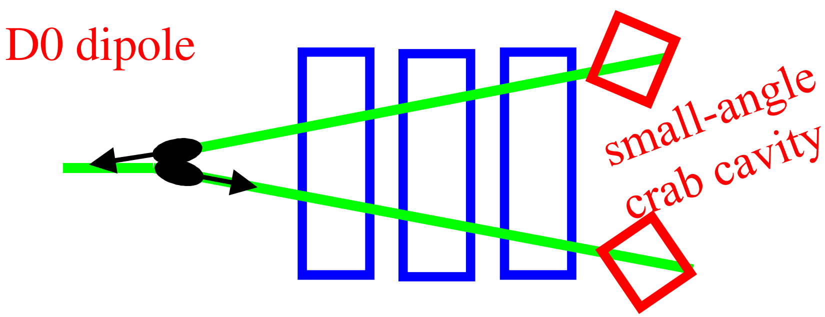
POSSIBLE LAY-OUTS FOR PHASE II UPGRADE

G. De Rijk, E. Todesco
Magnets, Cryostats and Superconductors Group
Accelerator Technology Department, CERN

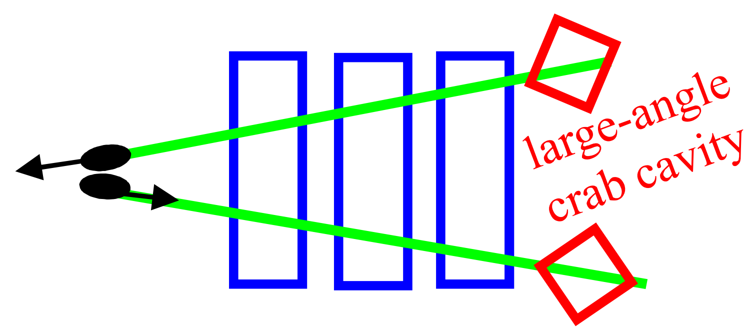
- Two ways to increase luminosity

$$L = \frac{f_{rev}\gamma}{4\pi\varepsilon_n}(N_b)^2 n_b \frac{F(\beta^*)}{\beta^*}$$

  - Larger intensity (num. of protons per bunch) N: from 10^{11} to $\sim 5\times10^{11}$
  - Smaller beta function in the IP β^* : from 0.55 to ~0.15 cm
- Smaller β^* does not improve luminosity if the adverse effect of crossing angle $F(\beta^*)$ is not canceled: two ways
  - Early separation scheme + small angle crab cavities
  - Large angle crab cavities



ES: Early separation scheme
(J. P. Koutchouk)

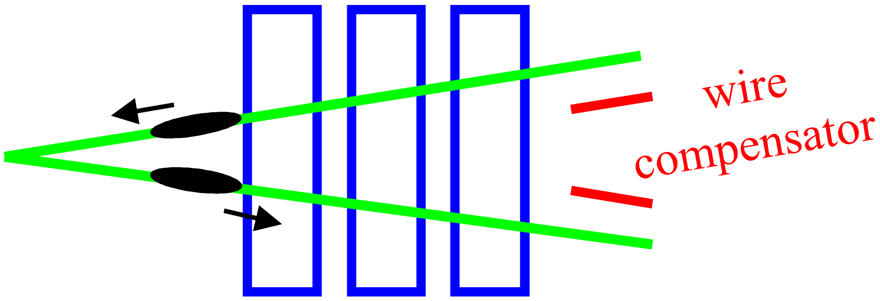


FCC: Full crab crossing
(L. Evans, W. Scandale, F. Zimmermann)

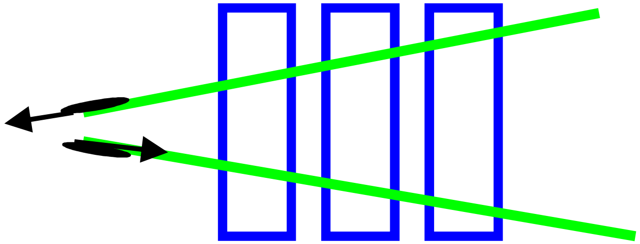
INTRODUCTION

$$L = \frac{f_{rev}\gamma}{4\pi\varepsilon_n}(N_b)^2 n_b \frac{F(\beta^*)}{\beta^*}$$

