HL-LHC: UPDATE ON MAGNETS

E. Todesco, G. L Sabbi

Thanks to the work of many colleagues in
(from East to West)
KEK,INFN,CERN,CEA,BNL,FNAL,LBL

Little highlights on LARP activities, covered by G. L. Sabbi talk

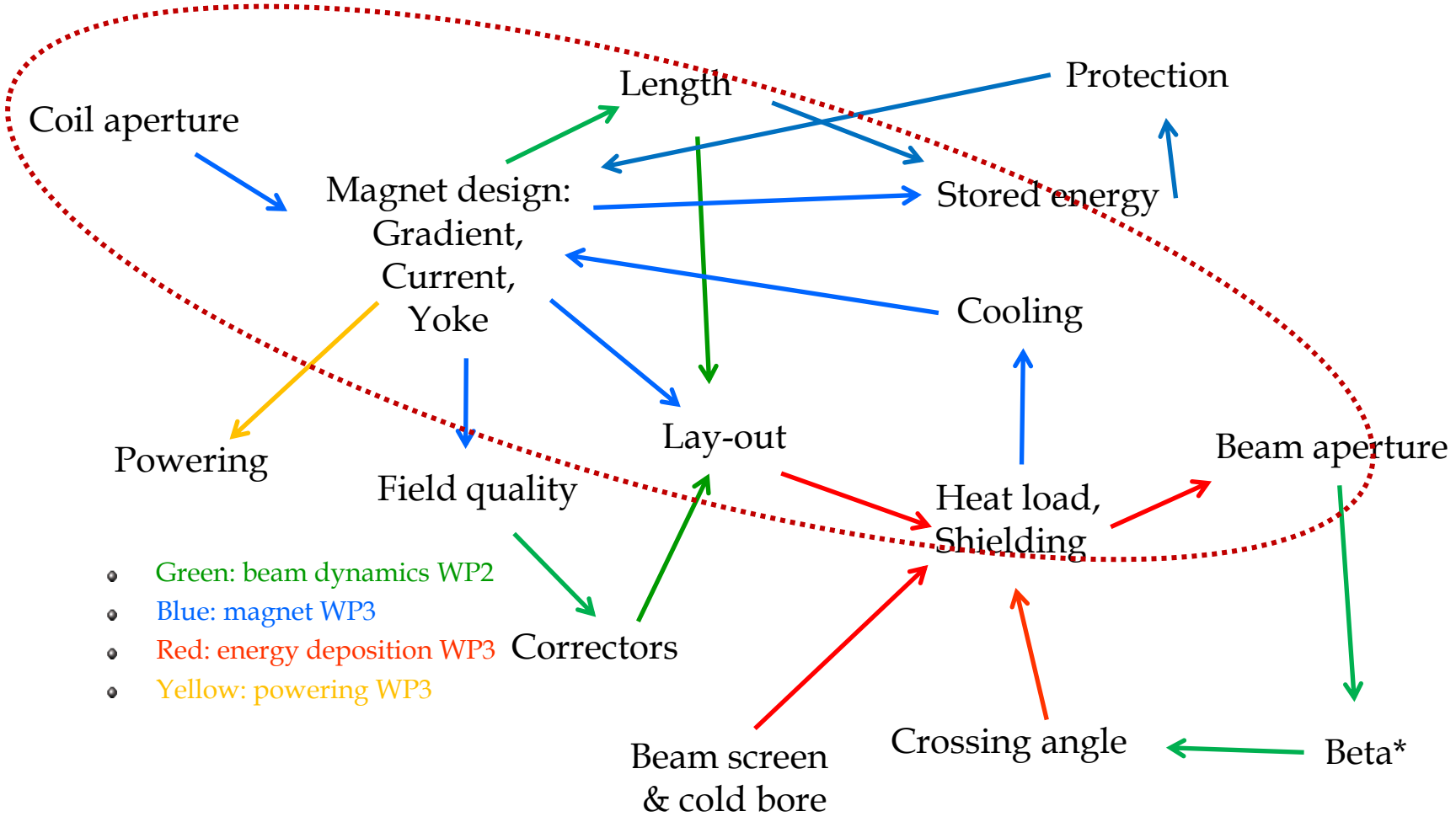
APERTURE

- Most urgent decision of 2012 was the triplet aperture
- The starting point: two technologies, two apertures
  - We focused on the 140 mm Nb_3Sn that provides more performance

