Linac4 Machine Advisory Committee
28th - 30th January 2008

Magnets for Linac4

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Outlook

- → New magnets for Linac4
- → New magnets for the Linac4 to Booster transfer line
- → Existing magnets in the Linac2 transfer line to be reused in the Linac4 transfer line
- → Summary and conclusions

New Linac 4 Magnets - Overview

- ➔ In total ~ 80 new electro-magnets needed for the Linac4 and transfer line:
  - 4 steerers for LEBT and MEBT
  - 23 quadrupoles + steeres for CCDTL
  - 13 quadrupoles + steerers for PIMS
  - 18 quadrupoles for TL
  - 4 dipoles for TL
  - 5 steerers for TL
  - Spare magnets of each type
- ➔ Important issues for the design:
  - Pulsed or dc operation ?
  - Water or air cooled ?
  - Linac steeres incorporated in quadrupoles or separated?
  - Incorporated measurement coils for field feed-back?
  - Only for Linac4 or to be used also for later SPL ?

DTL & CCDTL Quadrupoles - Parameters

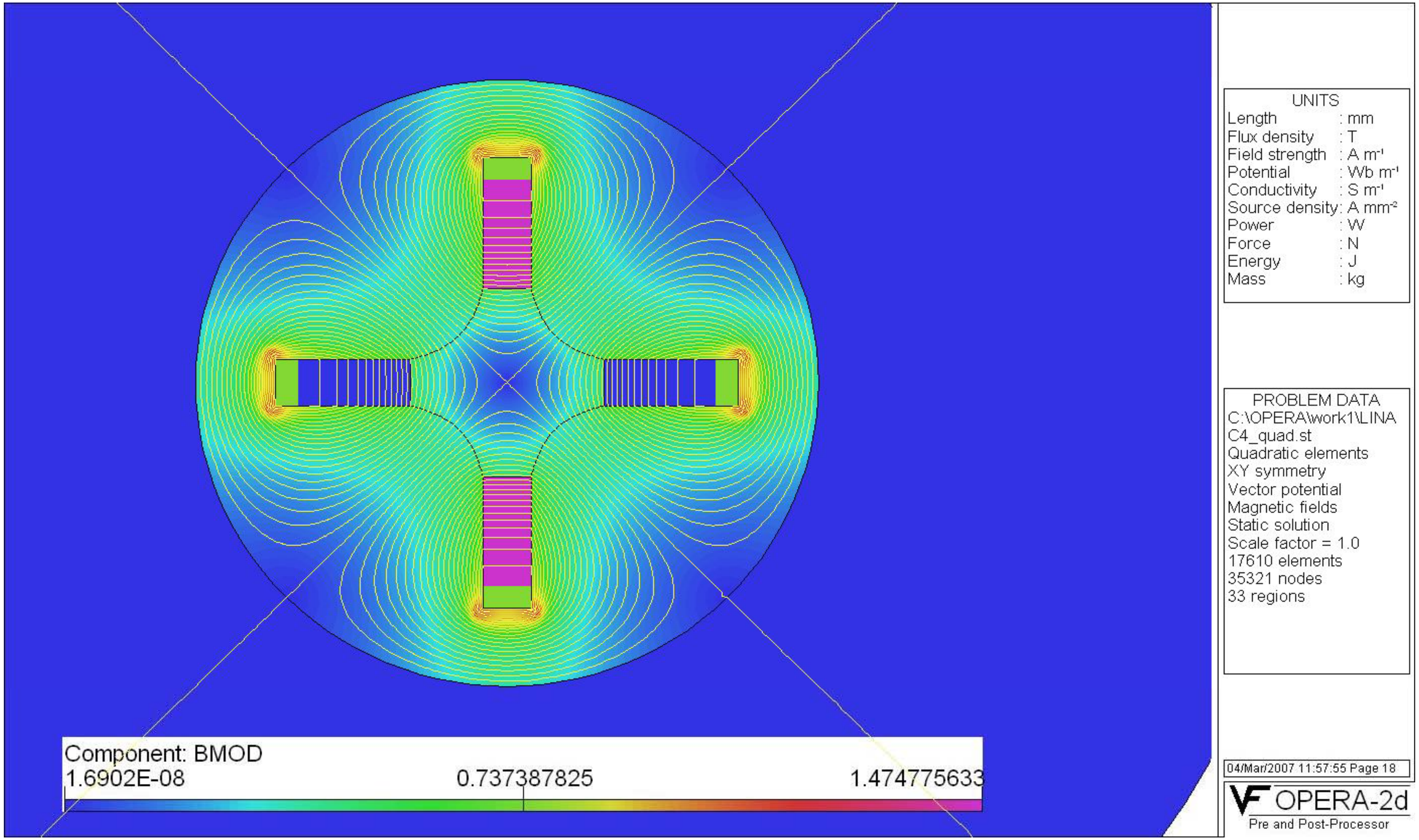
- Common design for both types (DTL & CCDTL) to reduce costs.
- Limitation in length and outer diameter (L < 120 mm, d < 220 mm).
- Corrector coils integrated to gain space: ∫Bdl = 3.5 mTm.
- Alternative: one-plane corrector only.
- Air cooled → only pulsed operation possible!
- Cannot be used for SPL.

