The RF-separated beams for the M2 beamline : update

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CERN | EN ENGINEERING DEPARTMENT

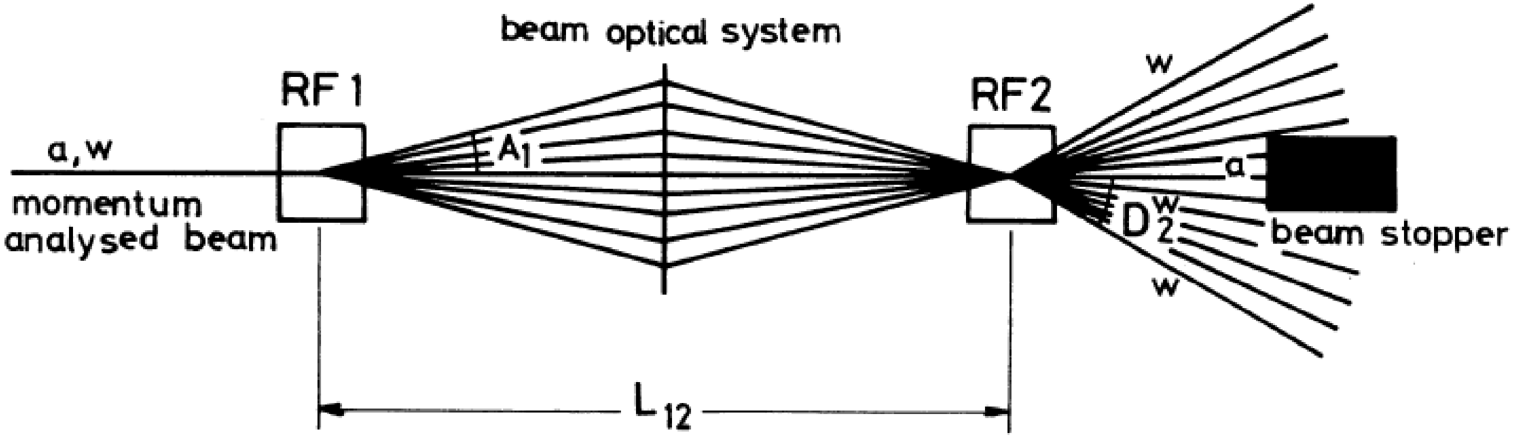
Physics Beyond Colliders

Outline

- What is an RF-separated beam?
- Our strategy
- Optics design
- RF requirements
- 3D integration
- Outlook

RF-separated Beams

Reminder: Panofsky-Schnell-System with two cavities (CERN 68-29)



- Particle species: same momenta but different velocities
- Time-dependent transverse kick by RF cavities in dipole mode
- RF1 kick compensated or amplified by RF2
- Selection of particle species by selection of phase difference
  $\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$
- For large momenta: $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2\mathbf{p}^2$

