FROM RESEARCH TO INDUSTRY

cea

BEAM DYNAMICS STUDIES FOR HILUMI LHC

BARBARA DALENA

IN COLLABORATION WITH:

J. PAYET , A. CHANCÉ, O. GABOUEV

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CONTENTS

- The HiLumi project
- Optics design
  - IR1/5 (ATLAS and CMS) matching sections layout for crab cavity operation
- Non linear beam dynamics
  - Non linear fringe field effects of large aperture magnets

@ SACM/LEDA

- Conclusion & Outlook

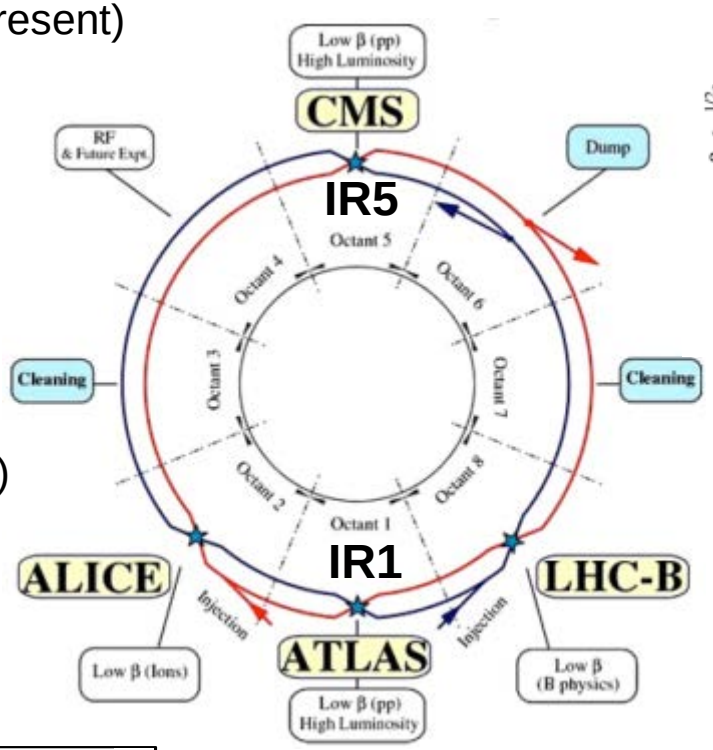
HL-LHC

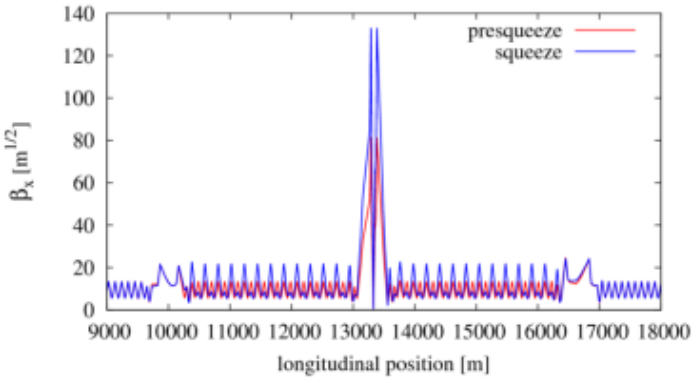
Goal: integrated luminosity ~**250 fb^{-1}** / y
(~10 times higher than present)

- New Optics Scheme
Achromatic Telescopic Squeezing (ATS)

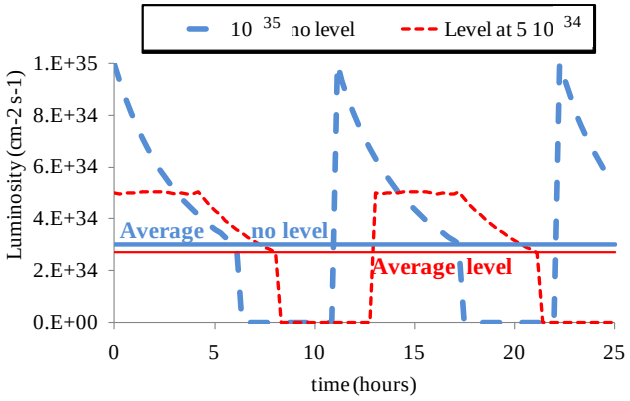
- Hardware changes (Nb_3Sn superconducting technology, crab cavities)

