SPL to PS2 transfer line and PS2 injection requirements

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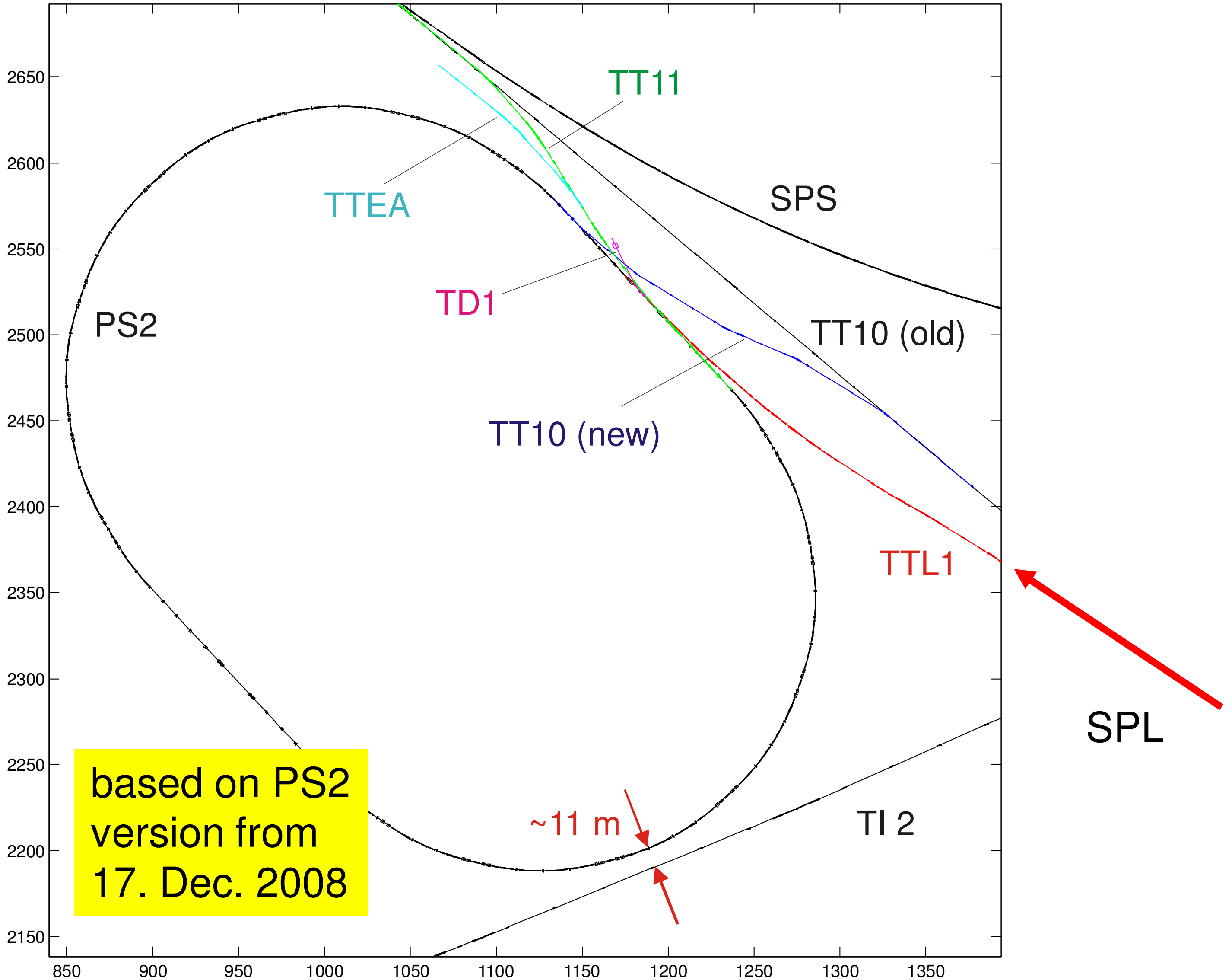
PS2 and Transfer Lines Overview

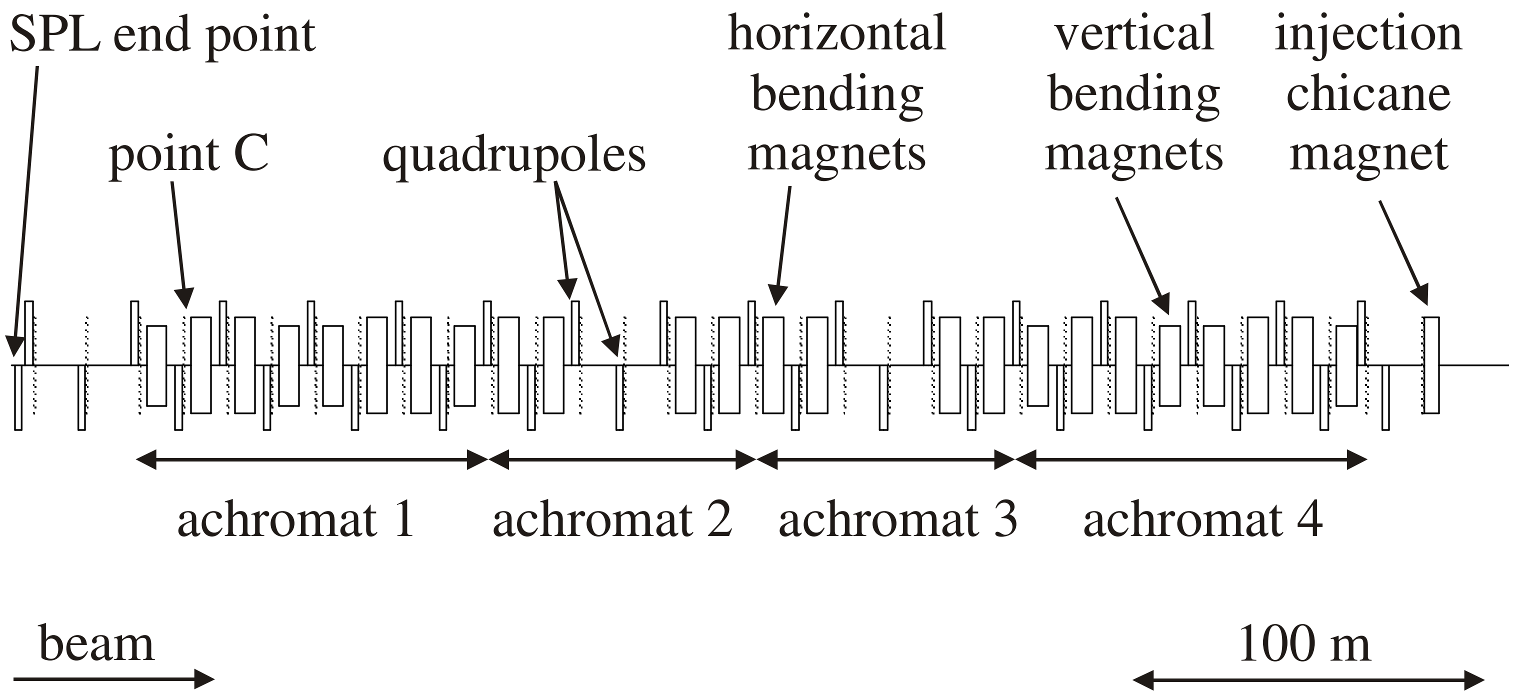


Driving Parameters for TTL1

	LP-SPL	LP-SPL-5G	HP-SPL
Kinetic energy [GeV]	4	5	5
Repetition rate [Hz]	2	2	50
Pulse length [ms]	1.2	1.2	0.4
Average pulse current [mA]	20	20	40
Beam power [MW]	0.192	0.24	4
Max. fract. loss [m^{-1}] (due to Lorentz stripping) assuming max. P_{loss} =0.1 W/m	5.2e-7	4.17e-7	2.5e-8
Max. dipole field [T]	**0.115**	**0.0950**	**0.0858**
Min. rho [m]	141	206	228

