EuPRA\textsc{XIA}@SPARC\textsc{L}AB
Start to end Simulations

C. Vaccarezza
on behalf of WA1
Outline

WA1 : Beam-Physics - S2E simulations

WA1 : Roadmap to TDR

Basic Layout & results
- General Notes
- Linac WoP’s for Plasma and FEL
- Plasma simulation results

On going Options

Conclusions
It provides that the machine physics simulations (from the gun to the users) are in line with the project objectives. Coordinates, promotes and ensures that the integration of the activities carried out by the interested WPs (1,2,3,4,6,8,9,13,17) are consistent with the rest of the WA and in line with the project objectives.
Milestones

**Dec 2023**

**TDR completion**

- Completion of machine layout & integration and S2E simulations (8-6 months for writing the TDR)

**June 2023**

- TDR completion

**July 2021**

- Machine layout «coarse» finalization in terms of:
  - Number and type of undulators
  - Number and type of transfer lines
  - Spectrometer / extraction lines
  - Submitted to «first magnets design and feasibility verification (April-May 2021)»

**Dec 2021–Mar 2022**

- Final machine layout refinement

**Dec 2021**

- Nominal WoP finalization

**Jun 2022**

- Virtual measurements - Diagnostic functional check - High level SW & Operating procedure definition

**Dec 2022**

- Assessment of lattice robustness and jitter/alignment sensitivity & counteractions

**June 2023**

- Commissioning strategy
X-BAND LINAC OPERATION:

• WoP1 : PWFA
The 500 MeV Witness+Driver scheme is adopted with a lattice able to drive the two bunches at the plasma entrance with the required characteristics

• WoP2 : Full X-band
The 1 GeV energy is achieved by means of only X-band RF sections, the beam is compressed with a Hybryd schem: VB + Magnetic chicane
## Nominal FEL parameters from CDR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>PWFA</th>
<th>Full X-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Wavelength</td>
<td>nm</td>
<td>3</td>
<td></td>
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<tr>
<td>Photons per Pulse</td>
<td>(\times 10^{12})</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Photon Bandwith</td>
<td>%</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Undulator Area Length</td>
<td>m</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>(\rho(1D/3D))</td>
<td>(\times 10^{-3})</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Photon Brilliance per shot</td>
<td>(s \text{ mm}^2\text{mrad}^2) (bw(0.1%))</td>
<td>(1 \times 10^{27})</td>
<td></td>
</tr>
</tbody>
</table>

## Electron Beam Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>PWFA</th>
<th>Full X-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Energy</td>
<td>GeV</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bunch Charge</td>
<td>pC</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Peak Current</td>
<td>kA</td>
<td>1-2</td>
<td>1-2</td>
</tr>
<tr>
<td>RMS Energy Spread</td>
<td>%</td>
<td>1.1</td>
<td>0.1</td>
</tr>
<tr>
<td>RMS Bunch Length</td>
<td>(\mu m)</td>
<td>6-4</td>
<td>24-20</td>
</tr>
<tr>
<td>RMS norm. Emittance</td>
<td>(\mu m)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Slice Energy Spread</td>
<td>%</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Slice norm Emittance</td>
<td>mm-mrad</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>
To do list in more detail

**S2E simulations:**

- **WoP1:**
  - PWFA acceleration and transport of 1 GeV 30 pC e-beam up to undulator exit
    - End of 2021
      - Comb scheme (only RF or hybrid)
      - 2-RFD and/or chicane schemes equipped with slit system
    - June of 2022
      - Diagnostics functional check
    - End of 2022
      - Lattice robustness and jitter/alignment sensitivity & counteractions