- Luminosity Leveling

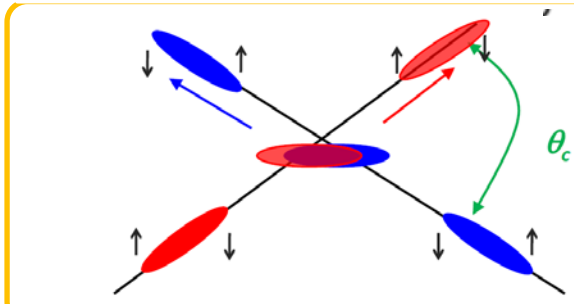




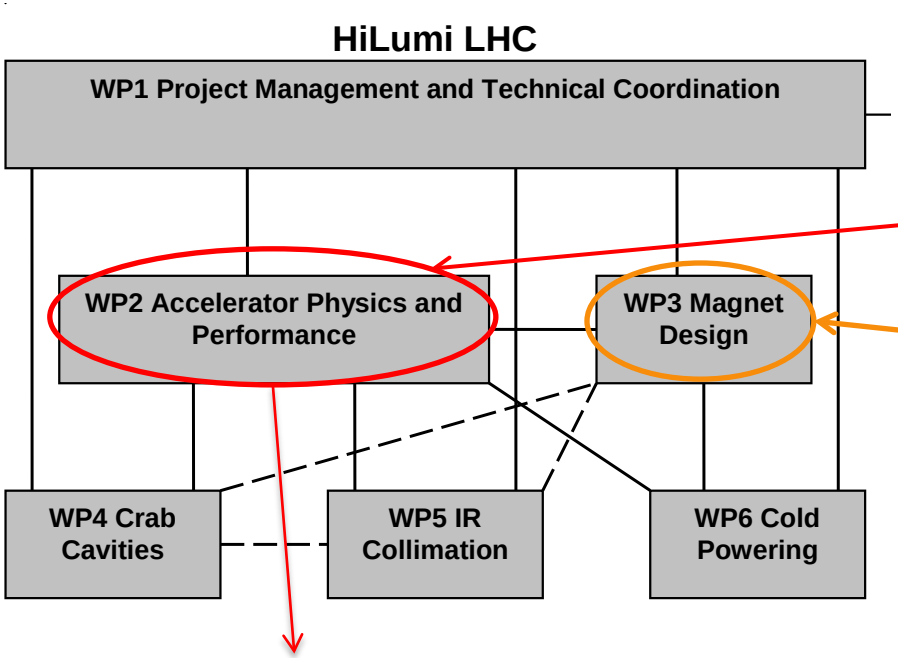
LARP Nb3Sn quadrupole



Transverse deflecting crab cavity



HILUMI WORKING PACKAGES



CEA-Irfu SACM/LEDA

CEA-Irfu SACM/LEAS

WP2.task 2: Optics & Layout ⇒ close collaboration with CERN

- Optics option with 170 T/m triplet gradient and 120 mm aperture
- IR1/5 matching sections layout for crab cavity operation

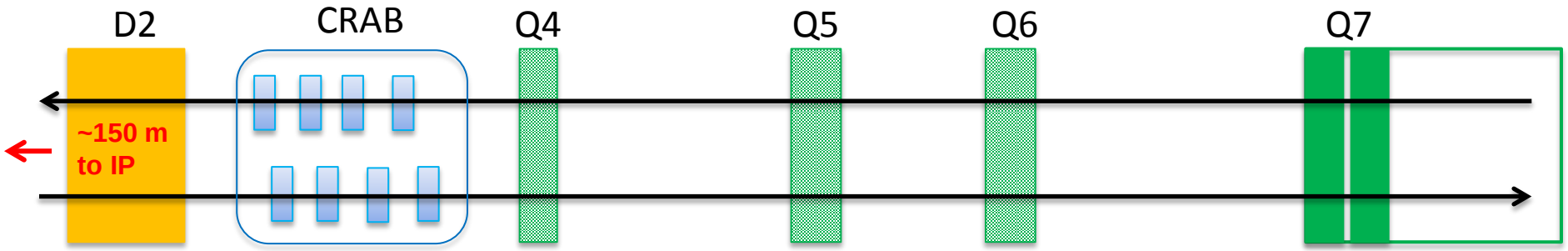
WP2.task 3: Tracking

- Field quality of HL-LHC magnets
- Non linear fringe field effect of large aperture magnets ⇒ close collaboration with Manchester University and CERN