Integrated Steering Magnet	
Magnet characteristics	
∫Bdl	3.5 mTm
Deflection angle	1.8 mrad
Electrical parameters	
Max. current	83 A
RMS current	3.6 A
Magnet resistance (hot)	52.9 mOhm
Max. dissipated power (pulsed)	0.6 W
Max. voltage	12 V

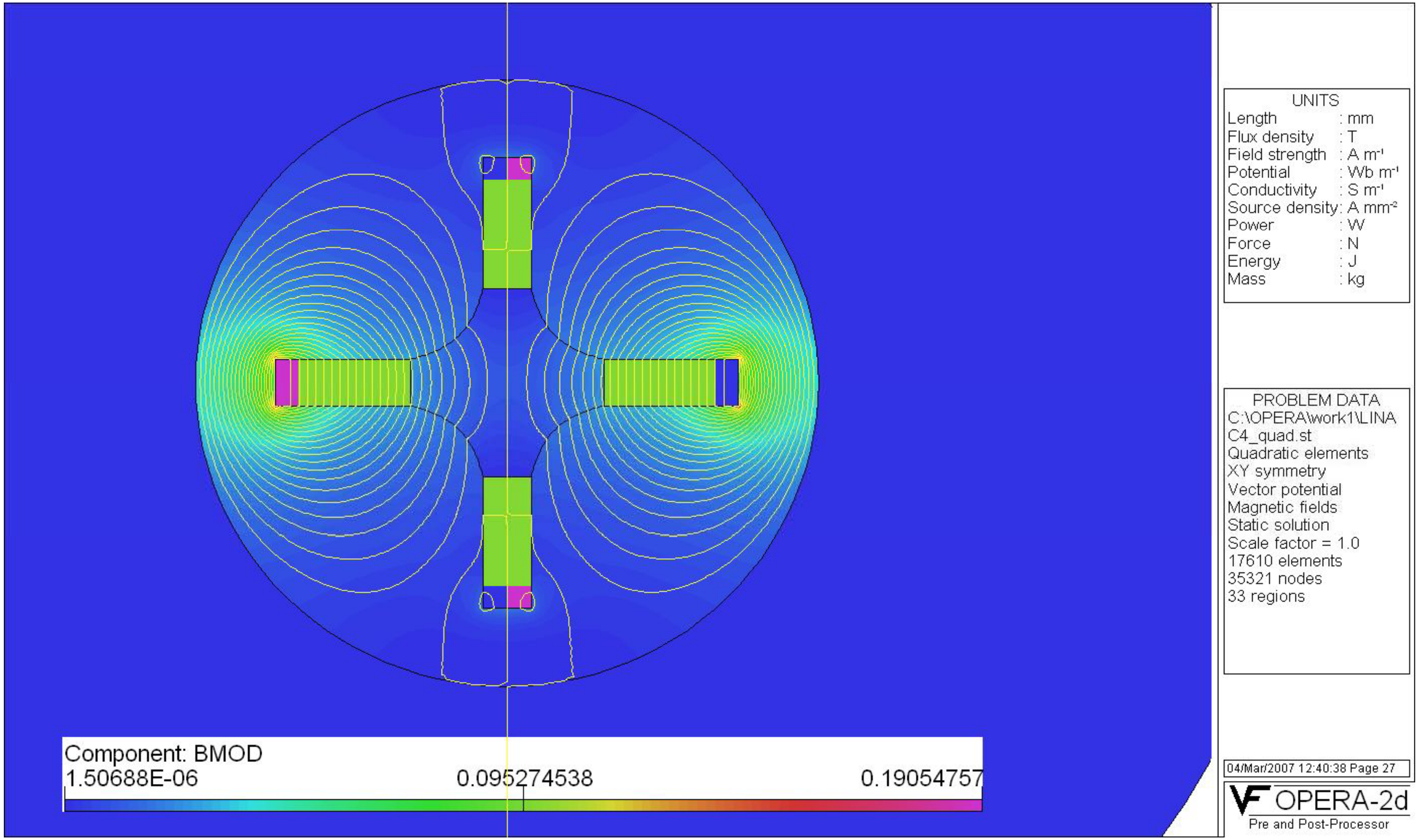
DTL & CCDTL Quadrupoles	
Number of magnets	23 + 3
Cooling	air
Magnet characteristics	
Gradient	19.0 T/m
Aperture radius	17.0 mm
Iron length	95.0 mm
Effective length	108.6 mm
∫Gdl	2.06 Tm/m
Field quality ($\Delta G/G_0$)	<1 %
Good field region	12.75 mm
Dimensions	
Total magnet length	115 mm
Outer diameter	156 mm
Total magnet weight	11.5 kg
Electrical parameters	
Max. current	100 A
Duty cycle (I_{max} / I_{RMS})	4.4 %
RMS current	4.4 A
Magnet resistance at 20 C	186.6 mOhm
Inductance	1.7 mH
Max. voltage	353 V
Max. dissipated power (pulsed)	3.6 W