- Two ways to increase luminosity
  - Larger intensity (n. of protons per bunch) N
  - Smaller beta function in the IP β^*
- Intensity is limited by beam-beam tuneshift $\propto N/\varepsilon_n$: two schemes to overcome this limit
  - Go to Large Piwinski Angles
  - Reduce the emittance
    - Both schemes require stronger/larger IR magnets [F. Zimmermann]



LPA: Large Piwinski Angle
(F. Ruggiero, W. Scandale, F. Zimmermann)



LE: Low Emittance
(R. Garoby)

INTRODUCTION

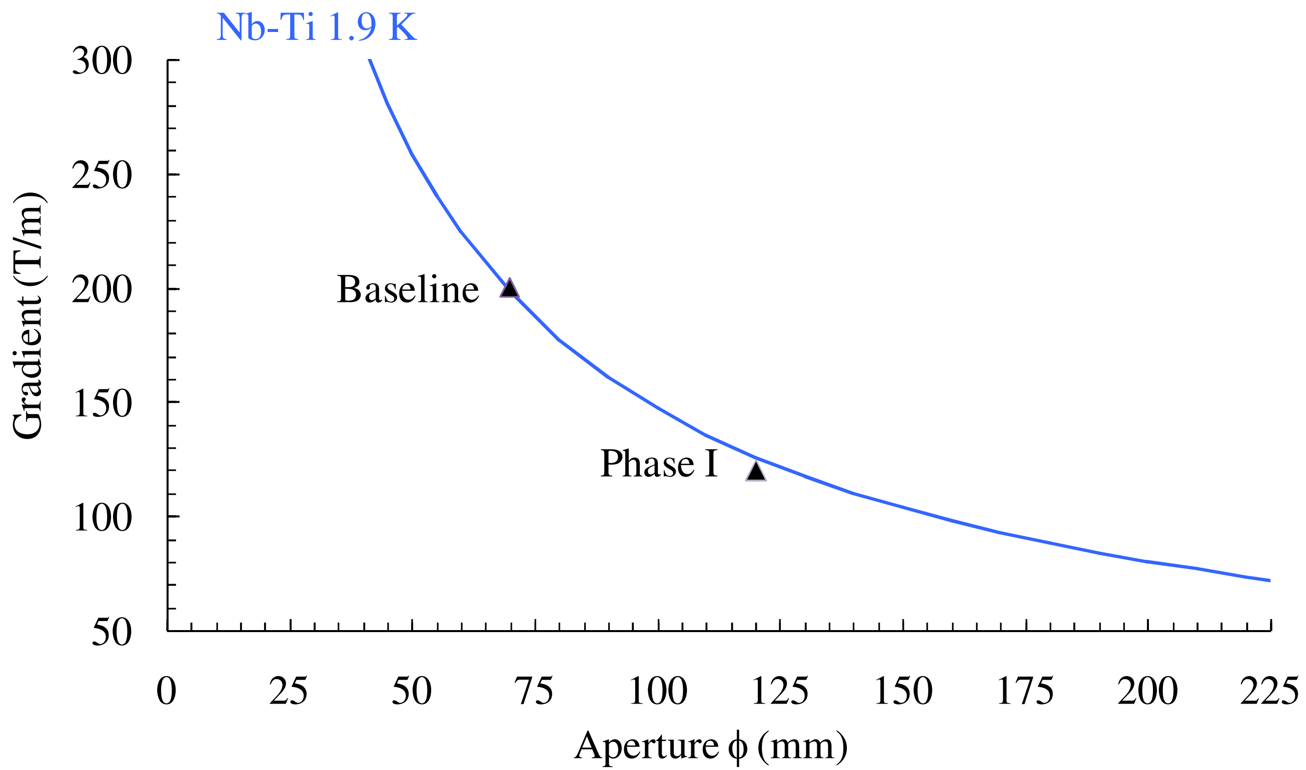
- The main idea for increasing luminosity through β^*:
  - If we want a smaller beta function in the IP β^*
    → larger beta function β_{max} in the IR quadrupoles $\beta_{max} \propto 1/\beta^*$
    → larger aperture of the IR quadrupoles $\phi \propto A + B\sqrt{\beta_{max}}$

- For a given material
  - Larger aperture is obtained by reducing the gradient
    → One has to make the triplet longer to match the required integrated force