OPTICS & LAYOUT

OPTIMIZATION FOR CRAB CAVITY OPERATION

Reduce the voltage of the crab cavity: $V \propto 1/(\beta_{crab}\,\beta_{IP})^{1/2}$

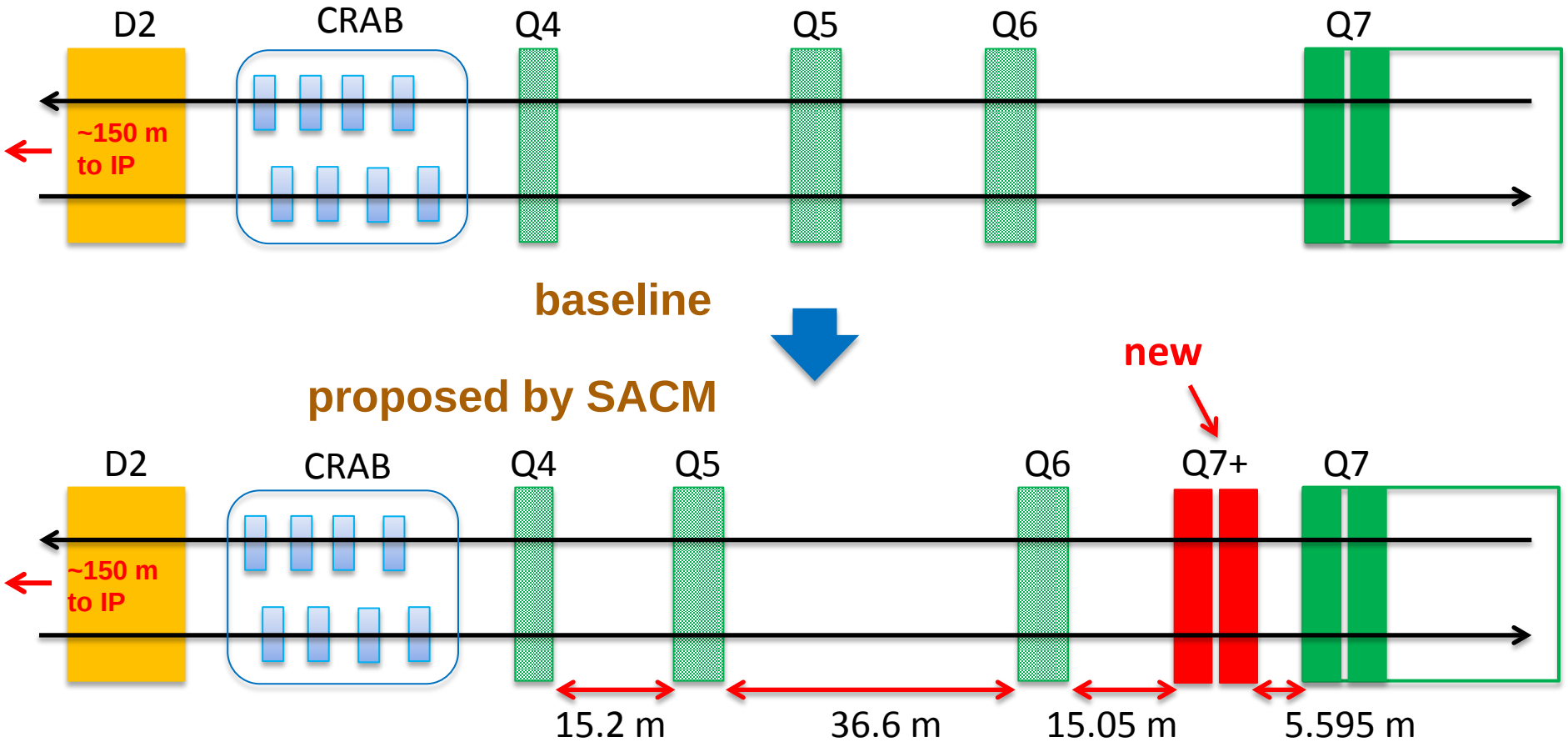


⇒ increasing the beta function at the CRAB

using
- quadrupole types
- quadrupole positions

	LHC	HL-LHC baseline
Q4	MQY, G=160 T/m @4.5 K ∅ = 70 mm, L = 3.4 m	MQYY, G=120 T/m @1.9 K ∅ = 90 mm, L = 3.5 m
Q5	MQML, G=160 T/m @4.5 K ∅ = 56 mm, L = 4.8 m	MQYL, G=160 T/m @4.5 K ∅ = 70 mm, L = 4.8 m
Q6	MQML, G=160 T/m @4.5 K ∅ = 56 mm, L = 4.8 m	"idem"
Q7	2×MQM, G=200 T/m @1.9 K ∅ = 56 mm, L = 3.4 m	"idem"