Note: magnet parameters are not yet frozen and can still change

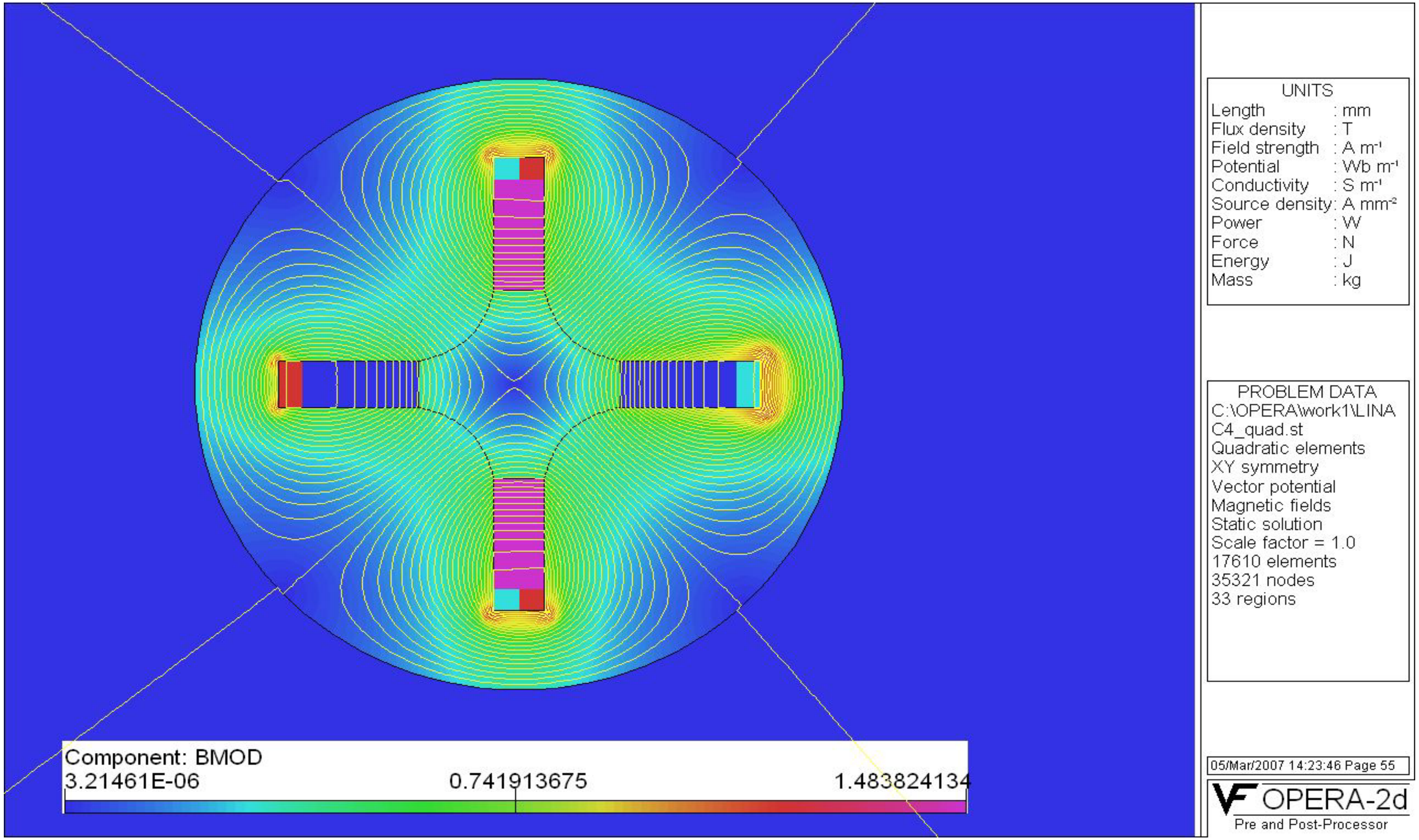
DTL & CCDTL Quadrupoles – Magnetic Design