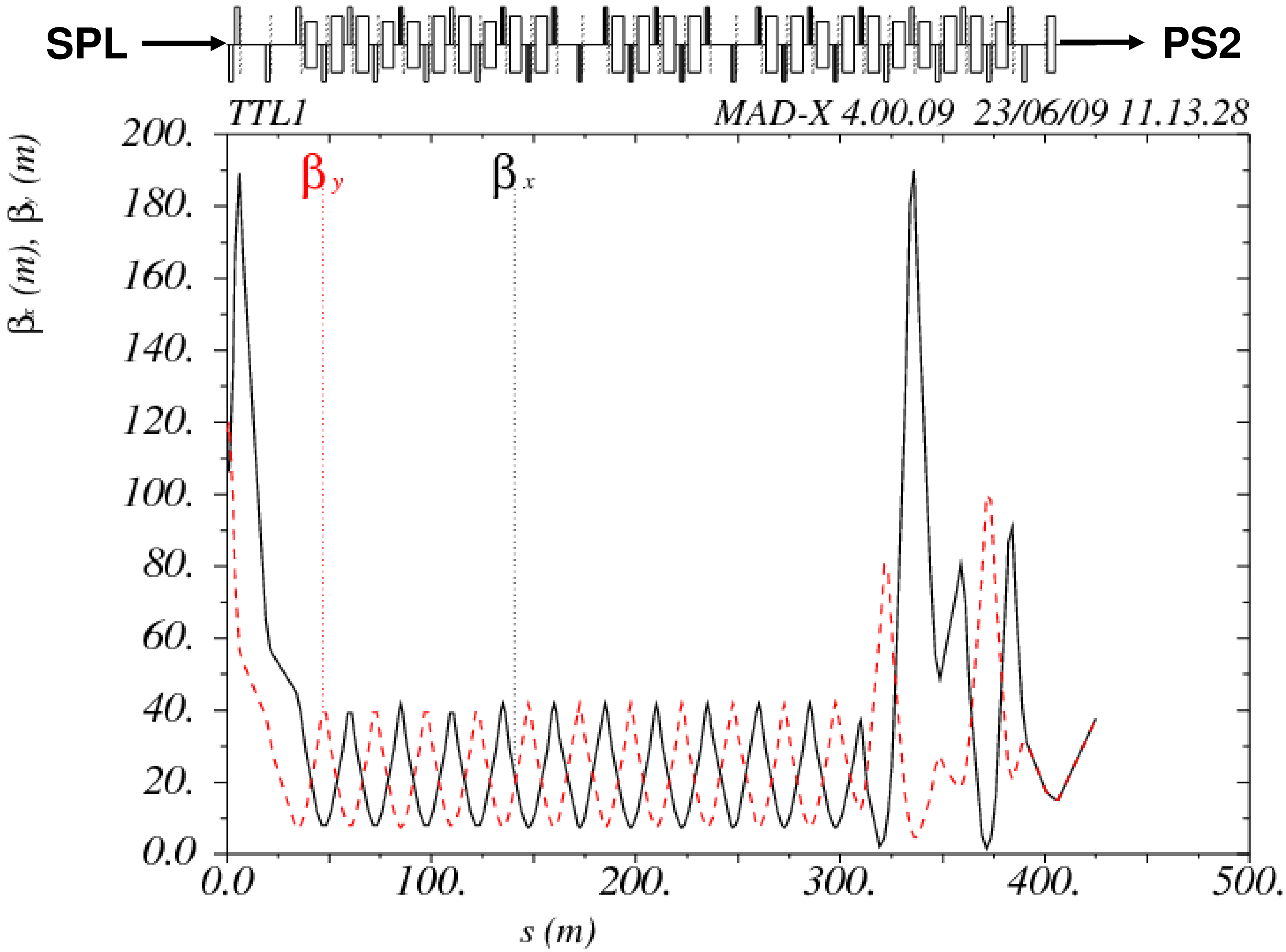
Expression fractional loss from A.J. Jason et al, IEEE Trans.Nucl.Sci. NS-28, 1981
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4331890&isnumber=4331887

Beam Line Geometry

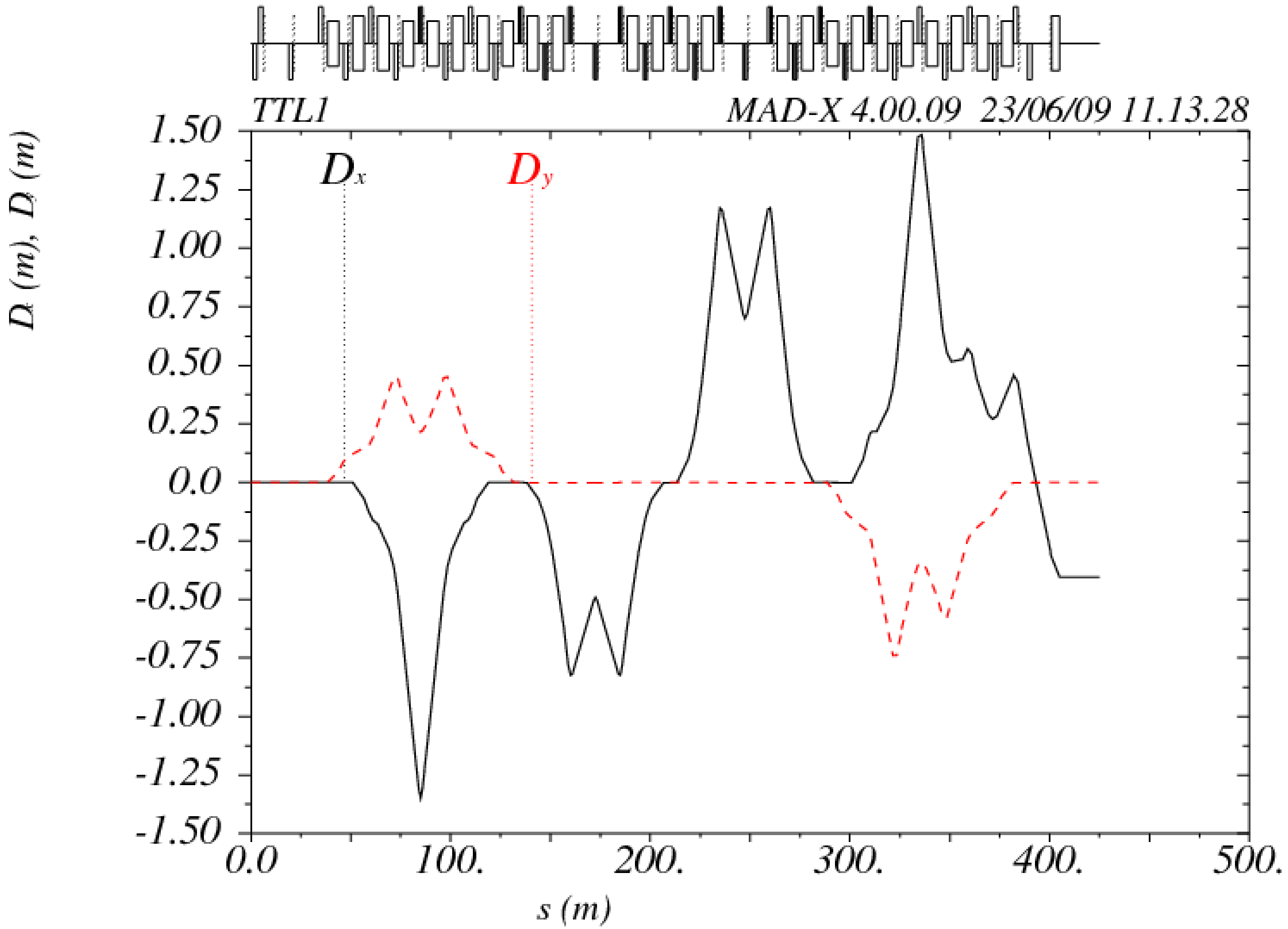


- first part compatible with HP-SPL, second part only compatible with LP-SPL @ 4 GeV
- second part can be compatible with LP-SPL @ 5 GeV if 7.2 m (instead of 5.75 m) long dipoles are used
- large slope of 8.1%