PROPOSED IR1/IR5 MATCHING SECTION LAYOUT



GAIN

	Left/Right side	Baseline [MV]	Proposed [MV]	Proposed non ATS [MV]
Horizontal crossing	IR5 beam 1	**10.8/12.0**	**8.9/8.8**	**8.8/9.4**
	IR5 beam 2	**12.0/10.8**	**8.8/8.9**	**9.4/8.8**
Vertical crossing	IR1 beam 1	**11.8/10.8**	**8.7/8.9**	**9.3/8.6**
	IR1 beam 2	**10.8/11.8**	**8.9/8.7**	**8.6/9.3**

Few changes in the interaction region layout $\Rightarrow$ several benefits:

➔ Possibility to reduce the crab voltage of > 20%
➔ Compatible with low β_{IP} at injection (5m)
➔ Compatible with the new optics scheme (ATS)
➔ Possibility to squeeze to very low β_{IP} (non ATS)

Drawbacks:
➔ Matching section apertures closer to the beam stay clear limit
➔ Additional hardware required (Q7+)

NON LINEAR BEAM DYNAMICS

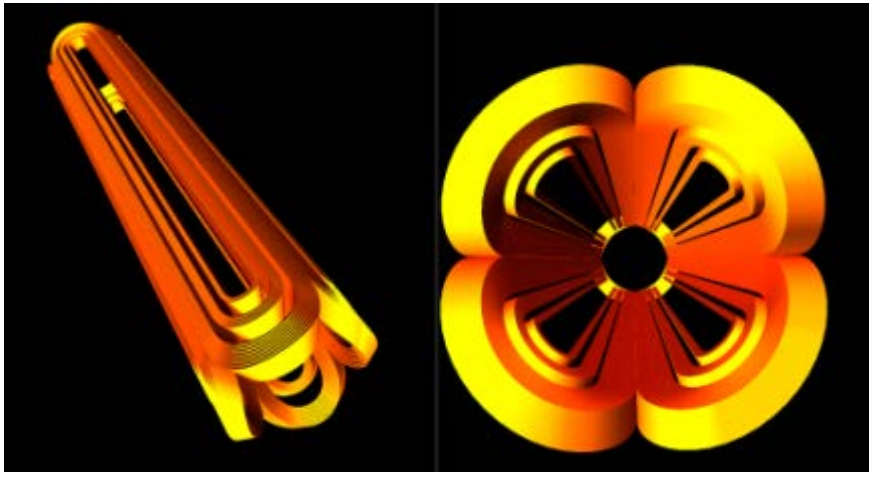
INNER TRIPLET NON LINEAR FRINGE FIELD EFFECT

The HL-LHC project relies on **large aperture magnets** (due to increased beam sizes before the IP)
⇒ The beam is much more sensitive to non-linear perturbations in this region.