DTL & CCDTL Quadrupoles – Magnetic Design



DTL & CCDTL Quadrupoles – Magnetic Design



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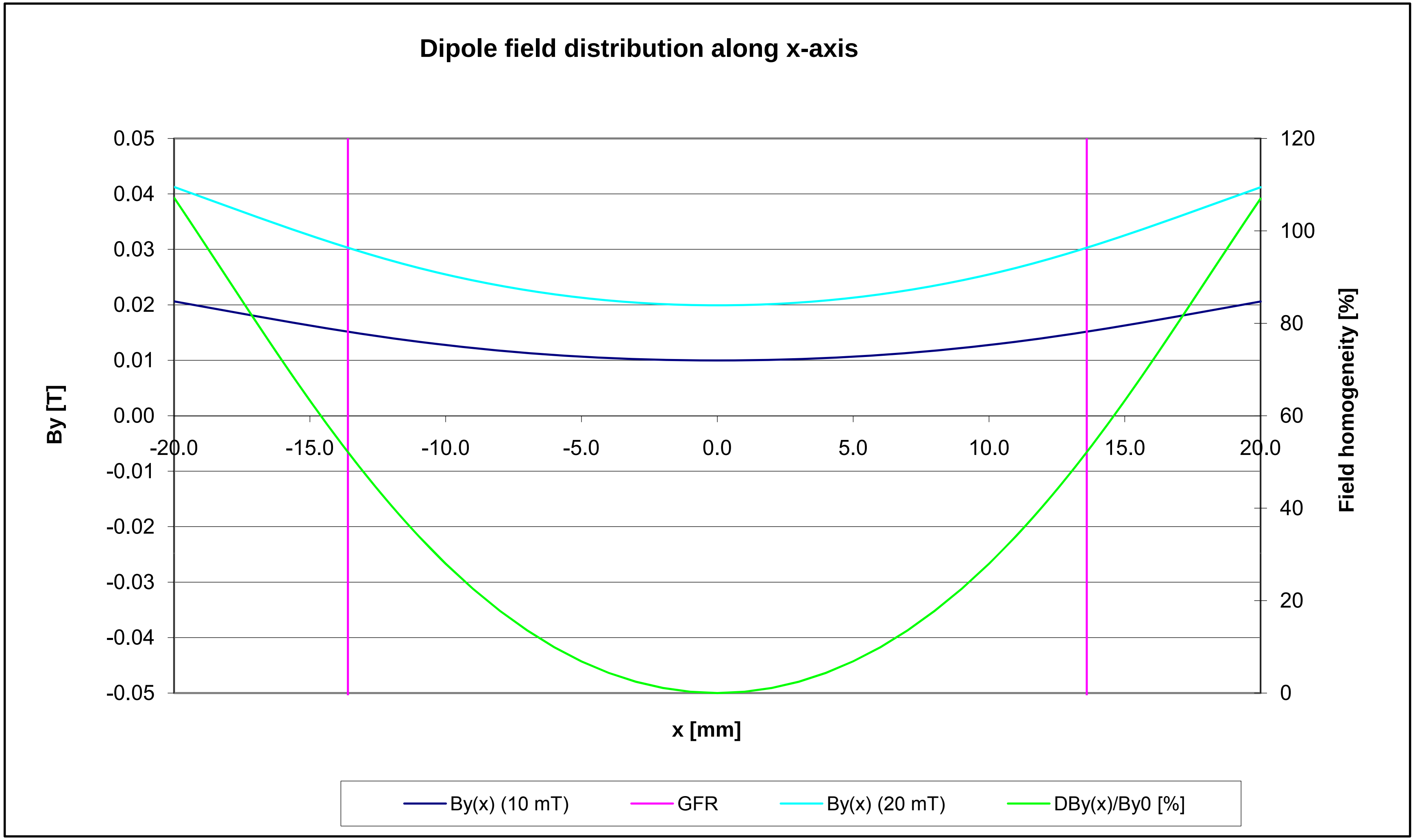