- **WoP2:**
  - X-band RF acceleration and transport of 1 GeV 200pC e-beam up to undulator exit
    - End of 2021
      - BC and transfer doglegs optimization/finalization (different schemes for transverse emittance control)
    - June of 2022
      - Microbunching instability studies (Wp1also) ad benchmark experiment at FERMI
    - Diagnostics functional check
    - End of 2022
      - Lattice robustness and jitter/alignment sensitivity & counteractions
  - June 2023
    - Commissioning Strategy: eg. Beams for alignment, dfs etc
• E_{max}=1.03 \text{ GeV} for all X-band configuration (w 10\% contingency on Kly output power)
• L_{max} \approx 60 \text{ m} (ex. 59.52 \text{ m}) from cathode + 1 \text{ m} distance from the wall
  vs 59 \text{ m} nominally available
• Extremely tight in:
  – plasma in\&out matching
  – Diagnostic sections for beam characterization
  – No room for doglegs upstream the undulator
General Notes

Since CDR completion the main efforts have been devoted to:

- Fitting the nominal machine into the available space provided by the building (e.g. the 3 s-band sections replacement by 2-sband + 2 x-band in the PhotoInjector)
- Iteratively balance the machine layout and the beam quality optimization with the RF system setup an distribution

S2E simulations:

- Tipical simulations are performed w 30 kp, (e.g. the incorrelated energy spread contribution is practically negligible so far) for the Comb case we have Dri 200kp-Wit 30kp
- Up to now SC effects are taken into account in the Photoinjector (Astra-Tstep), while in the Linac the LSC is considered in the drifts after the LH&BC (Élegant). Under the last Rev Comm recommendation, a fast check was made with a few Mp including it in the RF sections with no severe outcome. It is mandatory to include all the effects for a reliable finalization of the beam transport up to the FEL entrance.
- The considered trasverse and longitudinal wakefields are based on the K. Bane formula including the parameters coming from RF structures design.
- The hard-edge model considered so far for the magnetic elements has to be replaced with realistic field maps
Twiss parameters for basic layout (Elegant code)

WoP1 (30pC Wit)

2nd X-band exit (~11.27 m)

WP1

WoP2 (200 pC)

2nd S-band exit (~8.15 m)

WP2

Undulator entrance 50.374 m

Twiss parameters for 30pC,500MeV,n72,WH50pC,CH1200pC_awl_short_new_old silent
Summary

✓ Joining WA and layout meetings
✓ Identification of magnets families
✓ Dipoles: preliminary magnetic design of BC (beam compressor chicane)
✓ Dipoles: preliminary magnetic design of 1.2 GeV dump dipole (needed for the evaluation of the overall dimensions and placement choice)
✓ Quadrupoles: magnetic preliminary design of QS triplet (700MeV)

Ongoing:
• Start of quad+steerer magnetic design
• Start of magnetic design for quadrupoles enclosing diagnostics

Future activities Planning

By april 2021:
→ detailed design of all dipoles and quadrupoles
→ evaluation of power supplies (also on the basis of plant constraints, i.e. distance between magnets & ps)

By June 2021:
→ feedback from beam dynamics and diagnostics
→ magnetic design of steerers

Fall 2021:
Detailed design of all dipoles and quadrupoles
**Summary**

- **Main working point definition**
  - WoP1 PWFA beam
    - New injector setup with with 2 S-band accelerating structures instead of 3 to face with building size
    - Phase jitter studies have been addressed → to be enlarged with more statistics
  - WoP2 High charge case (200 pC)
    - Studies for on-crest and RF compression scheme → the hybrid compression is the best compromise
    - New injector setup that enables moderate peak current avoiding marked spike-like longitudinal distribution
    - Studies on space charge effects in the 2 X-band accelerating structures downstream the photoinjector (relatively low beam energy and moderate peak current exiting the photoinjector).
    - Longitudinal phase space linearization and stability
      - 10 cm long X-band SW structure has been inserted after the gun: studies performed for the 200 pC WP

- **Photo injector layout update**
  - SABINA photoinjector up to the end of the 2 S-band TW accelerating structures
  - X-band linac layout up to the laser heater inserted in the TStep model

- **Benchmark with different codes**
  - The machine model has been implemented in ASTRA
  - High charge WP cross-checked