Technology		Nb-Ti	Nb-Ti	Nb3Sn	Nb3Sn
Aperture	(mm)	140	120	140	120
Name		MQXD	MQXC	MQXF	MQXE
Gradient	(T/m)	100	118	150	170
Q1-Q3 length	(m)	10.6	9.5	7.7	7.2
Q2 length	(m)	8.7	8.0	6.6	6.2
Total length	(m)	38.6	34.9	28.5	26.8
Current	(kA)	12.5	12.9	15.4	14.7
Triplet differential inductance	(H)	225	167	251	190
Triplet stored energy	(MJ)	19.4	14.4	34.8	26.4

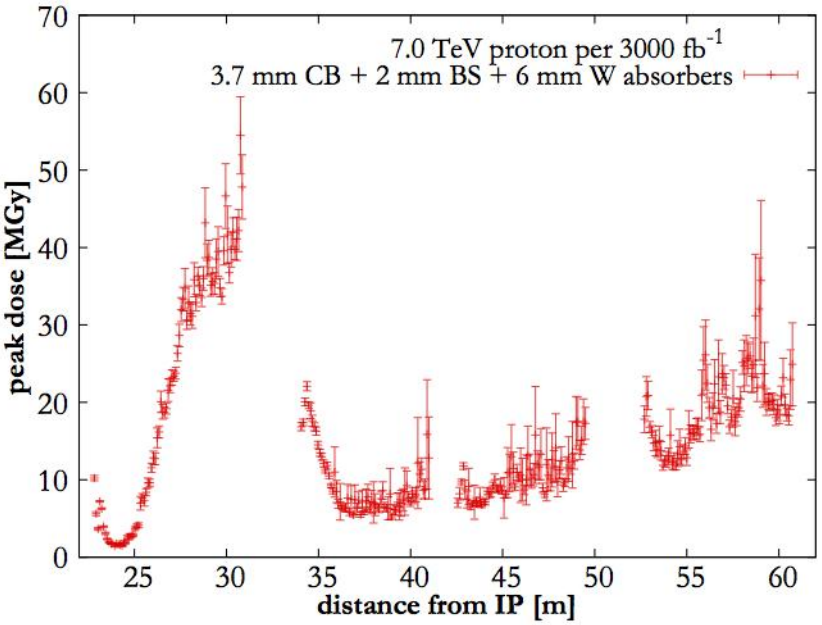
FLOWCHART

- First iteration for energy deposition, shielding, and cooling

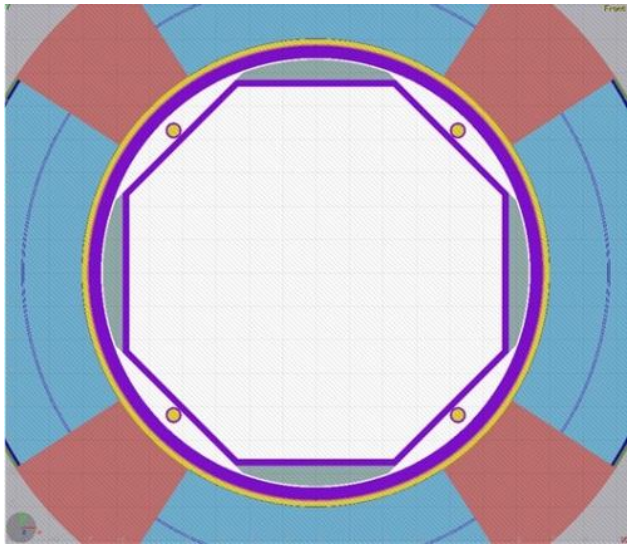


APERTURE CHOICE

- First loop between energy deposition, shielding and heat loads has been done for the 140 mm Nb_3Sn lay out
- Outcome: limiting factor is the radiation damage and not heat load – thick shielding with 6 mm (9 mm?) tungsten
  - Tentative value of 40 MGy assumed – with this we are at 4 mW/cm^3