PIMS Quadrupoles - Parameters

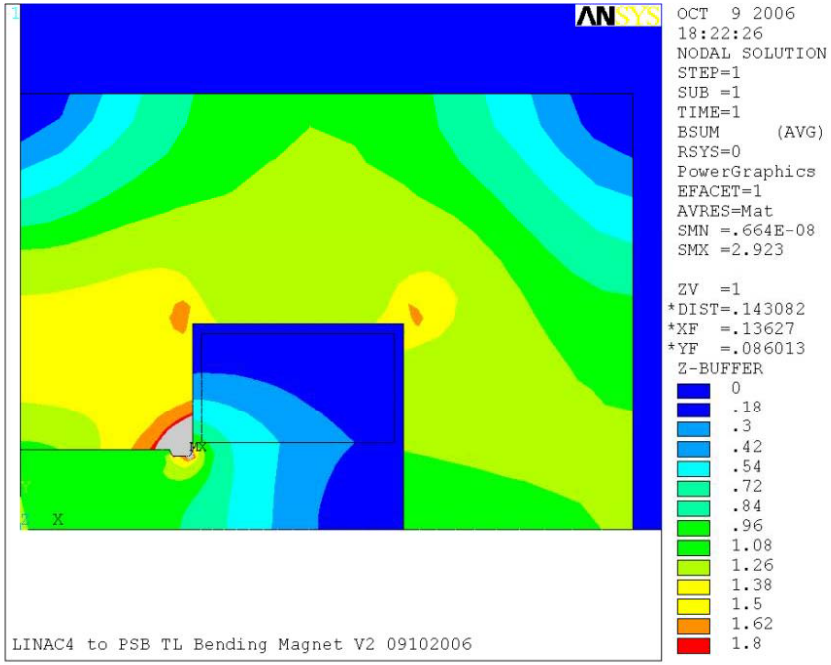
- A larger aperture (44 mm) needed for the PIMS section.
- Overall length: 140 mm, but only 115 mm presently foreseen.
- Otherwise, design similar to CCDTL-quads.
- Corrector coils integrated to gain space: ∫Bdl = 3.5 mTm.
- Air cooled → only pulsed operation possible!
- Cannot be used for SPL.

PIMS Quadrupoles	
Number of magnets	13 + 2
Cooling	air
Magnet characteristics	
Gradient	19.0 T/m
Aperture radius	22.0 mm
Iron length	120.0 mm
Effective length	137.6 mm
∫Gdl	1.58 Tm/m
Field quality ($\Delta G/G_0$)	<1 %
Good field region	16.50 mm
Dimensions	
Total magnet length	140 mm
Outer diameter	195 mm
Total magnet weight	14.9 kg
Electrical parameters	
Max. current	94 A
Duty cycle (I_{max} / I_{RMS})	4.4 %
RMS current	4.1 A
Magnet resistance at 20 C	270.1 mOhm
Inductance	2.4 mH
Max. voltage	475 V
Max. dissipated power (pulsed)	4.6 W

Note: magnet parameters are not yet frozen and can still change

Linac4 –TL Bending Magnets

- H-shape magnet type.
- A common magnetic yoke design for both types (H and V) to minimize tooling costs.
- Water cooled coils.
- Slow pulsed operation proposed (40 % duty cycle).