RF-separated Beams - Phases

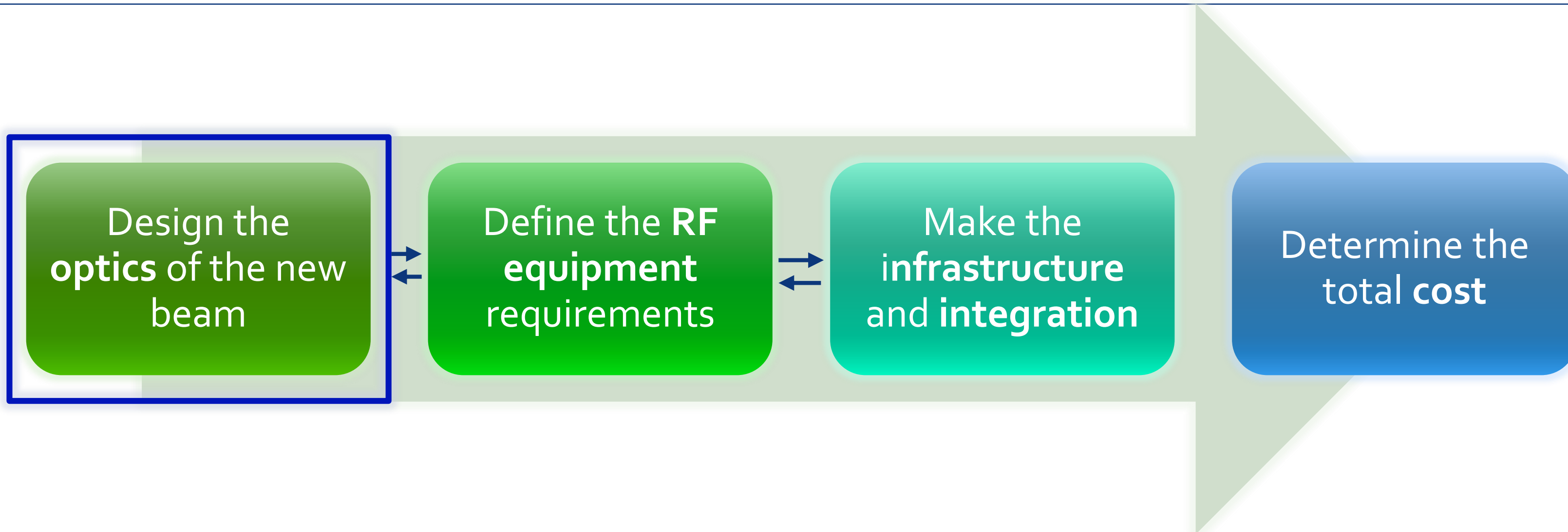
For $K^{\pm}$ beams: $\Delta\Phi_{\pi p} = 360^o$ and Φ_{RF2} such that both π and p go straight i.e. dumped

$\Delta\Phi_{pK} = 94^o$, i.e. a good fraction of K outside the dump, depending on phase at 1st cavity

For pbar beams: $\Delta\Phi_{\pi p} = 180^o$ and then $\Delta\Phi_{pe} = 184^o$, $\Delta\Phi_{pK} = 133^o$ with phase of RF2 such that pions go straight,

Antiprotons get reasonable deflection, electrons are dumped effectively and K reduced.

Strategy



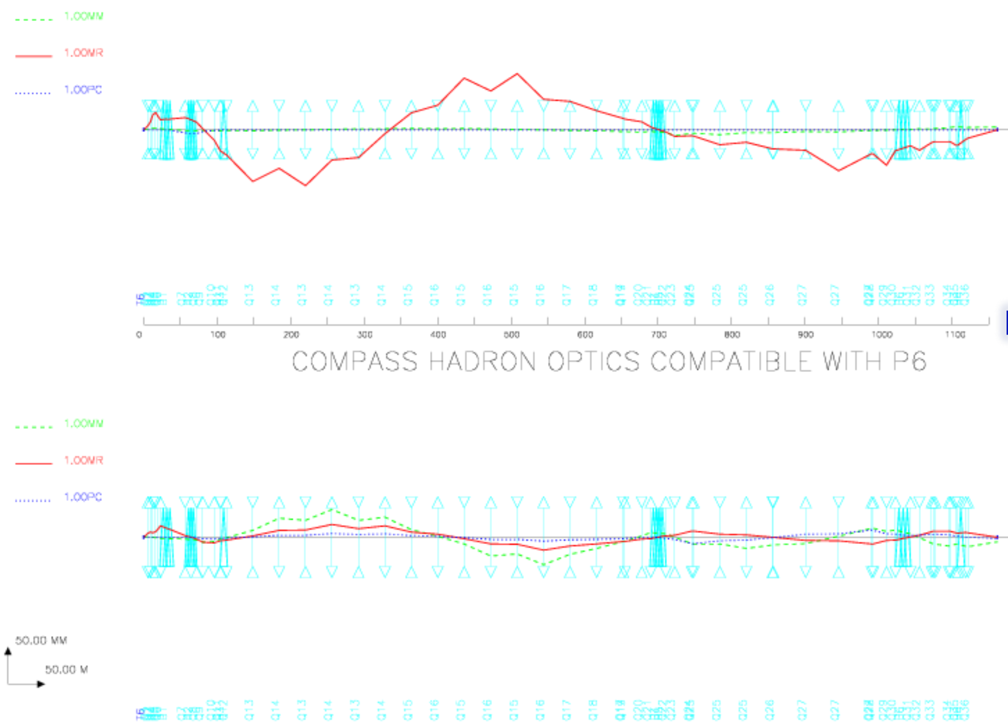
Requirements from the existing M2 beam line:

- All elements until Bend1 cannot move because of high radiative doses.
- The bending angles cannot change because of the shape of the tunnel.

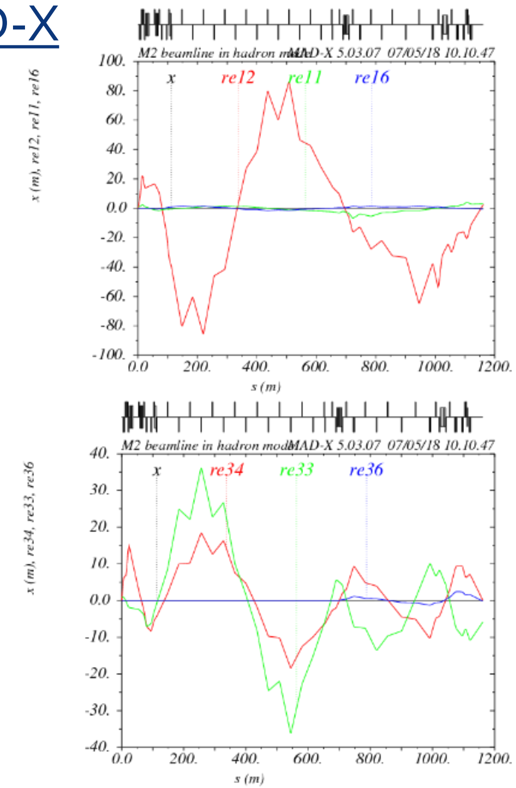
Optics design (1)

