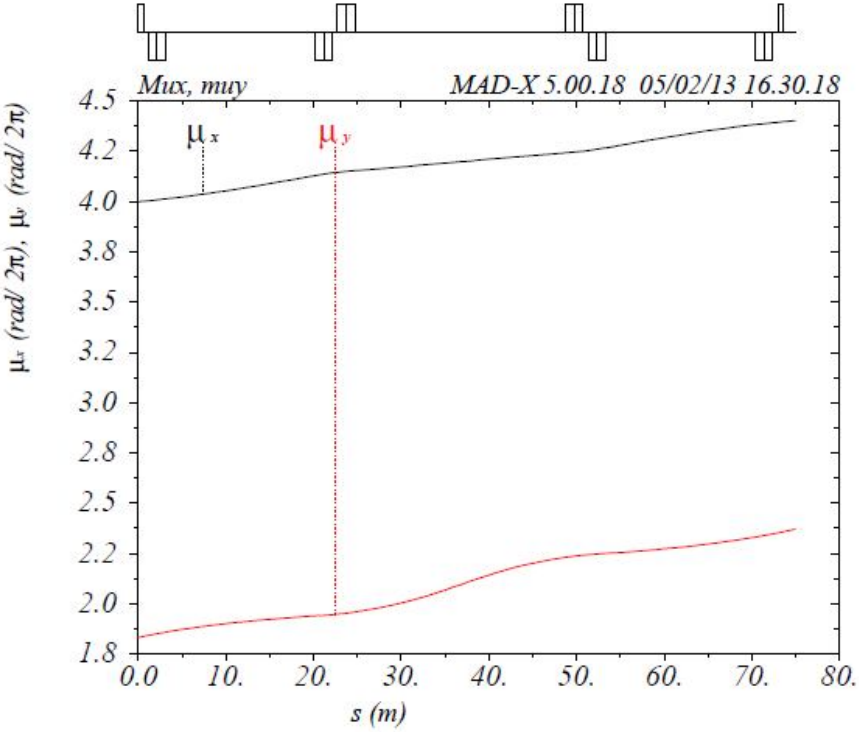
- **H- injection for beam from SPL**
  - Injection chicane with foil (and possible laser stripping section)
  - **Fast orbit bumps** (horizontal and vertical) **for phase space painting** during injection process
  - Septa, beamline and **dumps for the partially or unstripped H0 and H- beams are needed**
  - **keep low dispersion from chicane magnets** (<20 cm) to decouple longitudinal and transverse effects
- **This is a difficult system at 4 GeV!**
  - Limit on maximum dipole field H- beam can traverse, to avoid magnetic stripping and beam loss
  - 2 – 5 % of unstripped H- needs dedicated extraction septum and dump
  - Foil physics and beamloss control…
  - Dumping of stripped electrons….
  - Accommodation of laser stripping (**laser + foil option**)