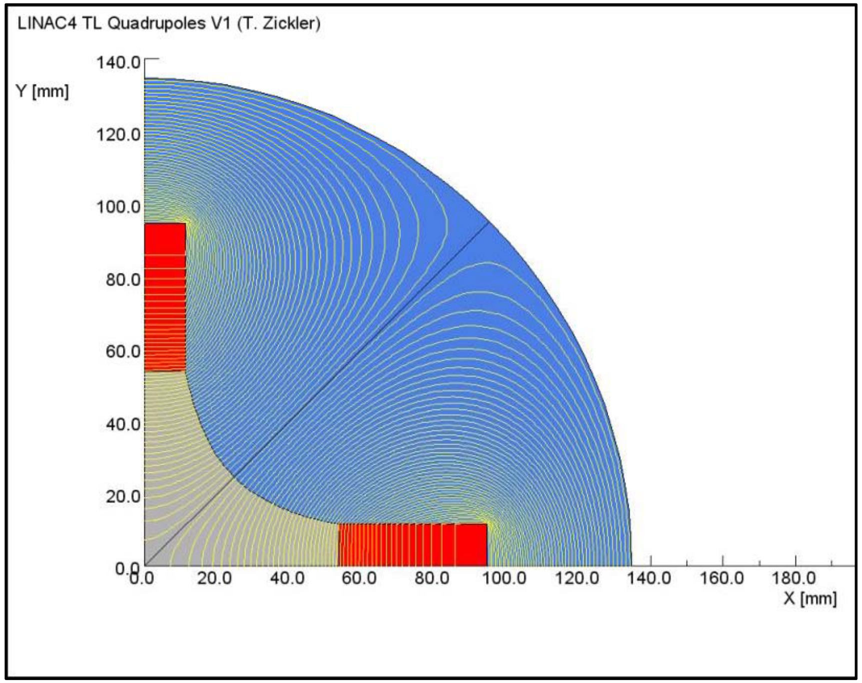


2D magnetic field computation in ANSYS (only one quadrant has been modelled)

TL Bending	
Number of magnets	4 + 1
Cooling	water
Magnet characteristics	
Magnet field	1.0 T
Gap height	50.0 mm
Iron length	1200.0 mm
Effective length	1255.0 mm
∫Bdl	1.255 Tm
Deflection angle	672 mrad
Dimensions	
Total magnet weight	1361 kg
Total magnet length	1396 mm
Total magnet width	482 mm
Electrical parameters	
Max. current	830 A
Duty cycle (I_{max} / I_{RMS})	34 %
RMS current	279 A
Magnet resistance (hot)	58.2 mOhm
Max. dissipated power (pulsed)	4.5 kW
Cooling parameters	
Pressure drop	5.0 bar
Temperature rise	19.2 K
Total cooling flow	3.4 l/min

Linac4 – TL Quadrupoles - Parameters

Air cooled → only pulsed operation possible!



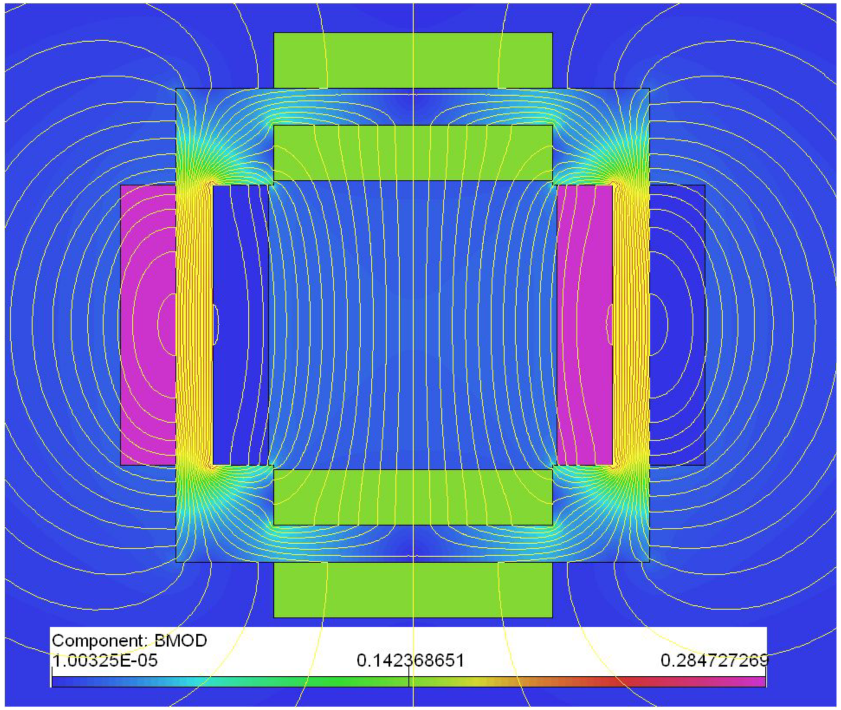
2D magnetic field computation in OPERA (only one quadrant has been modelled)