First work: M2 design with a more flexible software

Transport

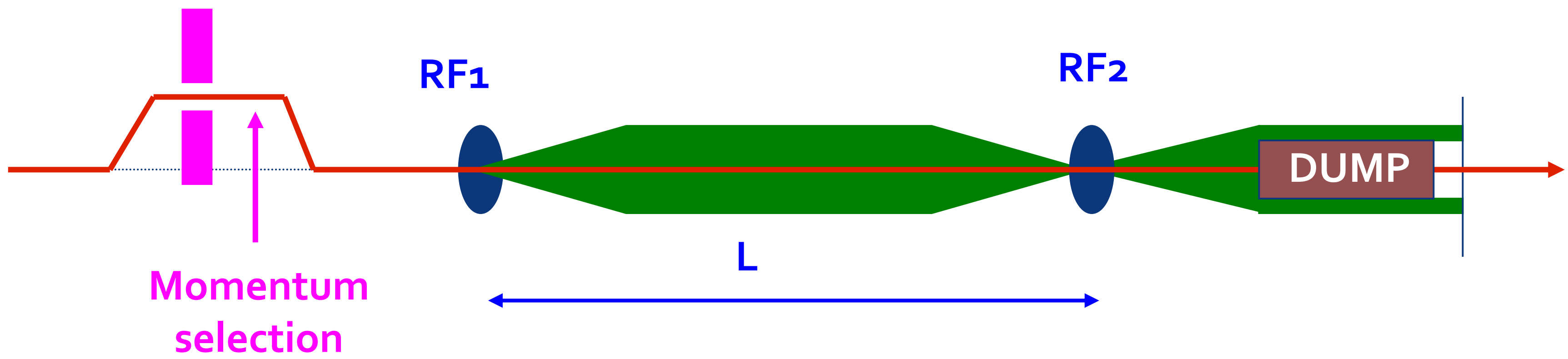


MAD-X



Starting point: 2 RF cavities to separate particles

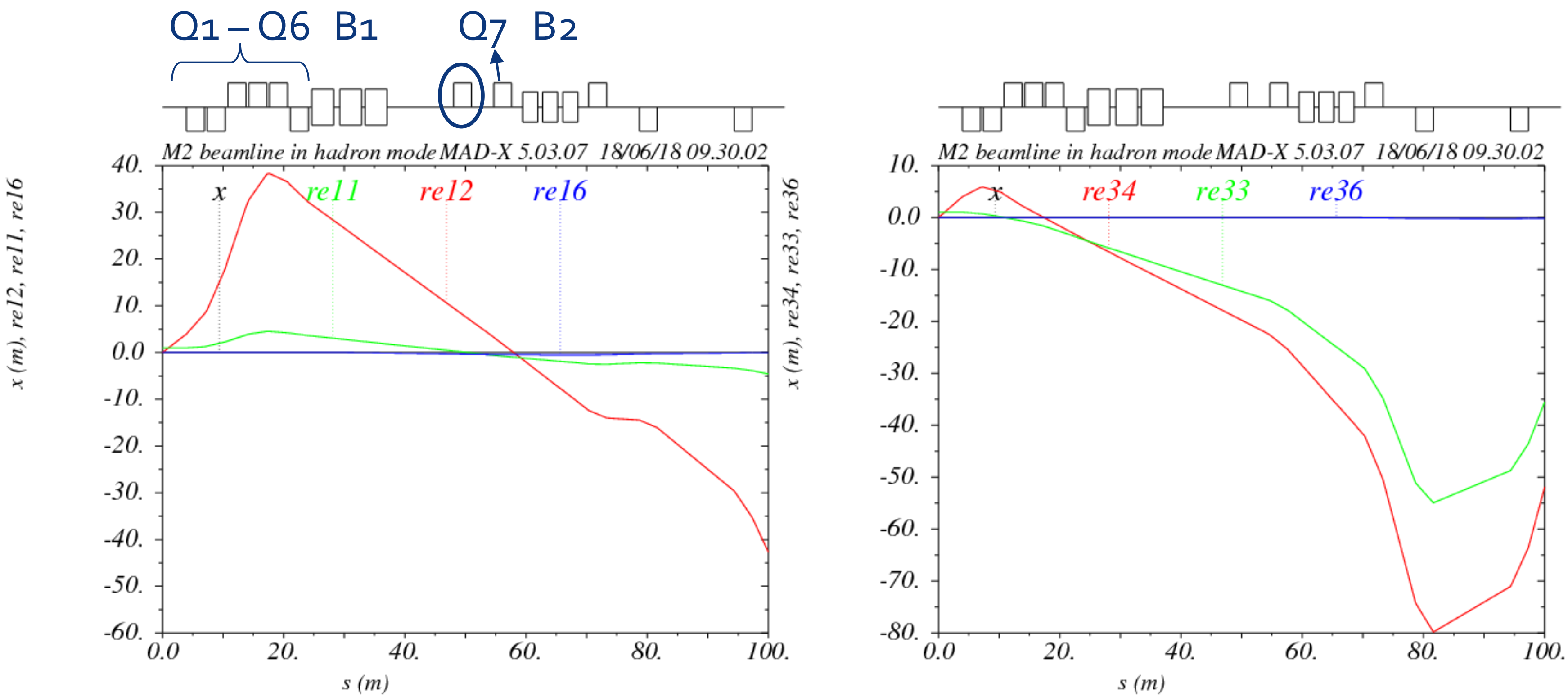
Optics design (2)