  - What is the limit to this?
    - Linear chromaticity correction
    - Off momentum beta beating
    - Hard limits not yet completely established, LHC operation will tell us

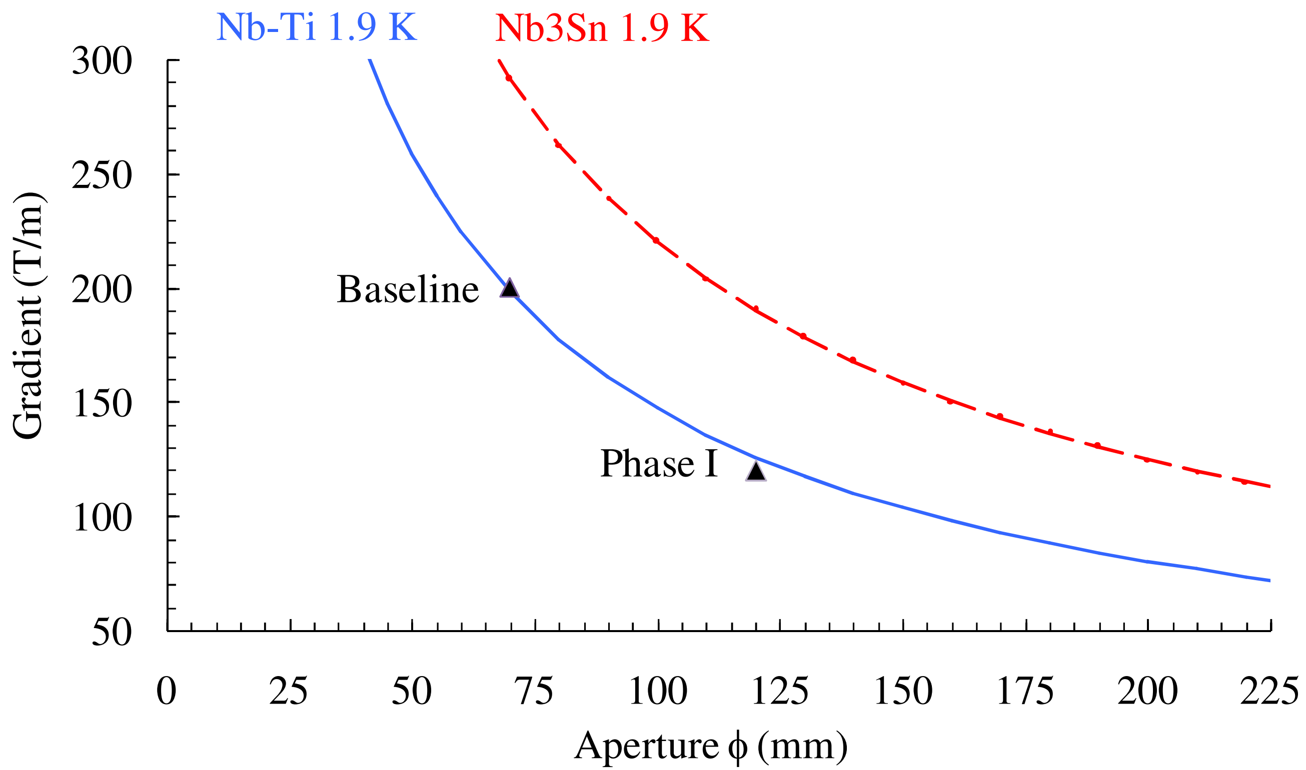
First ingredient: relation aperture _ gradient

- For Nb-Ti we use scaling laws giving the maximum achievable gradient (phase I slightly lower since the cable is fixed)