TL Quadrupoles	
Number of magnets	18 + 2
Cooling	air
Magnet characteristics	
Gradient	12.1 T/m
Aperture radius	50.0 mm
Iron length	250.0 mm
Effective length	290.0 mm
∫Gdl	3.50 Tm/m
Field quality ($\Delta G/G_0$)	<1 %
Good field region	37.50 mm
Dimensions	
Total magnet length	292 mm
Outer diameter	352 mm
Total magnet weight	107.8 kg
Electrical parameters	
Max. current	200 A
Duty cycle (I_{max} / I_{RMS})	5.0 %
RMS current	10.1 A
Magnet resistance at 20 C	292.2 mOhm
Inductance	3.8 mH
Max. voltage	812 V
Max. dissipated power (pulsed)	29.6 W

Disclaimer: only a preliminary magnetic design is presented in these slides. To optimize the gradient homogeneity and the integrated field quality, 3D-FE computations of the pole shape will be neccessary.

Steering Magnets for Linac4 TL

- ➔ Combined horizontal and vertical corrector design.
- ➔ Air cooled → only pulsed operation possible!



TL Steering Magnet	
Number of magnets	5 + 1
Cooling	air
Magnet characteristics	
Magnet field	27.0 mT
Gap height	70.0 mm
Gap width	70.0 mm
Iron length	80.0 mm
Effective length	147.2 mm
∫Bdl	4.0 mTm
Deflection angle	2.1 mrad
Dimensions	
Total magnet weight	4.2 kg
Total magnet length	103 mm
Total magnet width	116 mm
Total magnet height	116 mm
Electrical parameters	
Max. current	20 A
Duty cycle (I_{max} / I_{RMS})	11.2 %
RMS current	2.2 A
Magnet resistance (hot)	401.3 mOhm
Max. dissipated power (pulsed)	2.0 W
Inductance	4.5 mH
Max. voltage	53 V

Note: magnet parameters are not yet frozen and can still change

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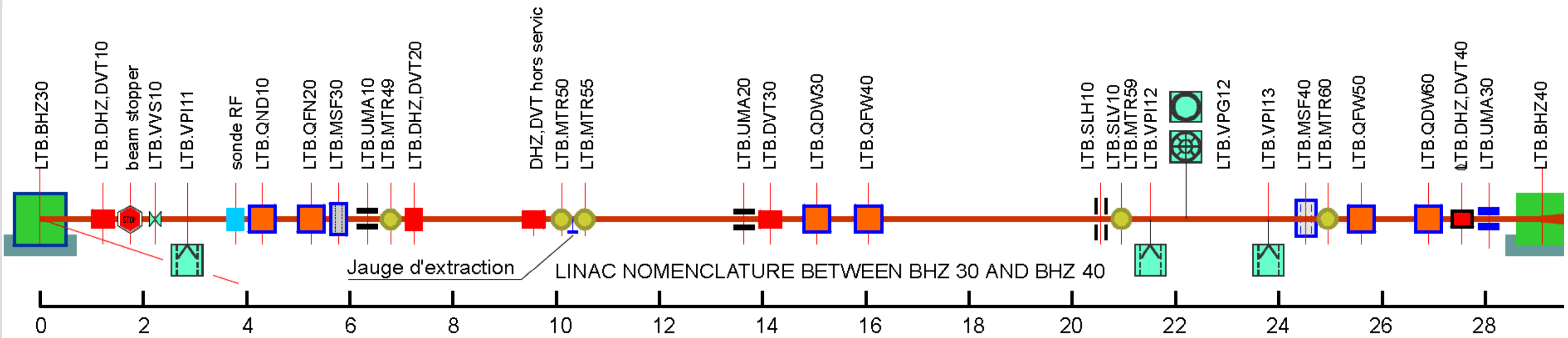
The existing magnets in the LT, LTB and BI transfer lines need to be checked if their performance is adequate for Linac4 operation:

- Field strength adequate (160 MeV = factor 1.9 in ∫Bdl with respect to Linac2)?
- Field (gradient) quality adequate?
- Upgrades possible (pulsed operation, increased cooling performance)?
- If not, replacements available?
- If not, parameters for new magnet design to be defined.