	Distance from the T6 target (m)	Comment
Momentum selection at collimator 1	57.98	The highest dispersion as possible, add achromat?
1st RF cavity	136.5	For the 2 cavities: soft focus
2nd RF cavity	862.5	After RF2, enough space to add a dump and a quadrupole

➡ L = 726 m, which gives a frequency ≈ 5 GHz

Optics design (3)

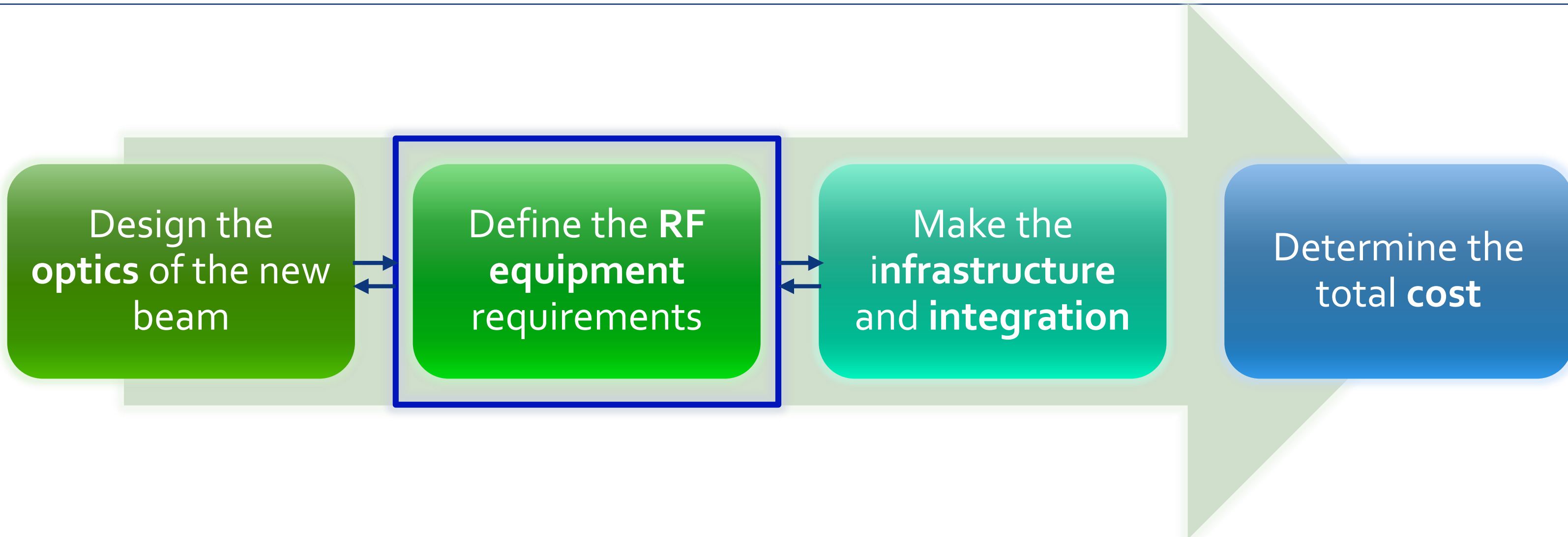


At collimator 1:

- Focus
- Beam size sufficiently small
- But, no large dispersion

➡ Add a **new quadrupole** before Q7 to increase the dispersion

Strategy



A) Rely on the **user requirements** and the **former studies**:

- Momentum of the wanted particles
- Phase difference (selection of particles)
- Frequency
  - ➡ Distance between cavities

B) Discussion with the RF group

RF equipment requirements (1)

For example: f = 5 GHz

Beam spot requirements:

- RF wavelength λ = c/f = 3 10^{10} cm s^{-1} / 3.9 10^{9} s^{-1} = 6 cm
- Coherence length (“phase is sufficiently preserved”, $\Delta\phi \approx \pi/10$)

$$L_{coh} \approx \lambda \cdot (\pi/10) / (2\pi) \approx 3 \text{ mm}$$

➡ Beam spot has to remain within **±1 mm** throughout the cavity.