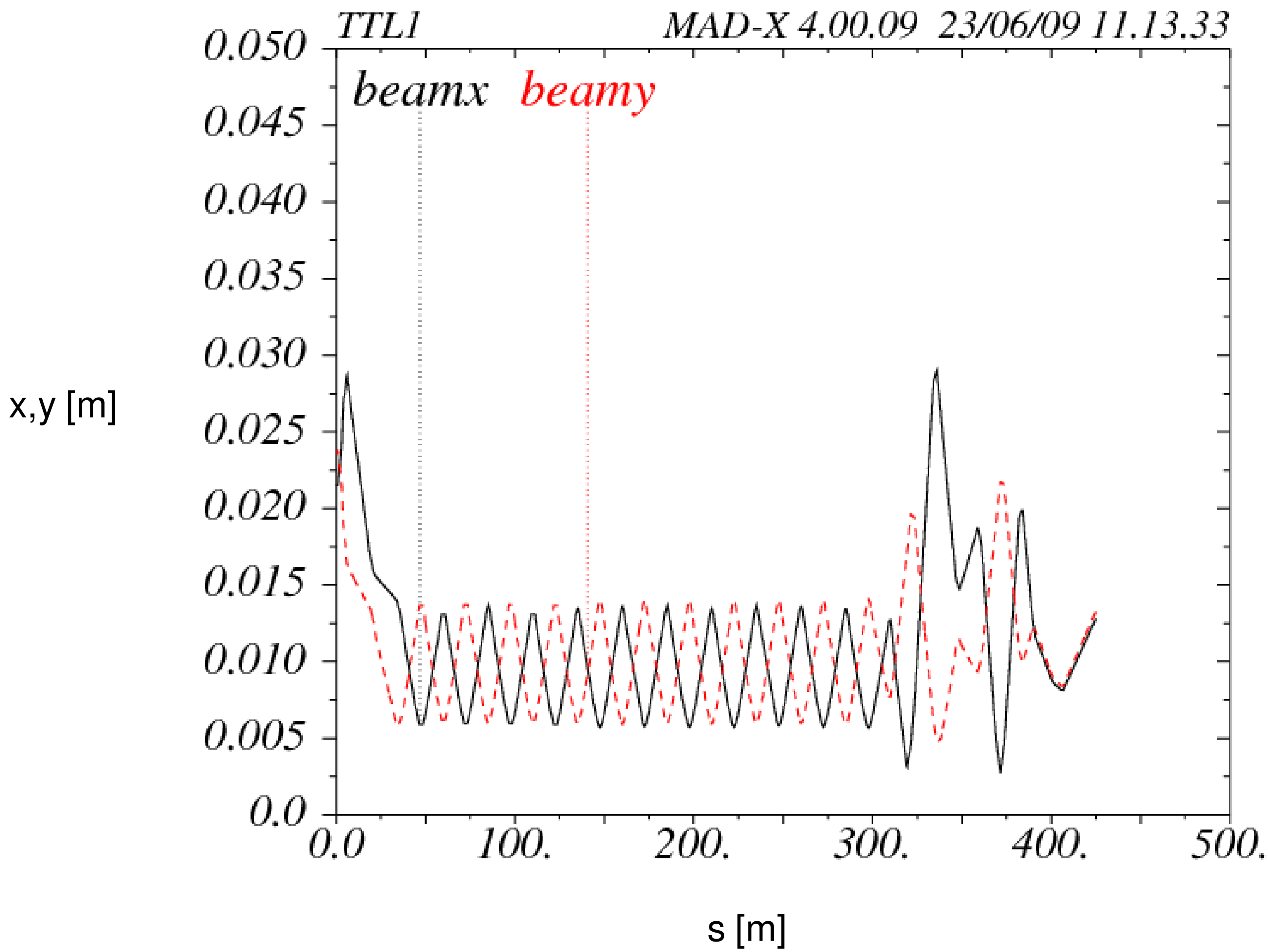
Optics Simulation



Optics Simulation



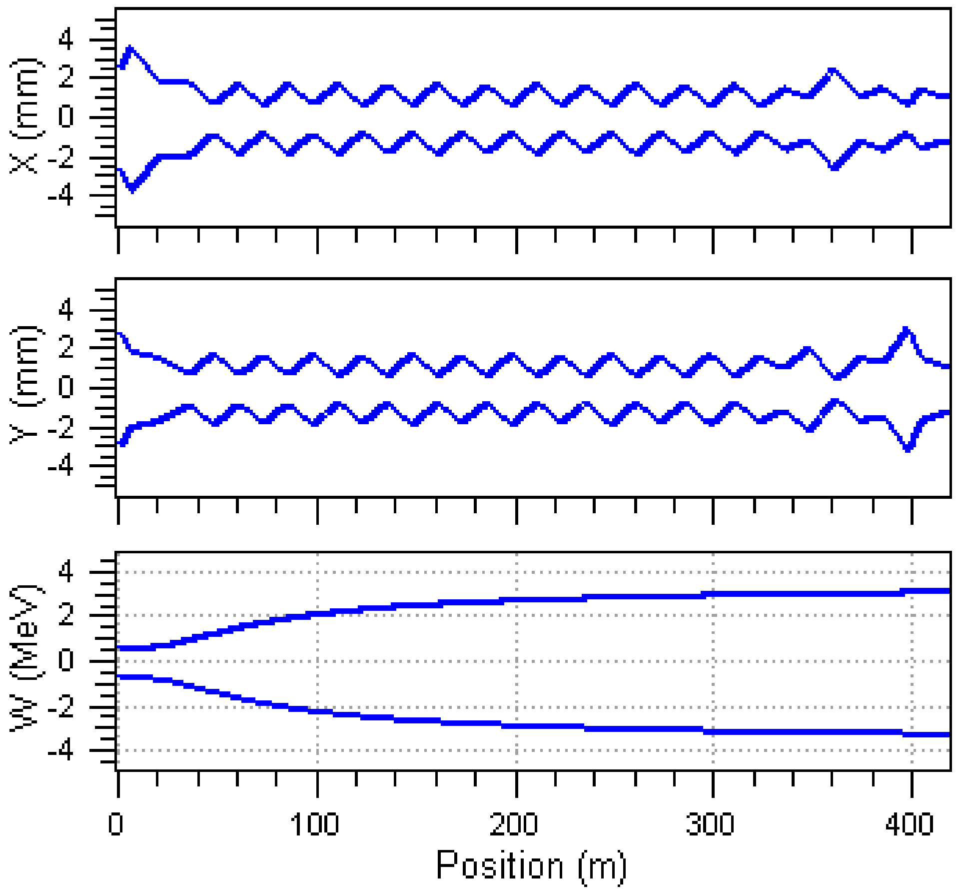
Aperture Calculation



beam envelope: $x, y = N \cdot \underbrace{\sqrt{\varepsilon_{phys} \cdot \beta}}_{\sigma} \cdot 1.1 + |D| \cdot \frac{\Delta p}{p} \cdot 1.1 + co \cdot \sqrt{\frac{\beta}{\beta_{\max}}}$