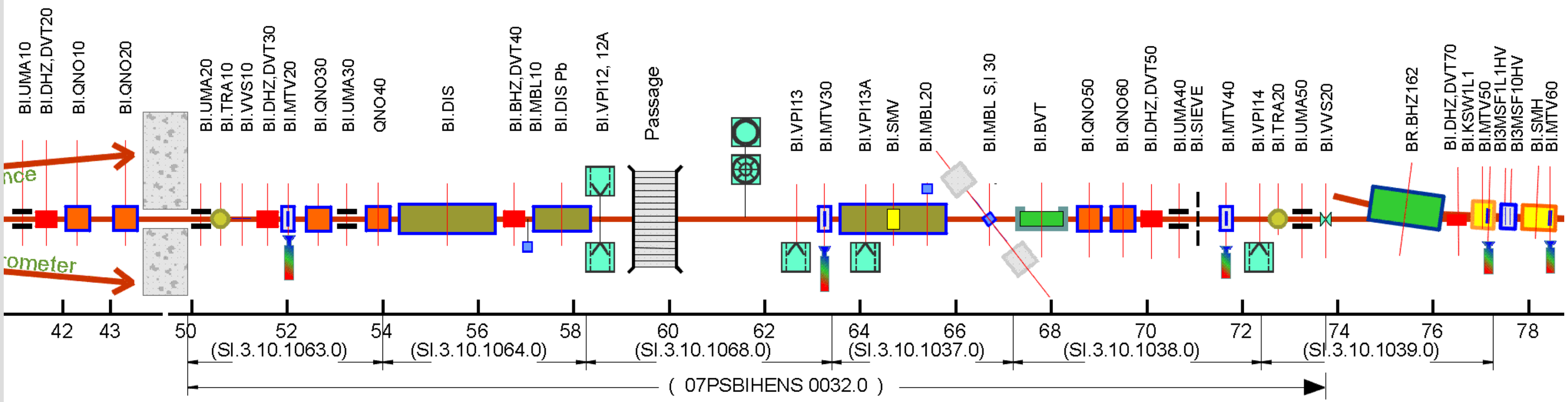
Existing magnets in the LT & LTB line

- ➔ All steering magnets in the LT(B) line can be reused without any modification.
- ➔ LT.QFN50, LT.QDN55, LT.QFN60, LT.QDN65, LT.QDN75, LTB.QDN10, LTB.QFN20 (all type LINAC VII) can be reused without any modification.
- ➔ The four laminated, air cooled quadrupoles (LTB.QDW30, LTBQFW40, LTB.QFW50, LTBQDW60) type TRIUMF installed in 1997 (actually in dc operation) can be used in (slow) pulsed operation.
- ➔ The field quality of LT.BHZ20 & LT.BHZ30 has to be checked when powered with twice the nominal current.
- ➔ LT.QFW70 type SMIT air-cooled (massiv yoke) needs to be replaced by a laminated quadrupole (type TRIUMF) for pulsed operation.



Existing magnets in the LBE, LBS & BI-line

- ➔ LTB.BHZ40 has to be equipped with new water-cooled coils.
- ➔ The 2 quads LBE.QFW10, LBE.QDE20 (type SMIT air) and the LBS.BVT10 of the measurement lines have to be replaced by new magnets.
- ➔ All steering magnets in the BI line can be reused without any modification.
- ➔ The four quadrupoles BI.QNO10, BI.QNO20, BI.QNO30, BI.QNO40 (type SMIT air) have to be replaced by new laminated magnets (type TRIUMF).
- ➔ BI.BVT (4 gaps) has to be replaced by a new magnet with increased strength (~ 0.36 Tm @ 160 MeV).
- ➔ BI.QNO50, BI.QNO60 (type SMIT water) can be reused without any modification.



Summary and conclusions

- The design of the new magnets for Linac 4 and TL has been presented: NO technical show stoppers identified.
- Approximately 80 new magnets of 5 different types are needed for the Linac and have to be built in industry.
- Most of the magnets in the existing TL can be reused.
- Three magnet types (9 magnets + spares) have to be replaced by new magnets to be built in industry.
- One magnet has to be equipped with new water-cooled coils to be built.
- Actual status: preliminary design exists for all magnets.
- Steel in stock at CERN (long delivery delays).
- First step: refine design for Linac quadrupoles with incorporated correctors and launch production.
- Schedule: although generous, design and specification to be started now!