Extraction System HP-PS: basic considerations

HP-PS LSS

β-functions , dispersion and phase advances

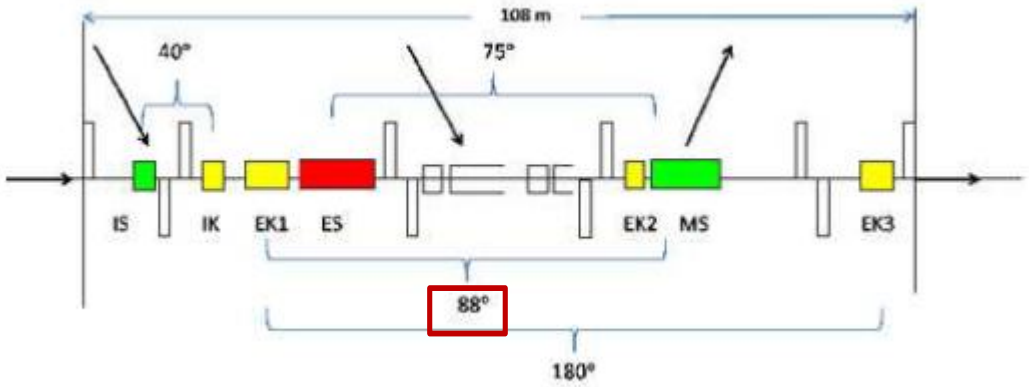




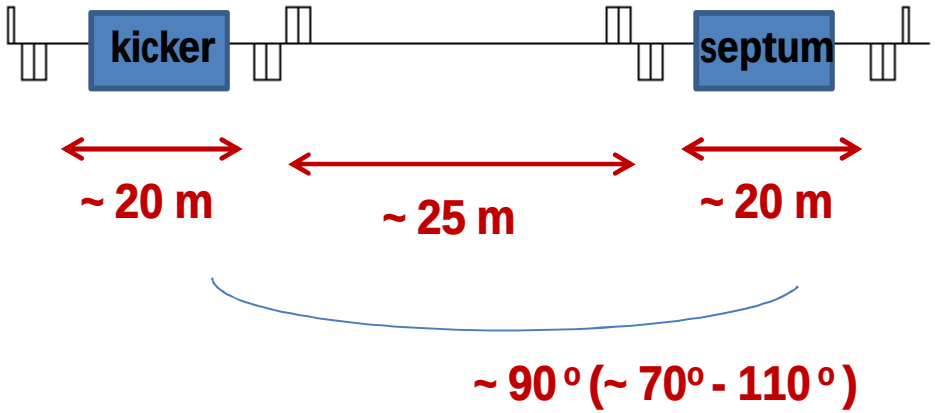
LSS length is 73.5 m

Comparision HP-PS LSS with PS2 LSS

- PS2

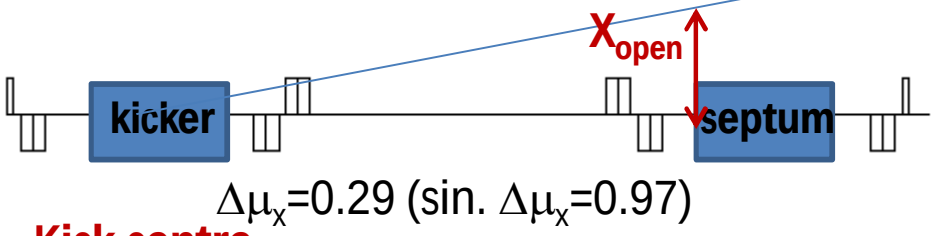


- HP-PS



Estimation of

the kick strength and opening at the magnetic septum



Kick centre

βx	μx
26.7	4.035

Septum entrance

βx	μx
21.7	4.319

4 GeV: $\gamma_{rel.} \cong 5$, $\beta_{rel.} \cong 0.9817$

70 GeV: $\gamma_{rel.} \cong 76$, $\beta_{rel.} \cong 0.9999$

Normalized $\varepsilon \cong 10^{-5}$ **m (talk F. Antoniou)**

X_{open} is estimated as a Σ of

- ~ 5 beam sizes at injection (**4 GeV**) $\quad \sigma_{x\,inj.} = \sqrt{(\beta_{x,Sept}\,\varepsilon_{x\,inj.})} \cong$ 6.5 mm
- ~ 5 beam sizes at extraction (**70 GeV**) $\quad \sigma_{x\,extr.} = \sqrt{(\beta_{x,Sept}\varepsilon_{x\,extr.})} \cong$ 1.5 mm
- ~ 5 mm fixed septum width
- ~ 1 mm uncertainties due to mechanics misalignments
- ~ 4 mm orbit distortion

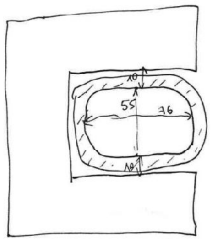
$$X_{open} \cong 50\ mm = \sqrt{(\beta_{x,\,kicker}\,\beta_{x,\,Septum})}\sin(\Delta\mu_x)\theta_{kicker}\ , \quad \theta_{kicker} = 2.1\ mrad$$

Kicker parameter table (c.f. PS2)

Parameter	Unit	PS2	HPPS
Energy	GeV	50	70
Angle	mrad	1.6	2.1
Rigidity	T.m	169.8	236.5
Required B.dl	T.m	0.27	0.50
Individual magnet length	m	0.75	1.46
Number of magnets		8	10
Total Magnetic length	m	6.0	14.6
Total installed length	m	7.8	17.5
Magnet inductance	H	1.25664E-06	2.352E-06
Magnet capacitance	F	1.25664E-08	1.5E-08
System Impedance	Ohm	10	12.5
Filling time	ns	126	200
Rise/fall time	ns	135	238
Pulse length	µs	24.5	24.5
Aperture height (**with** 20 mm for screen)	mm	90	75
Aperture width (**with** screen)	mm	120	96
Maximum voltage	kV	64.86	50
Peak current	kA	3.24	2
Gap field	T	0.045	0.033

Discussion

- **Extraction kicker system will be large**
  - 10 magnets
  - 17.5 m installed length…most of the drift
- **Rise time of minimum 238 ns (filling time + switch)**
  - Will be worse with impedance screening
  - Should assume 250 ns



- **Optimization directions?**
  - More magnets possible for faster rise time
    - But adds cost, plus installed length, man power
    - e.g. 20 magnets gives ~150 ns in 22.0 m (space problem)
    - But this would be extremely expensive system
    - Also effect of shielding proportionately worse
  - Larger beta functions at kicker and septa? e.g. 35 m (less kick strength)? BE/ABP

Conclusions

Conclusions

- **400 GeV beam from SPS**
  - LSS2 Extraction using LSS6 MKE kickers demonstrated at 440 GeV (backup option only for **100 GeV from LSS1**)
  - TT20 transport no issue
  - Switch from TT20 some 90 m before CENF switch
  - Arc geometry to LAGUNA target looks OK
  - Recuperation of TT41 magnet design should be possible
- **Injection and extraction from HP-PS**
  - 4 GeV H- system defines LSS layout (24 m drift), studied in detail for PS2 at 4 GeV and can be directly adapted for HP-PS
  - Extraction and kickers: basic considerations look OK