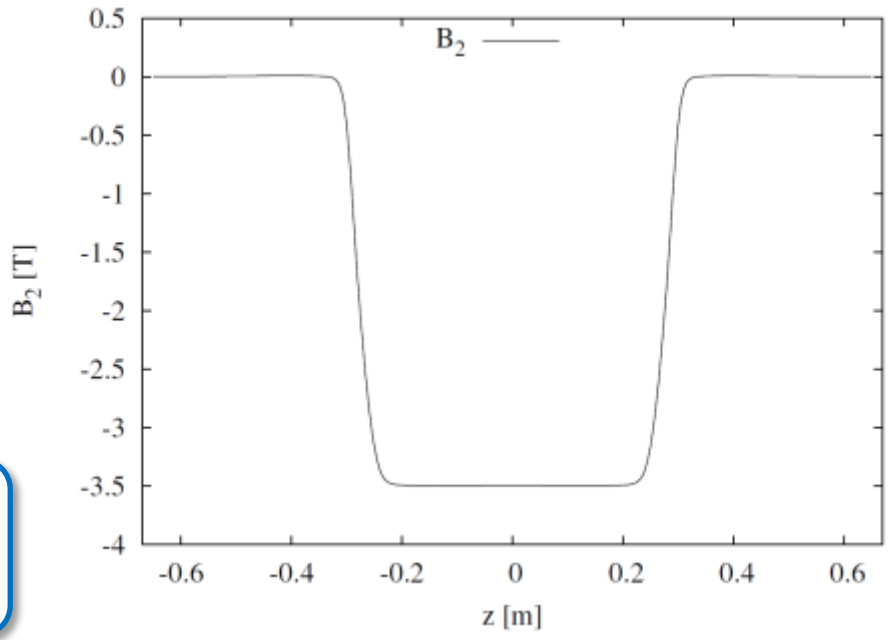
- The duodecapole component of the fringe field in the original design of LHC inner triplet was found to reduce of a factor 5 the dynamic aperture (Venturini et al.)
- Present design for the HL-LHC inner triplet shows an important duodecapole component of the fringe field

⇒ fringe field modeling studies and integration in SixTrack (CERN code used to perform dynamic aperture studies)

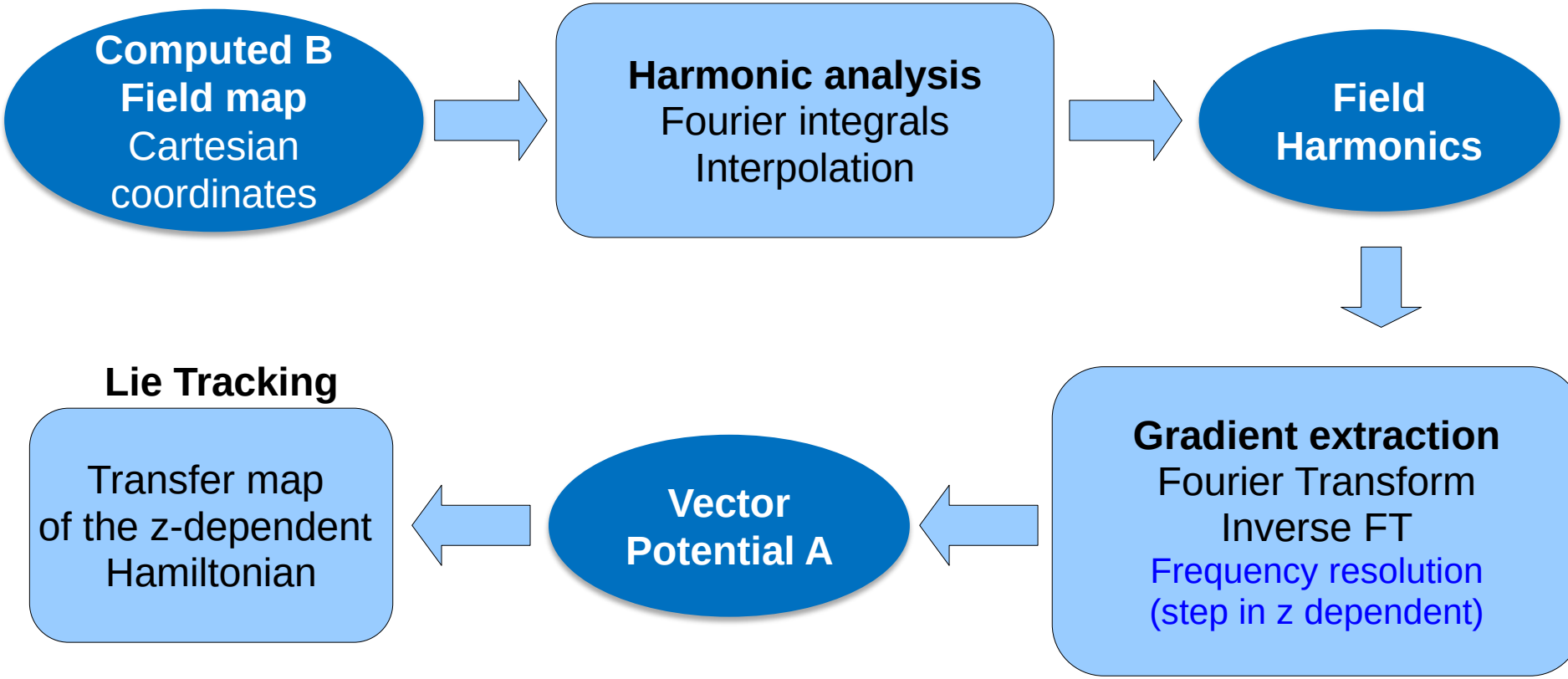
Ultimate Goals
- Definition of **field quality** and **corrections**
- Provide **feedback** to the designers of magnets