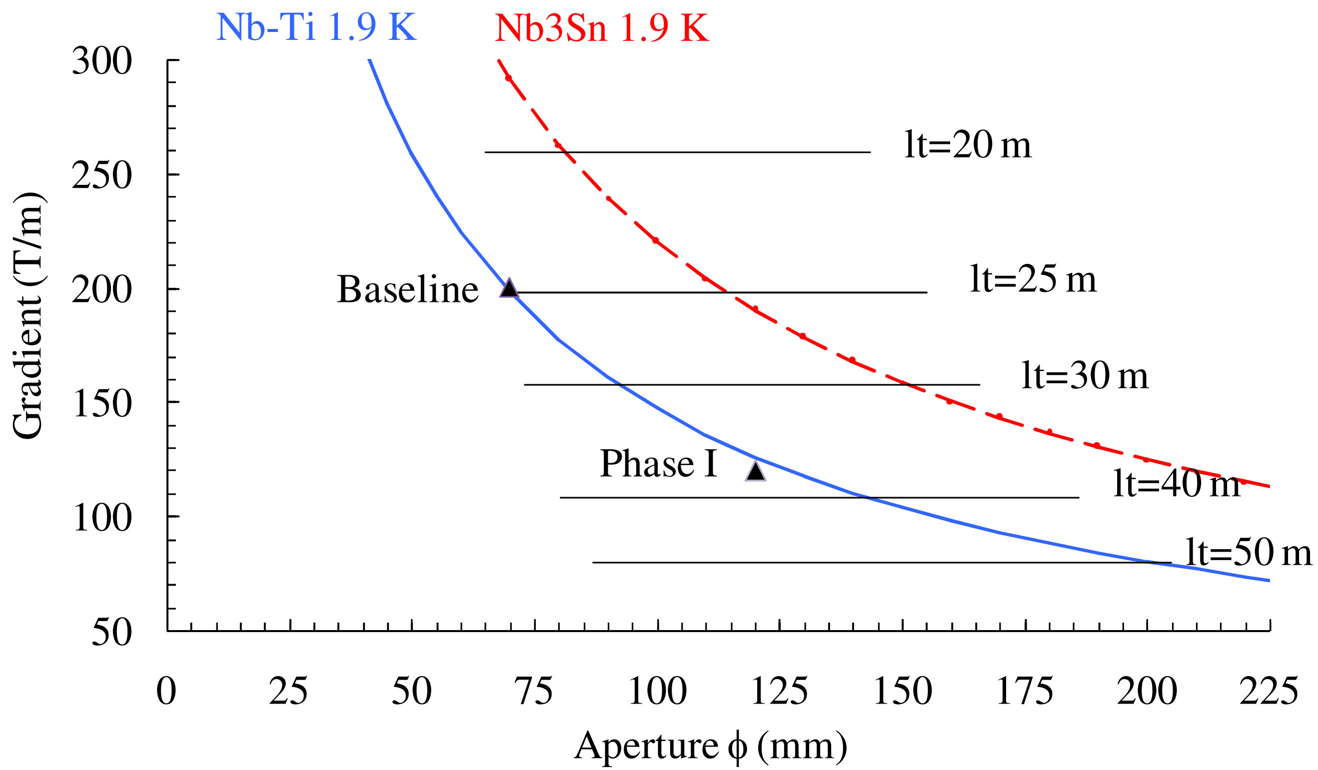
First ingredient: relation aperture _ gradient

- For Nb_3Sn we use a conservative j_c (2500 A/mm^2 at 4.2 K)
  - and a reasonable filling factor for the cable 0.3