**Roadmap**

- **Main working point definition:**
  - WoP1 PWFA beam
    - Validation of the proposed WoP at SPARC_LAB (1 year)
    - Witness-Driver extraction from the plasma and separation; transport up to the undulator (9 months)
    - Studies on other methods to generate the beam-driven WoP (chicane, RF deflector,...) (1 year)
    - Jitter and tolerances studies for main WoPs → steerer and BPM position, alignment procedure, etc... (3 months)
    - Longitudinal phase space linearization and stability
      - Studies on current shaping of the PWFA beam (3 months)
      - Studies on single bunch beam break-up at low energy up to the laser heater (6 months)
  - **Photo injector layout update**
    - Laser heater layout definition and related beam dynamics simulations (1 year)
  - **Cathodes and laser shaping**
    - Emission studies of metal photocathodes and beam dynamics simulations (ASTRA upgrade or new codes) (6 months)
    - Evaluation of new laser pulse shaping for main WPs (1 year)
    - Validation of beam dynamics evaluation at SPARC_LAB and CatLab Photocathode Laboratory at LNF (1 year)
    - Evaluation of advantages and impact of semiconducting cathodes on beam dynamics (6 months)
WoP 1-PWFA
WoP1- PWFA working point

- Beam dynamics for the WoP1 (PWFA beam) in the RF injector consisting in 2 S-band + 2 X-band TW accelerating Structures

Emittance (up) and longitudinal beam size (down) evolution along the old (line) and new injector layout (dashed line)

@ X-band exit: <E>=91.5MeV

- Transverse (up) and longitudinal (down) slice analyses at 2nd X-band TW structure exit

Transverse (up) and longitudinal (down) phase space at 2nd X-band TW structure exit

<table>
<thead>
<tr>
<th>X-band</th>
<th>L [cm]</th>
<th>g [MV/m]</th>
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<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>40</td>
</tr>
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</table>

\[ \gamma e_x = 1.70 \mu m \]

\[ \sigma_x = 79 \mu m, \sigma_E <E> = 0.95\% \]
WoP1: Driver & Witness at the capillary entrance:

- Driver (200 pC)

  \[ E_0 = 0.541 \text{ GeV} \]

  \[ \sigma_x = 0.008 \text{ mm} \]

  \[ \sigma_y = 0.007 \text{ mm} \]

  \[ \sigma_z = 0.05 \text{ mm} \]

- Witness (30 \( \mu \) pC)

  \[ E_0 = 0.54 \text{ GeV} \]

  \[ \sigma_x = 0.002 \text{ mm} \]

  \[ \sigma_y = 0.001 \text{ mm} \]

  \[ \sigma_z = 0.007 \text{ mm} \]

Currently problems w asymmetric beams w FBPI code!
Just a reminder of the CDR result (now from optimized Architect code on power9 unit -> 3 times faster) A. del Dotto
At first order the evolution of longitudinal momentum spread can be written as:

\[
\sigma_{pz}^2(s) = (E'_z)^2 \sigma_z^2 s^2 + 2 \sigma_{zpz}(0) s + \sigma_{pz}^2(0)
\]

BTW, now we have a nice tool to “see” LPS evolution, given an external force and and initial phase space:
Results can be satisfactorily compared with plasma simulations (Architect) for the Nature Physics results:

\[ \sigma_E \quad [\text{MeV}] \]

Results can be compared also for EuPRAXIA@SPARC_LAB CDR:

\[ \sigma_E \quad [\text{MeV}] \]
Stability studies

A. Del Dotto

Witness beam final energy and energy spread as a function of the Driver-Witness separation

$n_p = 10^{16} \text{ cm}^{-3}$ \hspace{1cm} $\lambda_p = 334 \mu m$

Witness beam final energy and energy spread as a function of the Driver-Witness separation
WP2- Plasma Phys. Summary & Roadmap

- Optimize PWFA 1 GeV WoP
- Add measured plasma profile to PWFA
- Coupled BD/PWFA tolerance
- Explore alternative WoP’s* for PWFA
  - Linear Regime (1 GeV only)
  - Highly nonlinear regime**
- Plasma dechirper