N = 6
co = 5 mm

Multi-particle Simulations

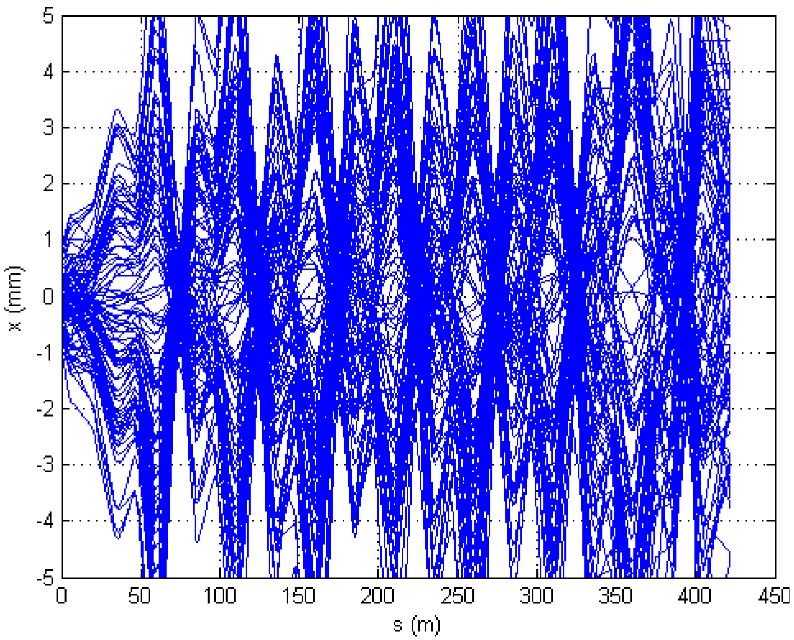


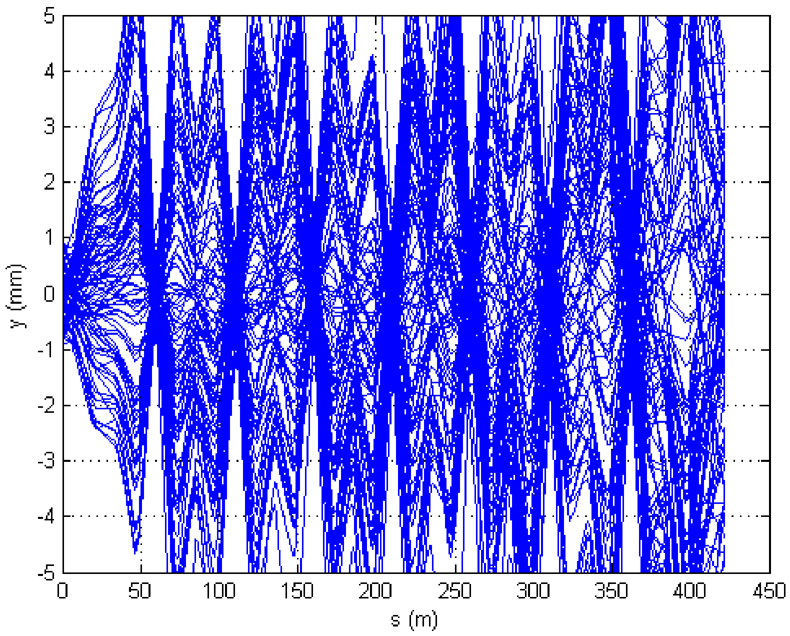
- Simulation code: TraceWin
- Beam current: 62 mA
- Emittance growth (H/V): 23% / 2%
- Energy spread increase: from ±1.5 MeV to ±7 MeV

M. Eshraqi

Trajectory Correction

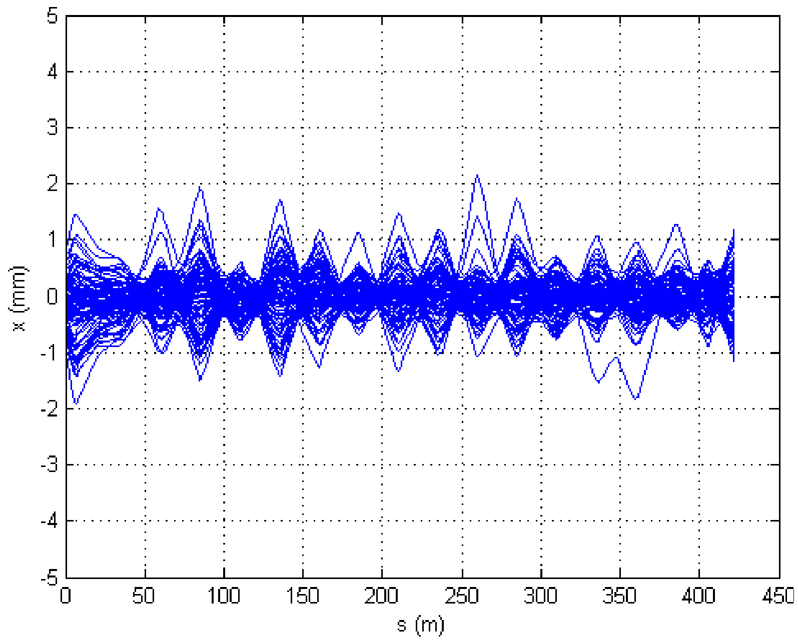
100 uncorrected trajectories:

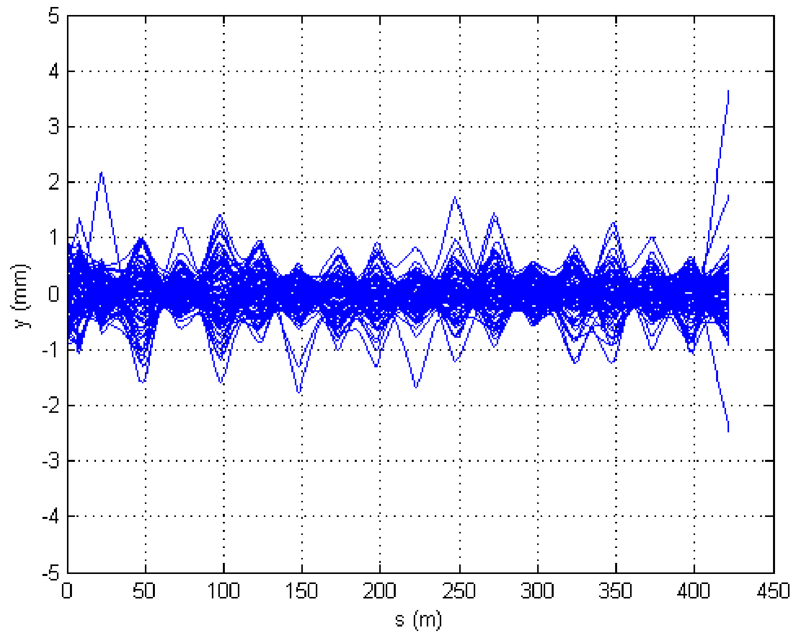




Trajectory Correction: Results

- Each quadrupole equipped with a H/V monitor
- 2 quadrupoles out of 3 equipped with a corrector