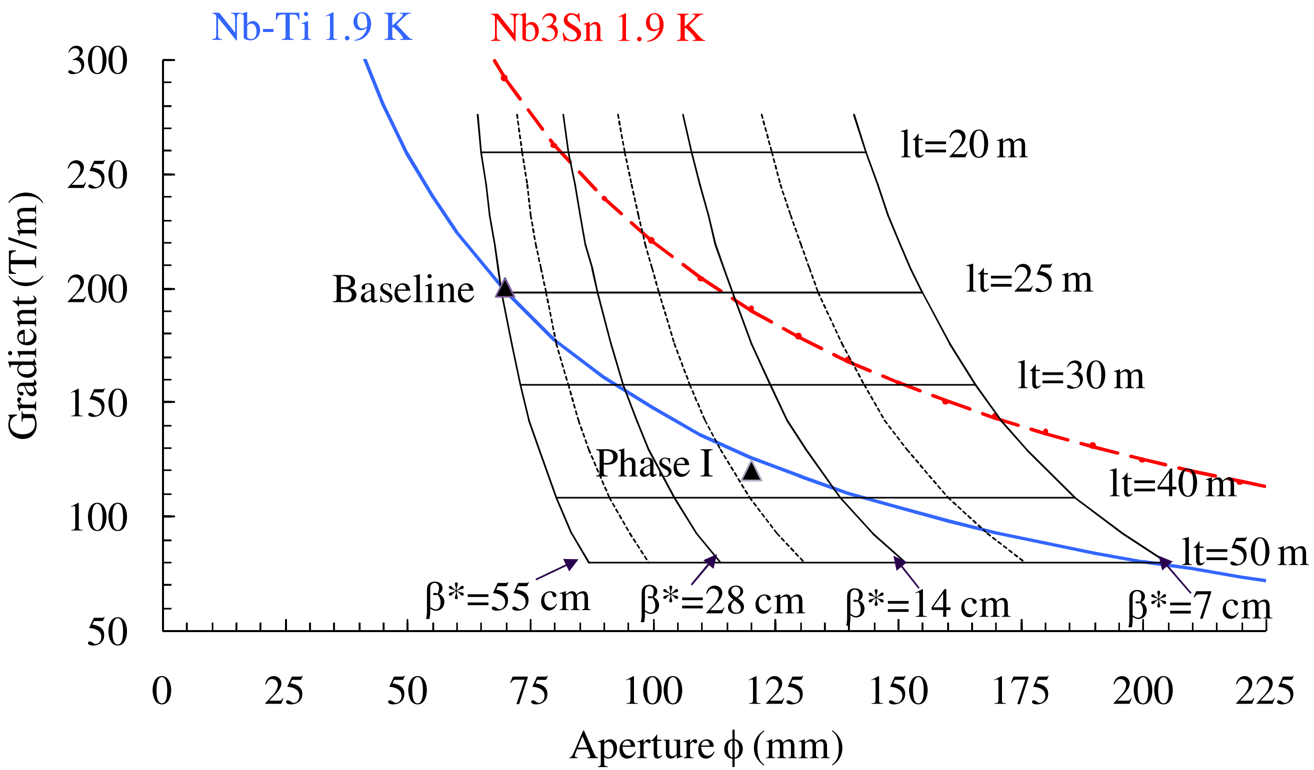
SECOND INGREDIENT: RELATION GRADIENT-TRIPLET LENGHT

- To each gradient a triplet length is associated, independently of the material



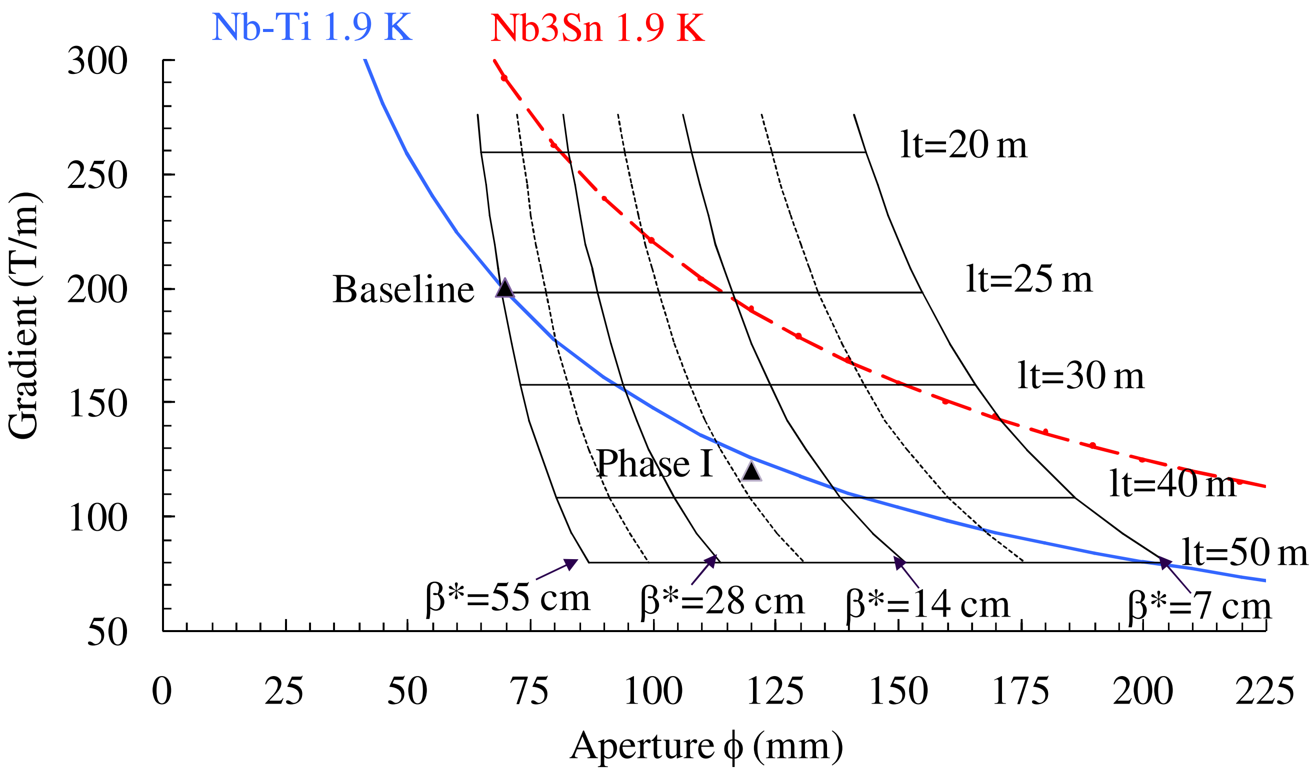
THIRD INGREDIENT: RELATION APERTURE-BETA STAR