* subject to proper input beams availability
** also subject to computational and manpower availability

<table>
<thead>
<tr>
<th>Acc. Witness</th>
<th>Symbol</th>
<th>Units</th>
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<td>Charge</td>
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<tr>
<td>Energy</td>
<td>E</td>
<td>GeV</td>
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<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>$\mu m$</td>
<td>4</td>
</tr>
<tr>
<td>Proj. norm. emittance</td>
<td>$\varepsilon_{n\times y}$</td>
<td>mm-mrad</td>
<td>1-2</td>
</tr>
<tr>
<td>Slice norm. emittance</td>
<td>$\varepsilon_{n\times y}$</td>
<td>mm-mrad</td>
<td>&lt;0.8</td>
</tr>
<tr>
<td>Proj. Energy spread</td>
<td>$\sigma_\delta$</td>
<td>%</td>
<td>~1 (4 sigma cut)</td>
</tr>
<tr>
<td>Slice Energy spread</td>
<td>$\sigma_\delta$</td>
<td>%</td>
<td>0.02-0.03</td>
</tr>
</tbody>
</table>
WP9 - Computing

P. Santangelo

- Currently available:
  - 1 Power9 unit (128 CPUs + 2 GPUs with running (Aladyn, FBPIC, Architect, OpenFOAM, ParaFOAM))
  - File system GPFS for KLOE: daily code packup+data storage with KLOE tape system

- Intermediate deliveries and coarse timing
  - End of 2021: 4 units (minimal net configuration)
  - 1-2 years: 10 units cluster + storage
  - Long term: cluster upgrade: Up to 60 kW covered by the existing conditioning system

- Resources and needs
  - 1 unit 184 CPU 20 k€
  - 1 GPU 10 k€ (2, 4 ..)

- Manpower:
  - Currently 4 people: P. Santangelo, F. Fortugno, A. Del Dotto (WP2), S. Romeo

- R&D:
  - Code installation and optimization
  - Different parameter test
  - GPU optimization (where needed)
  - Code parallelization
WP2- Plasma Phys. Summary & Roadmap

Plasma simulation tools & workflow

**Architect**: 2D cylindrical, hybrid, 2 h/cm -> 36 h/cm on a single CPU in SPMD

**FBPIC**: Cylindrical harmonics PIC, 1 h/cm -> 5 h/cm on a single TESLA GPU (possibly) in SPMD

**Aladyn**: Full 3D PIC, about 500 h core/mm Parallel execution on CPU

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OPTION 1: “ICU” configuration
Upgrade existing Power9 unit to 512 Gb RAM and 2 extra TESLA GPU*.

OPTION 2: “down but not out” configuration
As OPTION 1 + one more unit (2 total).

OPTION 3*: “starter kit” configuration
As OPTION 2 + two more units (4 total).

OPTION 4: “we are getting somewhere” configuration
As Option 3 + two more units (6 total).

OPTION 5: “power up” configuration
As OPTION 4 + two more units (8 total).

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<table>
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<tr>
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<tbody>
<tr>
<td>1</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<td>✓</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓ = Allowed
✓ = Very limited (short distance/volumes, comp. time > 5 days, few instances, ...)
✘ = Not allowed (Impossible, irrelevant setup, at best very preliminary run)

* parallel codes are SC tracking codes other than PIC (Tstep, Impact T, Elegant, ...), MHD (Plasma_LAB), Genesis...
* * long run = acc. length > few cm
WoP2- All X-band 200pC
WoP2 200 pC beam (2 s-band exit)
Longitudinal phASE space

Photoinjector exit

1° X-band 40 cm exit, Phi=+270°

2-3 X-band 90 cm exit, Phi=85.4°

BC1 entrance 4-10 X-band exit, 90 cm Phi=85.4°

Und entrance, 11-18 X-band exit, 90 cm Phi=90°
WoP2 200 pC emittance & spotsize

CSR-Emittance dilution w Elegant

Beam size along the Linac

C. Vaccarezza
WoP2 up to the undulator entrance

\[ \langle E \rangle = 1034.580 \text{ MeV}, \text{ RMS energy spread} = 0.104\% \]