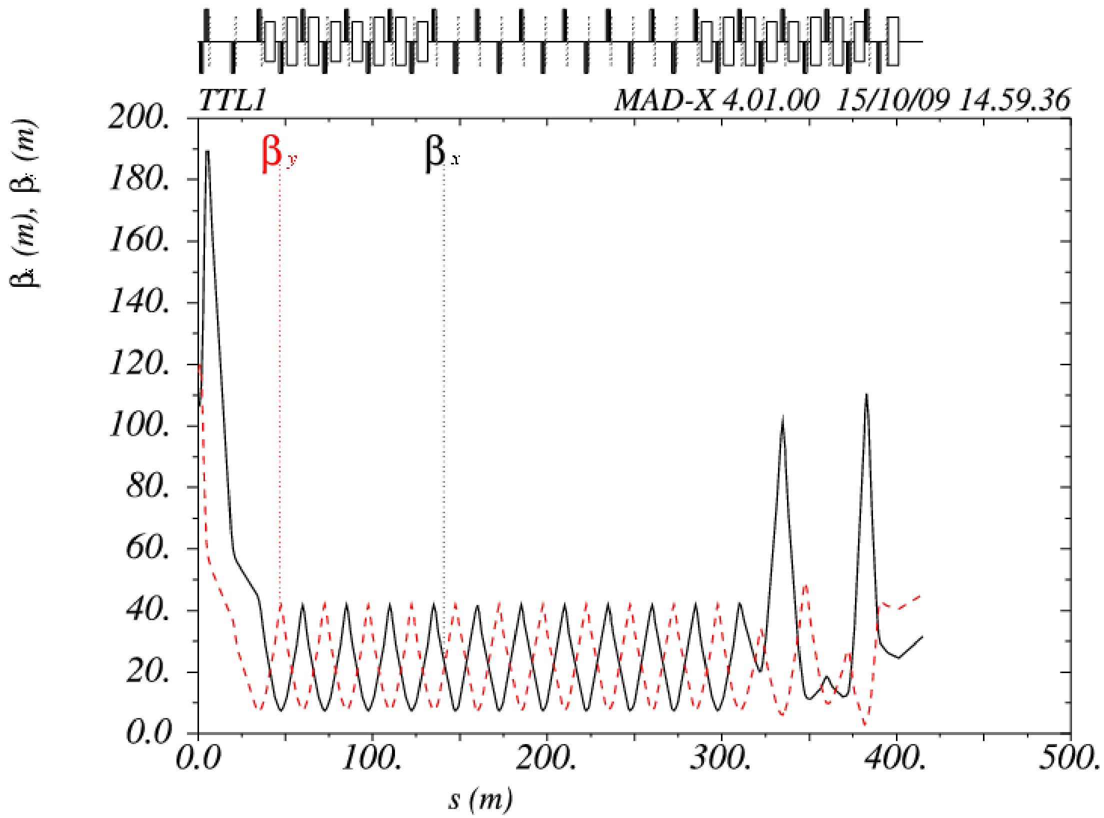




→ Correction OK

Outlook TTL1

- Complete new PS2 LSS1 layout to disentangle injection/extraction region
- New TTL1 version (work in progress):



Parameters for ISOLDE/EURISOL Beam Lines

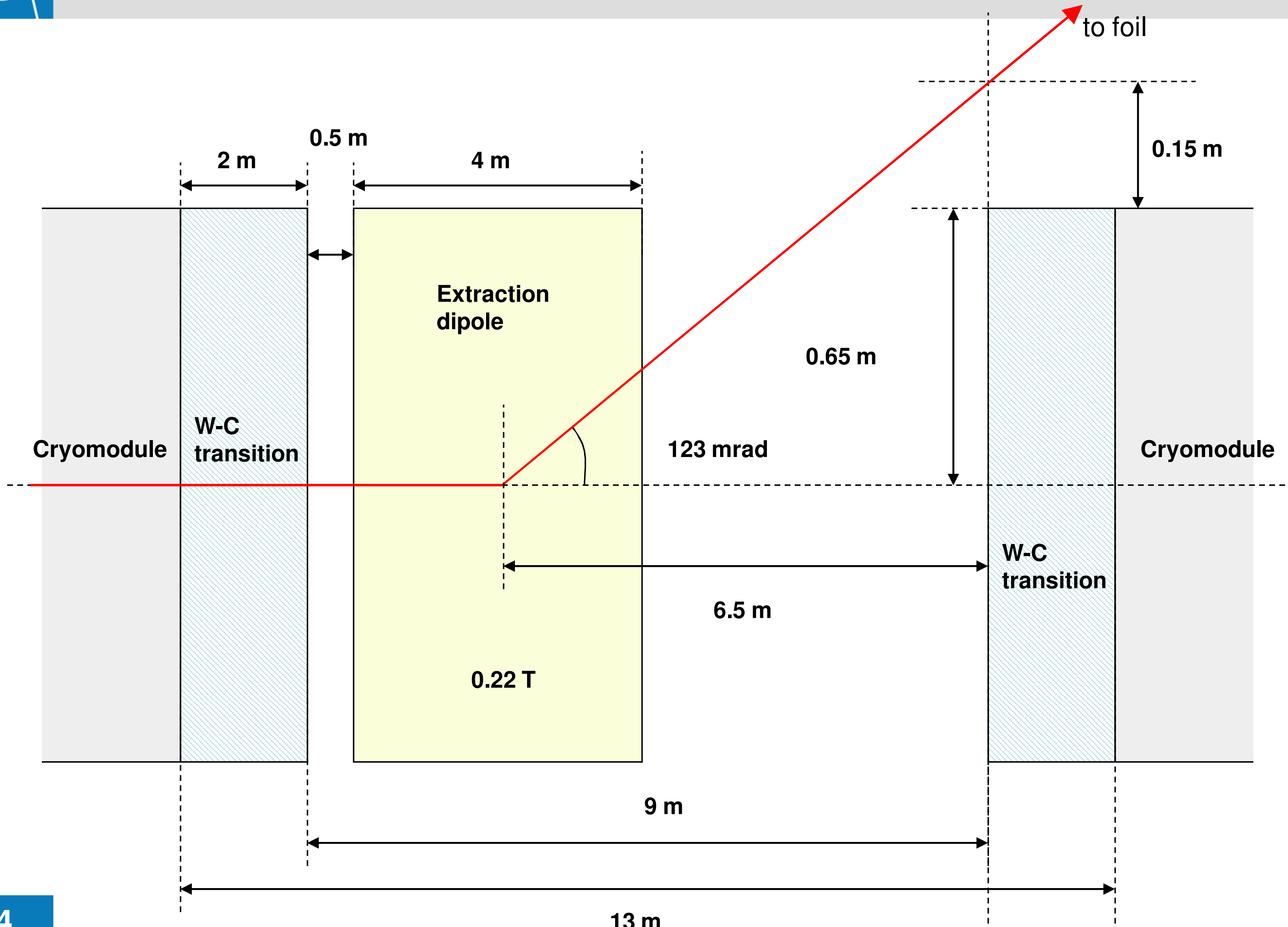
	ISOLDE	EURISOL	
	LP/HP-SPL	LP-SPL	HP-SPL
Kinetic energy [GeV]	1.5	2.5	2.5
Repetition rate [Hz]	1.25	1.25	50
Pulse length [ms]	1.2	1.2	0.8
Average pulse current [mA]	20	20	40
Beam power [MW]	0.045	0.075	4
Max. fract. loss [m^{-1}] (due to Lorentz stripping) assuming max. P_{loss} =0.1 W/m	2.22e-6	1.33e-6	2.5e-8
Max. dipole field [T]	0.254	0.172	0.149
Min. rho [m]	29.5	64.1	74.0

Expression fractional loss from A.J. Jason et al, IEEE Trans.Nucl.Sci. NS-28, 1981
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4331890&isnumber=4331887

Extraction from SPL to ISOLDE

- **Input parameters**
  - p^+ beam
  - 1.4 GeV p^+, $B\rho$ = 7.14 Tm
  - 42 kW
  - 0.29 T maximum bending field (0.1 W/m)
  - 0.65 m cryomodule radius
  - Same radius assumed for Warm-Cold transition
- **Results**
  - Use 0.22 T dipole, 4 m long, 123 mrad
  - 0.15 m clearance at cryomodule/W-C transition
  - Pulsed dipole, 1.25 Hz repetition rate
  - Stripping foil outside the extraction region
  - Losses
    - in extraction dipole N/N_0 ~1e-7 (0.02 W/m)
    - from stripping foil, 4.3 e-5 (1.8 W)