- To each aperture, gradient and triplet length one can associate the minimal beta star that can be achieved (hard limit)
  - independently of optics aberrations (chromaticity, beta beating …)!!!



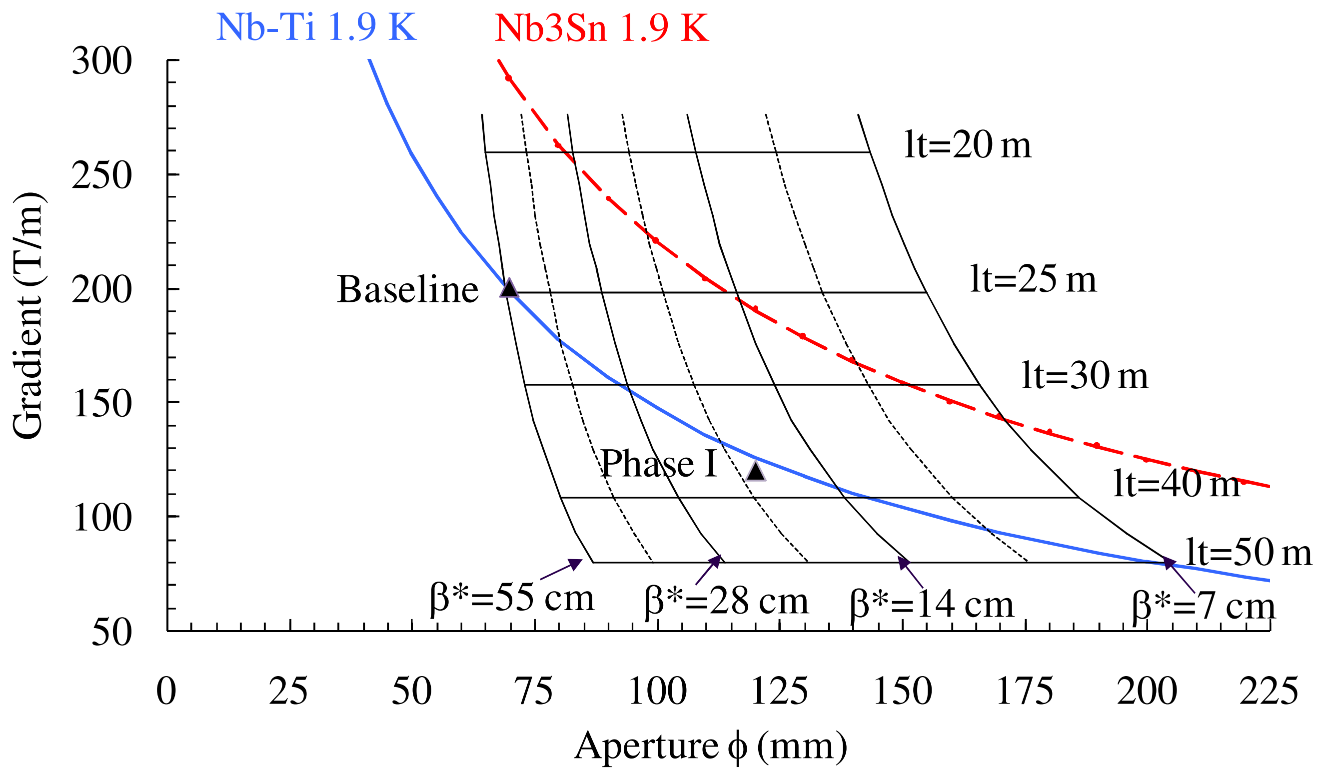
Third ingredient: relation aperture-beta star