Courtesy of M. Segreti (CEA SACM/LEAS)



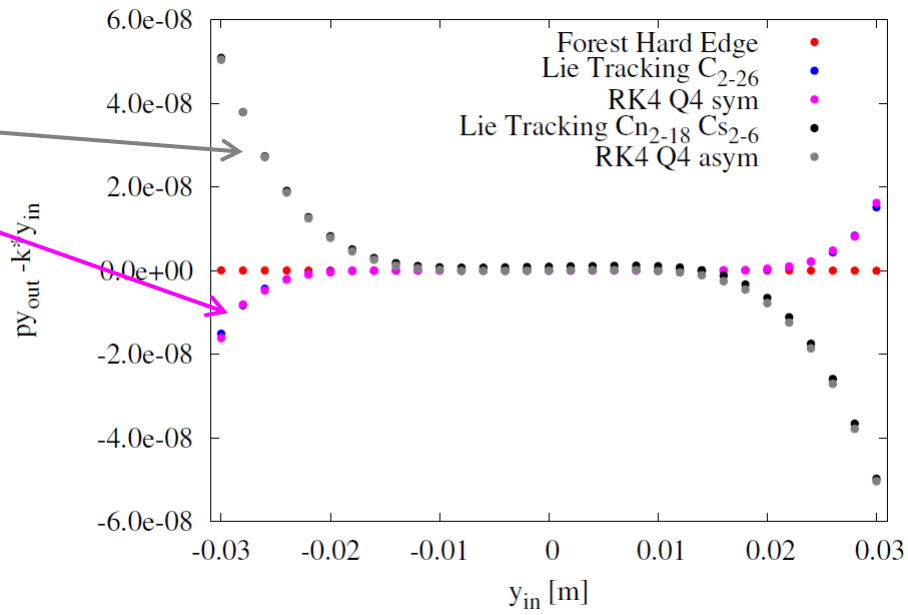
FROM 3D MAGNETIC FIELD DATA TO TRACKING



Internship Master 2
Oleg Gabouev

MODEL VALIDATION & DISCUSSION

- Lie Tracking has been validated against a symplectic 4th order integrator (RK4) for the design of different magnets



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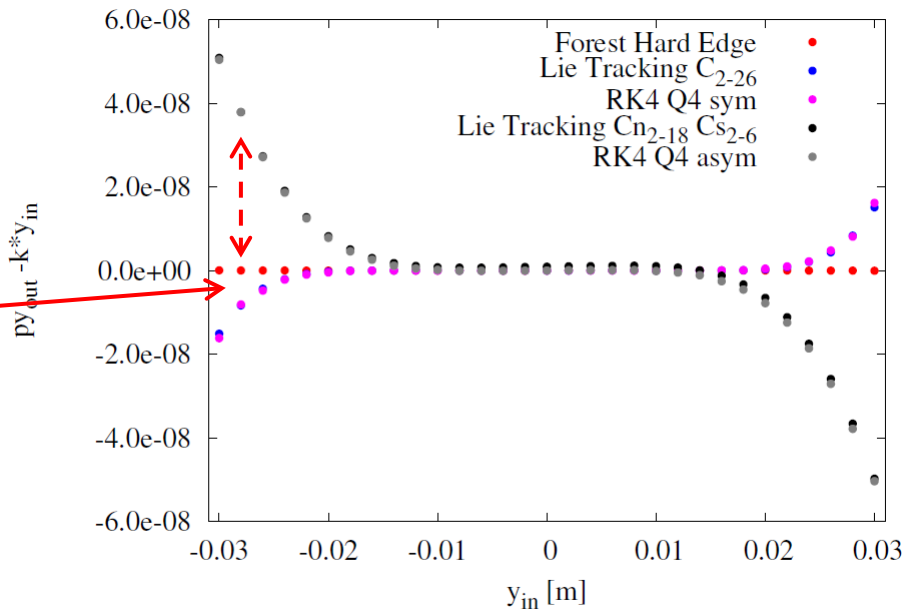
- Lie Tracking compared to analytical kicks model shows differences related to the actual shape of the magnet fringe field