Slice length = 10.00 \( \mu \text{m} \)
WoP2 - high charge working point for more uniform transverse phase space

- Beam dynamics for the WoP2 (high charge beam) in the RF injector consisting in 2 S-band TW accelerating Structures

@ S-band exit: \( <E> = 97.0 \text{ MeV} \)

\[ \gamma_e = 0.46 \, \mu\text{m} \]

\[ \sigma_z = 155 \, \mu\text{m}, \, \sigma_E / \langle E \rangle = 0.94\% \]

Energy spread (up) and emittance (up) evolution along the new injector layout

Transverse (up) and longitudinal (down) slice analyses at 2nd S-band TW structure exit

Transverse (left) and longitudinal (right) slice analyses at 2nd S-band TW structure exit

Transverse (up) and longitudinal (down) phase space at 2nd S-band TW structure exit
WoP2 - Longitudinal phase space shaping

- A 10 cm long X-band SW structures has been inserted after the gun
- Beam dynamics has been studied by means of simulations varying the compression factor and X-band structure set point
- From analytical calculations the integrated voltage we should use for compensation at the photoinjector exit is of about 2.5-3.0 MV that corresponds to $E_{\max} = 25-30$ MV/m on average with higher voltages dumping the beam or disrupting its phase space quality.

**Without X-band structure**

**With X-band structure**

Transverse (up) and longitudinal (down) slice analyses at 2\textsuperscript{nd} S-band TW structure exit for three VB set point with X-band structure after the gun switched off. 

Transverse (up) and longitudinal (down) slice analyses at 2\textsuperscript{nd} S-band TW structure exit for three VB set point with X-band structure after the gun switched on.

C. Vaccarezza
## WoP2 summary table & work in progress

<table>
<thead>
<tr>
<th></th>
<th>Symbol</th>
<th>Units</th>
<th>Base_line no X-band at Gun</th>
<th>Jan 21 + transv. uniformity No X-band at Gun</th>
<th>Jan 21 + transv. uniformity w X-band at Gun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge</td>
<td>$Q$</td>
<td>pC</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Energy</td>
<td>$E$</td>
<td>GeV</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Peak Current@Linac ex.</td>
<td>$I_{\text{peak}}$</td>
<td>kA</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bunch length at PhInj ex</td>
<td>$\sigma_z$</td>
<td>$\mu m$</td>
<td>140</td>
<td>180-110</td>
<td>180-110</td>
</tr>
<tr>
<td>Bunch length at Linac ex</td>
<td>$\sigma_z$</td>
<td>$\mu m$</td>
<td>24</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proj. norm. emittance at PhInj ex</td>
<td>$\epsilon_{n,x,y}$</td>
<td>mm-mrad</td>
<td>0.5,0.5</td>
<td>0.5</td>
<td>0.8-0.9</td>
</tr>
<tr>
<td>Proj. norm. emittance at Linac ex</td>
<td>$\epsilon_{n,x,y}$</td>
<td>mm-mrad</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slice norm. emittance at PhInj ex</td>
<td>$\epsilon_{n,x,y}$</td>
<td>mm-mrad</td>
<td>0.4,0.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slice norm. emittance at Linac ex</td>
<td>$\epsilon_{n,x,y}$</td>
<td>mm-mrad</td>
<td>0.6-0.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proj. Energy spread at PhInj ex</td>
<td>$\sigma_\delta$</td>
<td>%</td>
<td>1.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proj. Energy spread at Linac ex</td>
<td>$\sigma_\delta$</td>
<td>%</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slice Energy spread at Linac ex</td>
<td>$\sigma_\delta$</td>
<td>%</td>
<td>0.4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Ongoing options:

**a)**
- 2 s-band
- 10 x-band
- DL &/or compressor

E~ 90 MeV-WP2 (200pC beam)  
E~ 100 MeV-WP1 (COMB beam with 40MV/m first 2 x band)

**b)**
- LH-chicane
- DL compressor

Emax~ 640 MeV-WP1  
Emax > 700 MeV-WP2  
E > 1.1 GeV-WP2 (200pC beam)
The key element is an optimized dogleg to control the emittance dilution due to CSR effect.