Requirements on divergence:

- p_t-kick 15 MeV/c (see CKM system), i.e. 0.15 mrad at 100 GeV
- Beam divergence must be smaller than this in the bending plane
- Non-bending plane: sufficiently small divergence, e.g. **± 0.5 mrad**

➡ RF system limits transverse emittance.

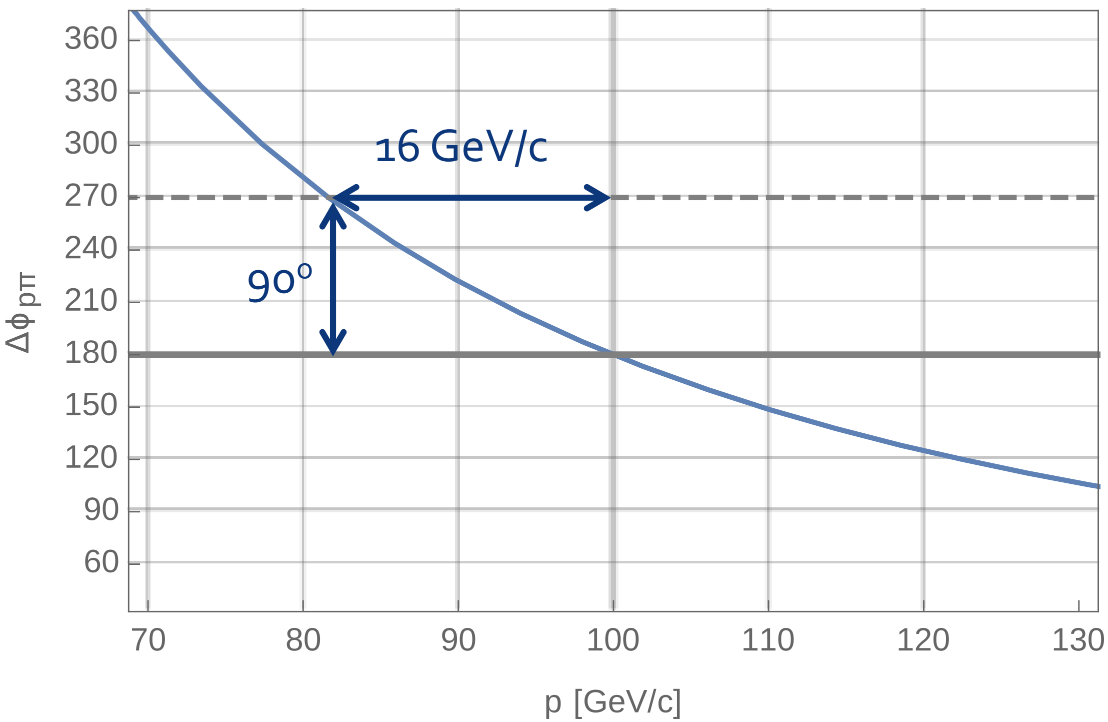
RF equipment requirements (2)

Requirements on the momentum dispersion in the RF cavities:

$\Delta\Phi_{final} = \Delta\Phi_{initial}\,(1 - 2\,\Delta p/p)$

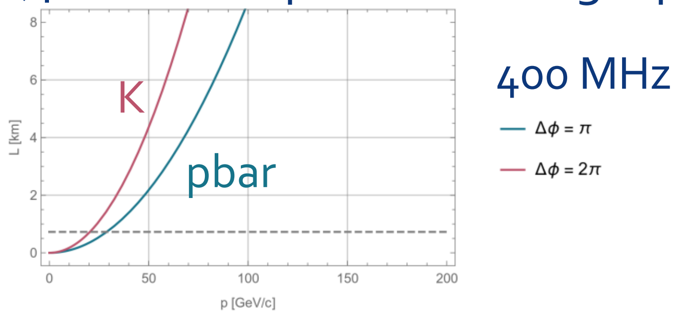
➡ It limits **Δp/p** to about **1 %.**

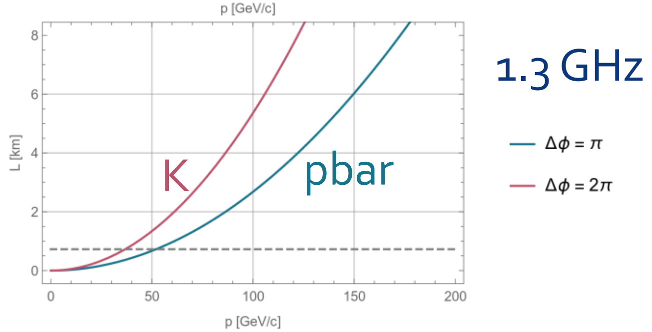
If the phase difference $\Delta\phi_{final}$ is too high, then the momentum dispersion becomes large!

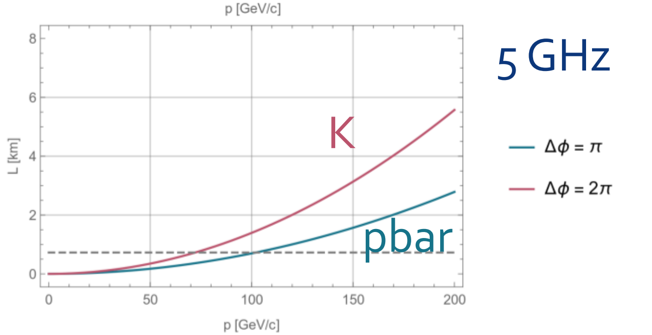


Crab cavities example

Currently available technology at CERN: Crab Cavities for LIU SPS upgrade (400 MHz superconducting dipole cavities)