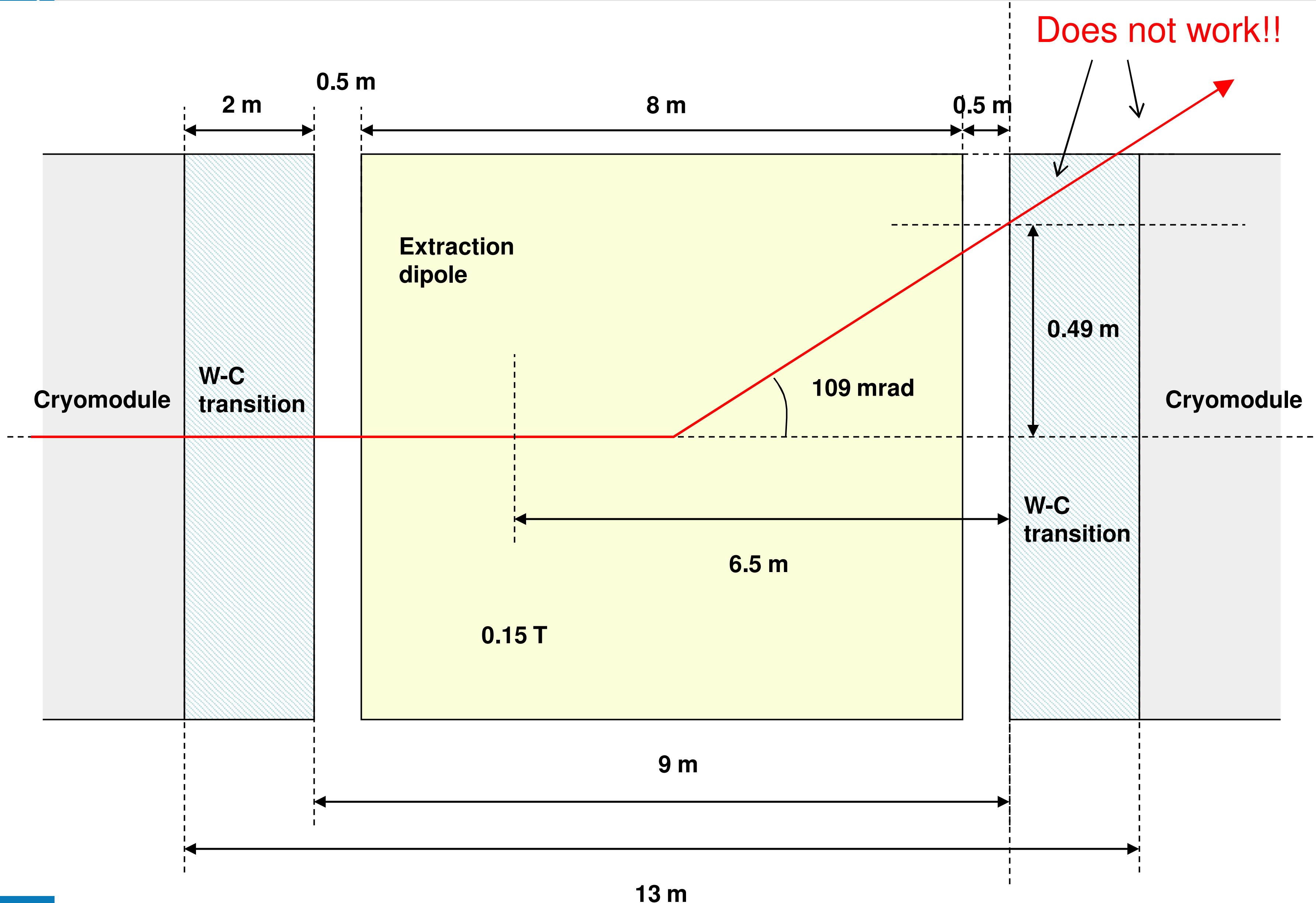
Layout for 1.4 GeV p+ extraction



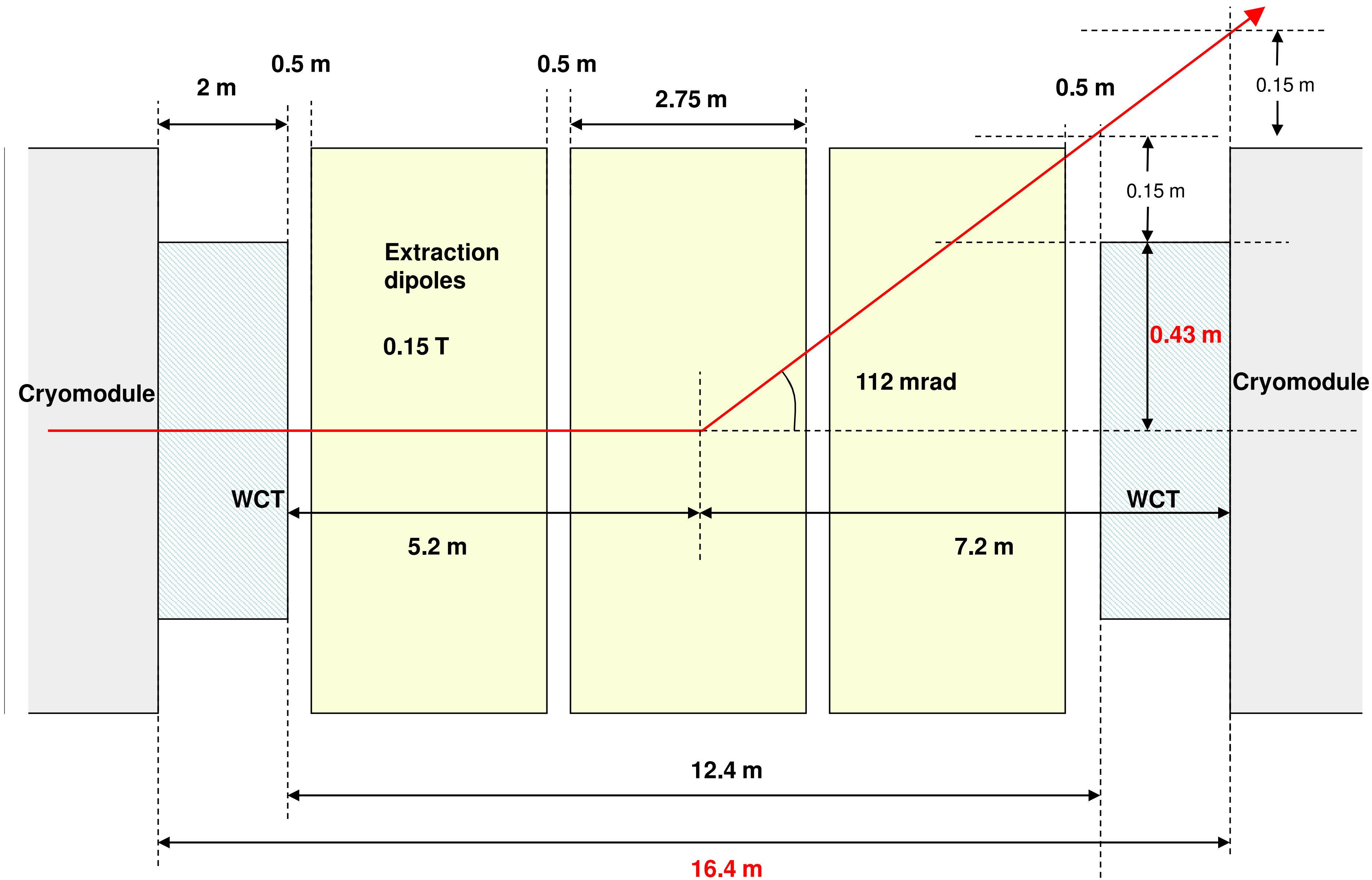
Extraction from SPL to EURISOL

- **Input parameters:**
  - H^- beam
  - 2.5 GeV H^-, $B\rho$ = 11.03 Tm
  - 6 MW (!)
  - 0.15 T maximum bending field (0.1 W/m)
  - 0.65 m cryomodule radius
  - Same radius assumed for Warm-Cold transition
- **Results**
  - Use 0.15 T dipole, 8 m long (!), 109 mrad
  - 0.15 m clearance at cryomodule/W-C transition