Several approaches can counteract the emittance dilution:

- CSR kick-canceling by means of a betatron $\pi$-phase advance between two chicanes (not so effective between LH and BC) (P. Emma et al. SLAC-PUB-7554, May 1997)

- Five bends chicane (D. Khan, T. Raubenheimer. JACoW-FEL2017-TUP030 - option set aside for the time being pending comparison with MBI instability)


- R-matrix analysis and CSR suppression condition for a double achromat (PRST- AB 17, 060701 (2014) (--> dogleg compressor)


C. Vaccarezza

Key point: Transverse Emittance dilution control

It is an extension of the transport matrix in presence of a momentum dispersion (ex. sector dipole):

$$ \begin{pmatrix} \cos \theta & \rho \sin \theta & \rho(1 - \cos \theta) & \rho(1 - \cos \theta) & \rho^2(\theta - \sin \theta) \\ -\frac{1}{\rho} \sin \theta & \cos \theta & \sin \theta & \sin \theta & \rho(1 - \cos \theta) \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & \rho \theta \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} $$

The off axis motion of an electron caused by the initial momentum error is expressed in terms of the momentum dispersion function:

$$ (\eta_x(s_1), \eta_x'(s_1), 1, 0, 0)^T = R_{0 \rightarrow 1}(\eta_x(s_0), \eta_x'(s_0), 1, 0, 0)^T $$

In a similar way the CSR wake dispersion function $\zeta_x(s)$ to track the off axis motion due to the CSR effect:

$$ (\zeta_x(s_1), \zeta_x'(s_1), 0, L_B(s_1), 1)^T = R_{0 \rightarrow 1}(\zeta_x(s_0), \zeta_x'(s_0), 0, L_B(s_0), 1)^T $$

so the displacement of the electron in the $(x, x')$ phase space will be $(k\zeta_x, k\zeta_x')$ with $k = W_{CSR}/E_0$ - normalized CSR wake potential in the bending path.

Valid if the bunch length remains the same along the achromat.
In the first order approximation each bunch slice aligns on the line
\[ \zeta_x x' - \zeta'_x x = 0 \]
And matching the CSR kick to the phase ellipse orientation should minimize the emittance growth, with the following expression for the matched \( \beta_{0,\text{match}} \)

\[
\beta_{0,\text{match}} = \frac{\alpha_0}{2\rho} \left[ \rho^2 \tan(\theta/2) - \cot(\theta/2) \right] + \frac{\sqrt{2\rho^2(2 + \alpha_0^2) + \alpha_0^4 \cot^2(\theta/2) + \rho^4 \tan^2(\theta/2)}}{2\rho} \]

\[ \zeta_x x' - \zeta'_x x = 0 \]
\[ \tan 2\phi = 2\alpha(\gamma \beta) \]

\( R_{56} \sim 0.5 \text{ mm} \)
Projected transverse emittance dilution

Simple dogleg

Optimized dogleg
Adding the compression

\[ R_{56} \approx -19 \text{ mm} \]
Conclusions

- A lot of work is in progress to reach in July 2021 the milestone to freeze the layout including the room availability for electron beam extraction towards future experiments (e.g. sec. particle sources) and mostly in order to address:
  - MBI instability budget and countermeasures
  - Comb beam production by slit system (double RFD and/or chicane)
  - Lattice robustness vs jitters/instabilities
  - Layout vs Diagnostics efficiency -> virtual measurements
  - ....and so on through the roadmap
- Energy spread compensation & Jitter sensitivity issues in plasma acceleration play a major role

The computing power upgrade to «starter-kit» (~200k€ including 4 ws) is a key point for being in time with the commitments.
Thanks for your attention