- With the baseline we are sure to be limited at β^* =55 cm in the aperture (hard limit)



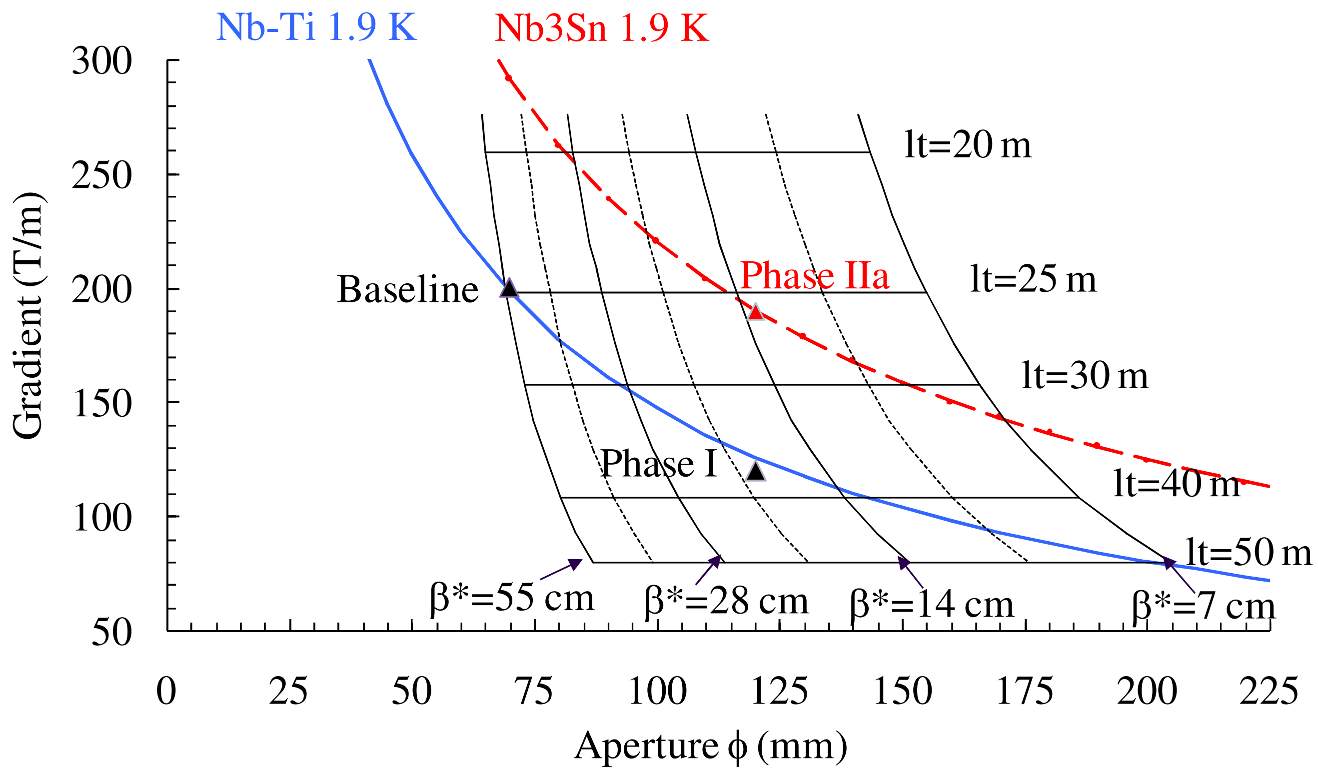
THIRD INGREDIENT: RELATION APERTURE-BETA STAR

- With the phase I the hard limit is β^* =19 cm, but estimates on aberrations give a limit to β^* =30 cm [S. Fartoukh, LIUWG]