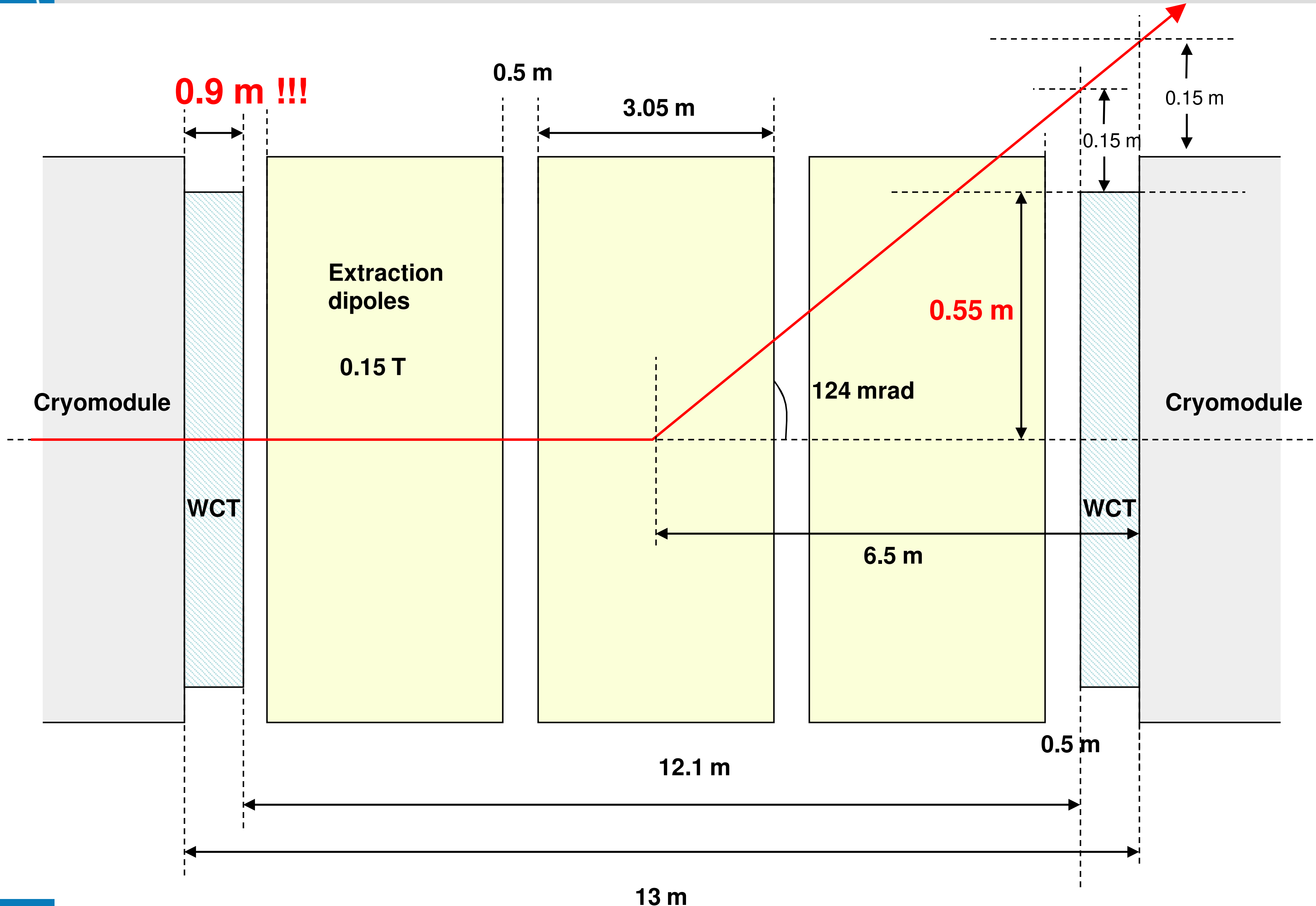
Layout with 9m available drift



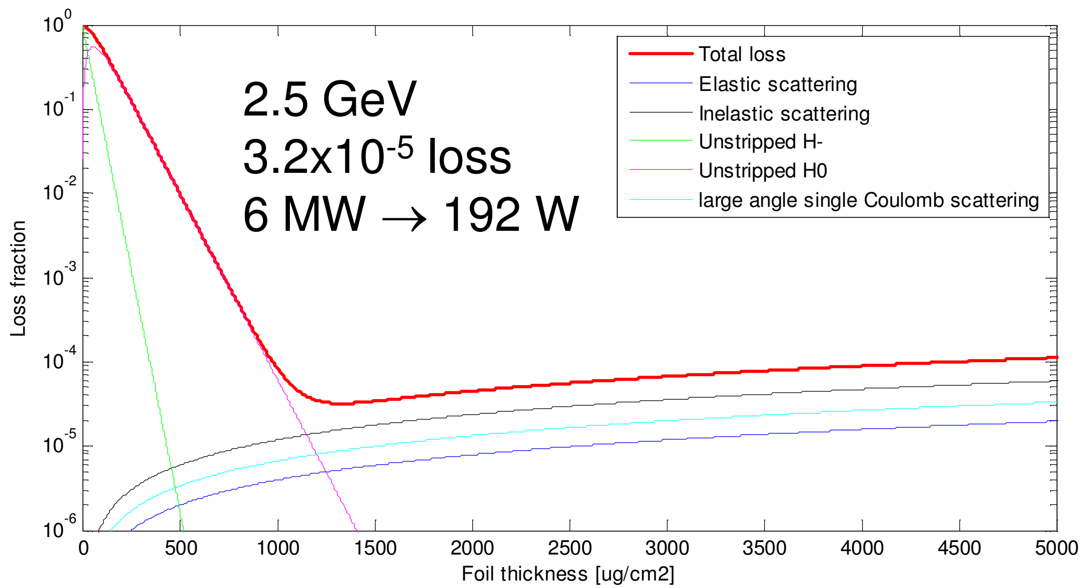
Layout with minimum possible drift

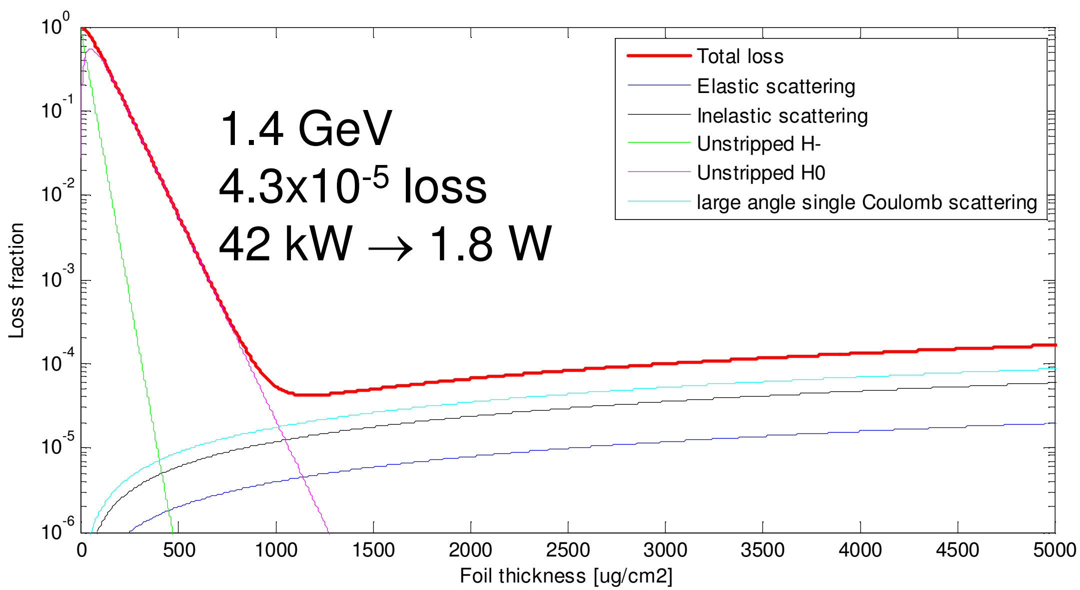


Length/Height of WCT for 13 m period



Stripping foil thickness optimisation





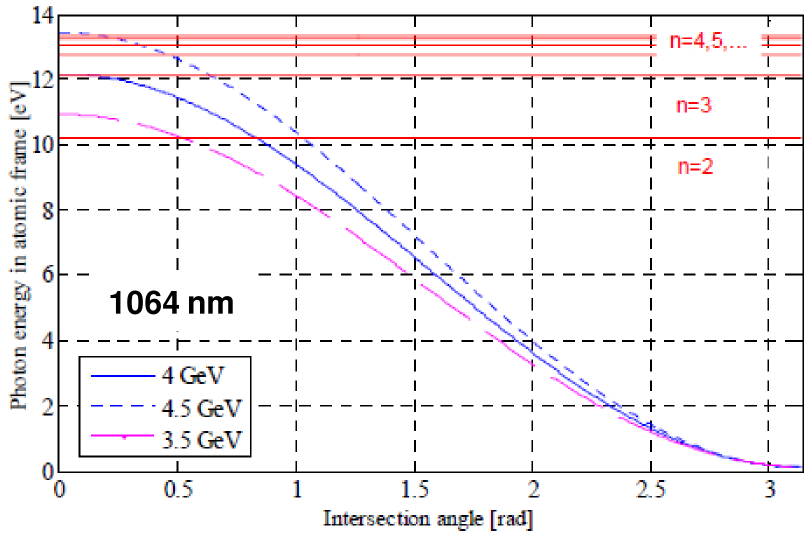
Loss minimum for a foil thickness of 1200 – 1300 ug/cm^2

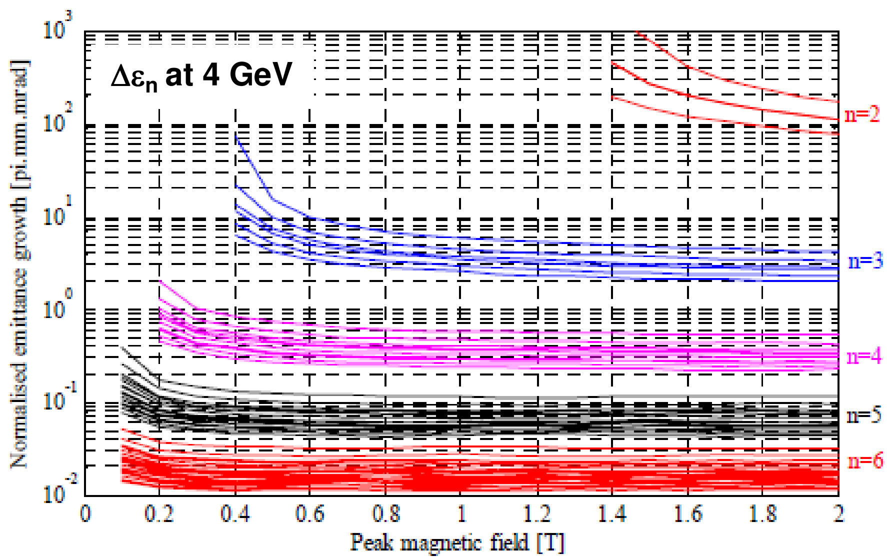
PS2 Injection Requirements

- Potential H^- injection issues for **Foil stripping**
  - Longitudinal Painting → constraint on dispersion in injection region with Δε from dispersion mismatch
  - Heating: Injection repetition rate, intensity
  - Transverse emittance → beam size on foil
  - Uncontrolled losses :
    - Halo – collimation in TL?
  - Kinetic Energy significantly less than 4 GeV → scattering, aperture, …

- Potential H^- injection issues for **Laser stripping**
  - Longitudinal Painting → large momentum range would dramatically increase required laser power
  - Bunch length → increases Laser average power, optimisation to study
  - Energy jitter → increases range of frequencies to be swept → 100 keV jitter OK
  - Trajectory jitter
    - Match laser and ion beam as much as possible, vertically more stringent – more laser power required (to get necessary power density)
  - Kin Energy significantly less than 4 GeV → Laser power, emittance growth

Energy Jitter





- Need divergence in Laser beam to cover the spread of exciting resonance frequencies due to Doppler broadening
- Laser frequency range is determined by effective momentum spread
- To have no big effect, need energy jitter one order below initial momentum spread
  - → **$\Delta E_{kin} = 10^{-4}$ GeV**

- Laser stripping much more difficult for significantly reduced kinetic energy (e.g. 3.5 GeV) – can only access n=2 state with 1064 nm which means huge emittance growth in last magnetic stripping step

Conclusion TTL1

- TTL1 design:
  - First part compatible with all SPL versions
  - Second part only with LP SPL (4 GeV), if LEP yokes not used but longer magnets also for LP SPL (5 GeV)
  - 8.1 % slope → civil engineering!
- Multiple particle simulations
  - Emittance growth (H/V): 23% / 2%
  - Energy spread increase: from ±1.5 MeV to ±7 MeV
- Trajectory correction → OK
- Outlook:
  - TTL1 optics studies ongoing because of new PS2 injection region design

Conclusion Extraction and PS2 Injection

- Extraction to ISOLDE → OK
- Extraction to EURISOL → Not feasible within constraints!
  - 2 possibilities:
    - Opening up distance between cryomodules to **16.4 m** and reducing radius of WC transition to **43 cm**
    - Within given **13 m**, reduce WC transition length to **90 cm** and radius to **55 cm**
- PS2 Injection
  - Study on H^- injection is work in progress…
  - Significantly reduced energy makes injection much more difficult!
  - Large momentum range and bunch length increase Laser power → need to optimise
  - Energy jitter of 100 keV → OK
  - Losses in injection region → Halo collimation in TL?

- Back up slides

Beam and Twiss Parameters

SPL end point (Source: M. Eshraqi):

	x plane	y plane
norm. 1s emittance [µm]	0.351	0.350
beta [m]	106.5	117.3
alpha	-0.055	-1.352
dispersion [m]	0	0
dispersion derivative	0	0

Injection point (Source: W. Bartmann):

	x plane	y plane
beta [m]	15	15
alpha	0	0
dispersion [m]	-0.4	0
dispersion derivative	0	0

Trajectory Correction: Assumed Errors

- Quadrupole displacement errors: Gaussian distribution in x/y with σ = 0.2 mm, cut at 3σ
- Dipole field errors: Gaussian distribution of deflection with σ = 10 μrad, cut at 2σ
(→ relative field error of 5e-4)
- Dipole tilt errors: Gaussian distribution with σ = 0.2 mrad, cut at 4σ
- Monitor errors: Flat random distribution of ±0.5 mm in both planes
- Injection error: Gaussian distribution of position / angle with σ = 0.5 mm / 0.05 mrad, cut at 2σ
- Monitor failure probability: 5%