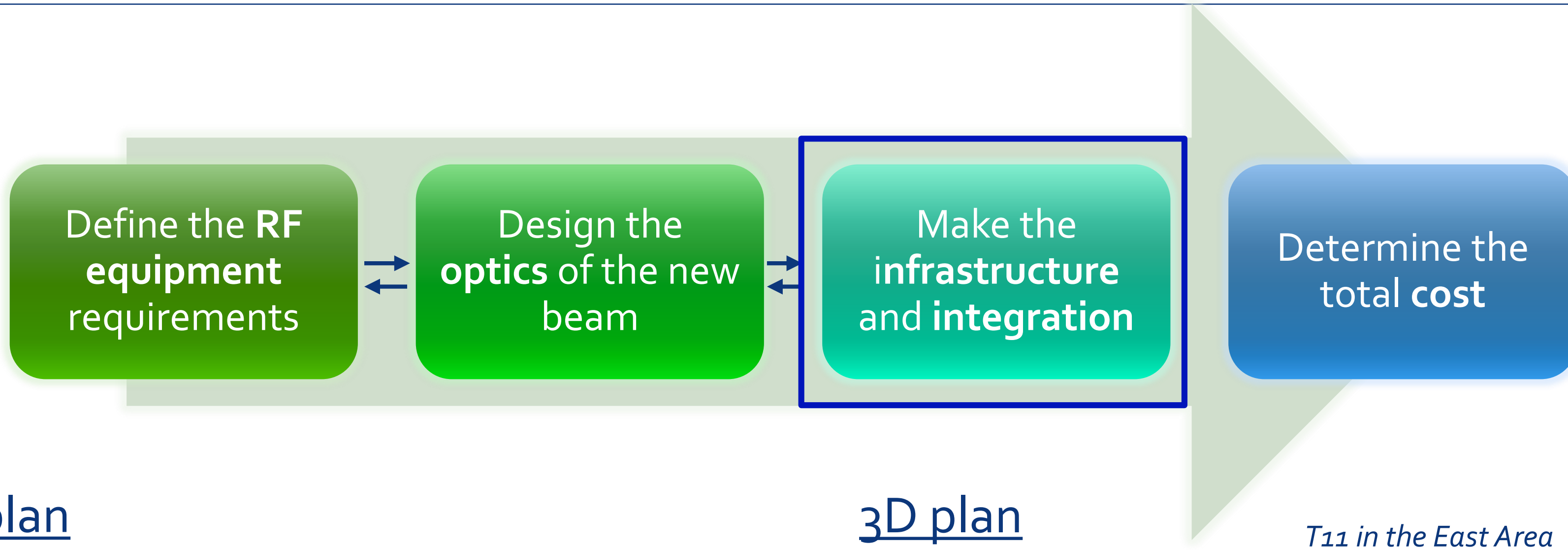


Assume availability of L=800m:

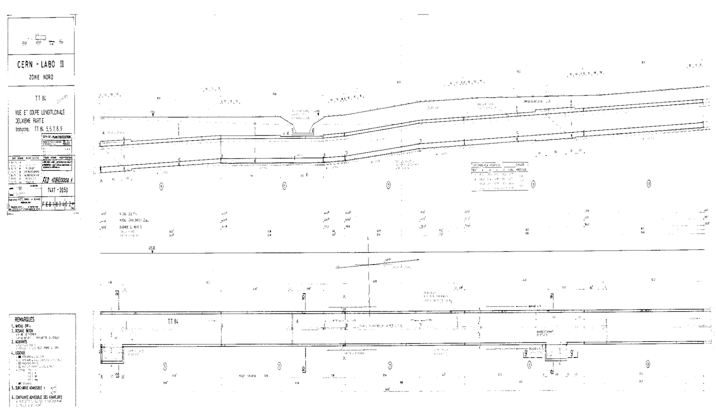
RF frequency	Limit p(K)	Limit p(pbar)
400 MHz	20 GeV/c	30 GeV/c
1.3 GHz	37 GeV/c	55 GeV/c
5 GHz	72 GeV/c	102 GeV/c

Conclusion: crab cavity design so far not compatible with user requirements, new developments necessary

3D integration of the tunnel

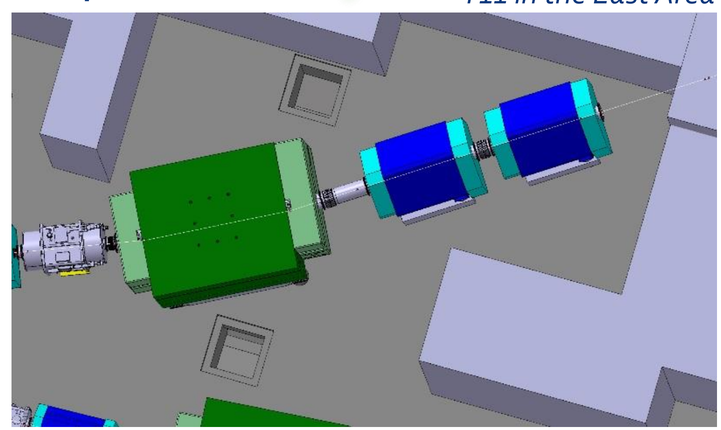


2D plan



3D plan

T11 in the East Area



- Add 3D drawing of the future experiment?

Outlook

- There is a strong correlation between RF requirements and optics design.
- In order to address the requirements, some **optimisations** in the optics design have to be done: add quadrupoles, move the location of collimators, maybe add an achromat for better momentum selection.
- These changes have to be taken into account in the **cost** estimate and scheduling as well as the R&D of the RF system.
- The next round of **discussions with the RF** group is expected soon.
- The **3D integration** of the EHN2 tunnel will be done during the next month.
- A dedicated study for the required **beam instrumentation** will start end of this year.

Thanks!