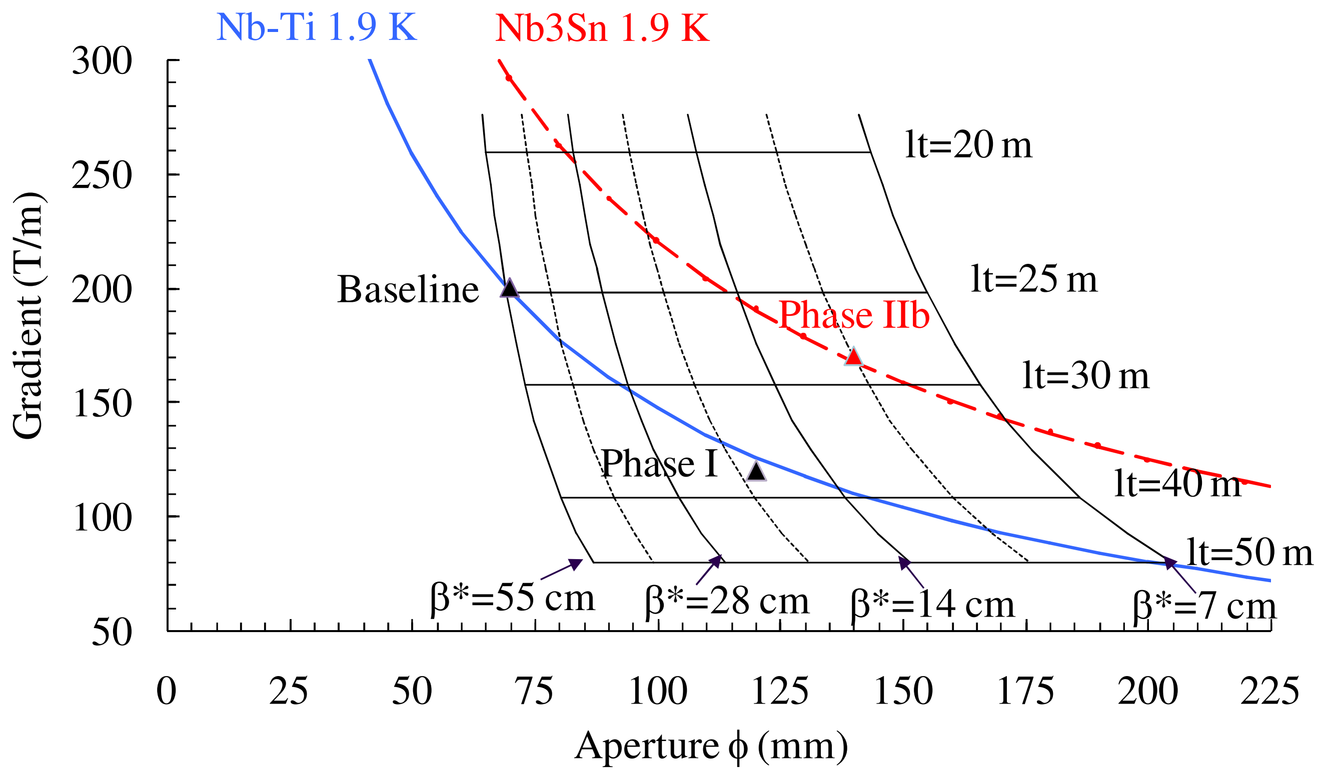
FIRST PROPOSAL (CONSERVATIVE)

- 120 mm aperture, 190 T/m operational gradient, 5.8 and 6.5 m long magnets (similar to the baseline)
  - Hard limit at β^* =14 cm



Second proposal (more aggressive)

- 140 mm aperture, 170 T/m operational gradient, 6.5 and 7.5 m long magnets
  - Possibility of reaching up to β^* =10 cm



CONCLUSIONS

- The choice of the phase II parameters strongly depends on some informations that will be given only by the LHC
  - Optics and aberrations
    - Linear chromaticity correction
    - Off momentum beta beating
  - Is margin in aperture needed ?

- In the present conditions we can outline two possibilities
  - Phase IIa: the same layout as the baseline, but with the PhaseI aperture of 120 mm – possibility of reaching 14 cm of β^*
  - Phase IIb: a longer layout, a larger aperture of 140 mm – possibility of reaching 10 cm of β^*
    - Beyond limits of linear chromaticity correction – very challenging