MODEL VALIDATION & DISCUSSION

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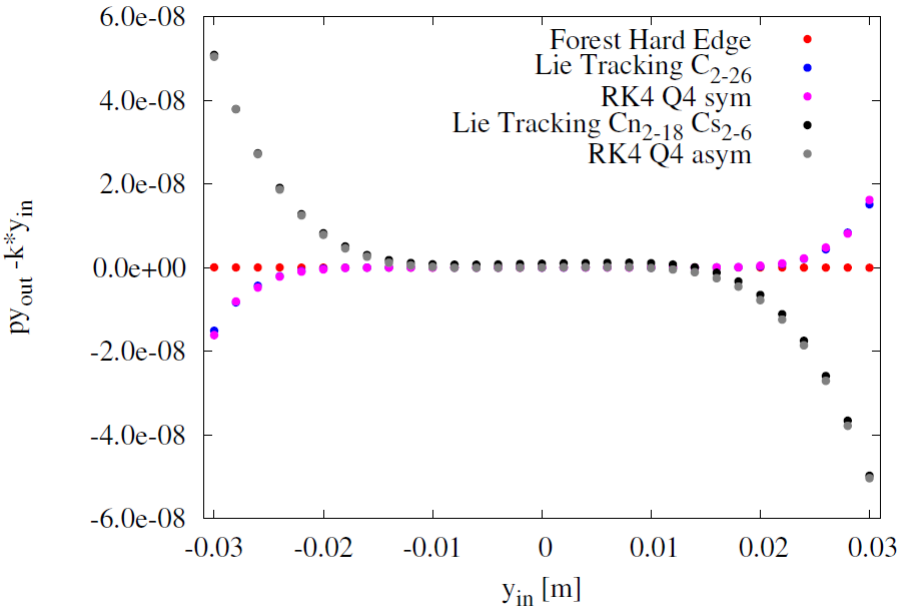
- Lie Tracking compared to analytical kicks model shows differences related to the actual shape of the magnet fringe field
- Integration in SixTrack under discussion ⇒ try to find the best compromise between computational speed and actual field ends shape



CONCLUSION & OUTLOOK

- WP2 activities @ CEA-Irfu:

  Alternative optics of the high luminosity matching sections is studied

  • crab cavity voltage gain > 20%
  • more flexibility in collision optics

  ⇒ Investigation of injection and transition to collision optics

  Non linear fringe field effects for the large aperture quadrupoles of the interaction regions is investigated

  • model developed and validated
  • implementation in SixTrack on going

  ⇒ Evaluation of the effect on long-term beam dynamics

- HL-LHC @ CEA-Irfu:

  Keep on beam dynamics and machine development studies to prepare the LHC for the High Luminosity physics program

- Participate to the design of future colliders

Thank you for your attention

Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Saclay | 91191 Gif-sur-Yvette Cedex
T. +33 (0)1 69 08 61 97 | F. +33 (0)1 69 08 64 42

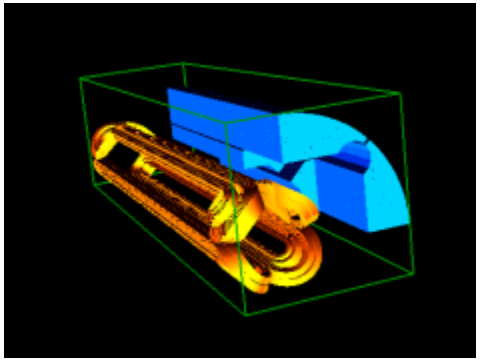
Direction DSM
Département Irfu
Service SACM

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

INNER TRIPLET DESIGN

Susana Izquierdo Bermudez (CERN)

G=140 T/m, ∅ = 150 mm



dx:dy:dz
3 : 3 : 5
[mm]

Harmonics	Old map February 2013
B6	28.24
B10	3.91
B14	0.80
B18	1.76
B22	-0.18
B26	-0.015

⇒ Prototype scaled version