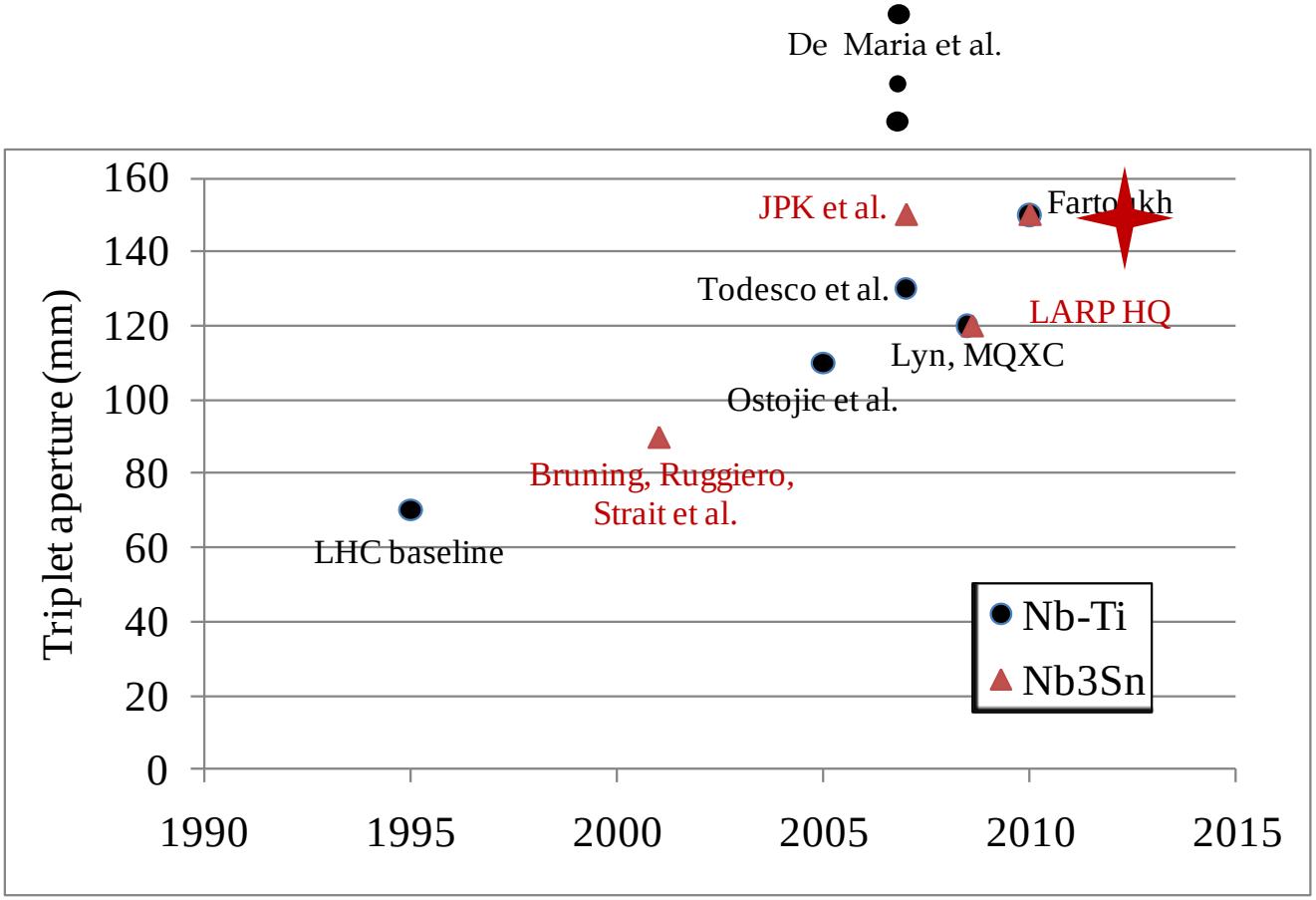


Energy deposition for the 140 mm case [F. Cerutti, L. Esposito]



Sketch of beam screen and cold bore [R. Kersevan]

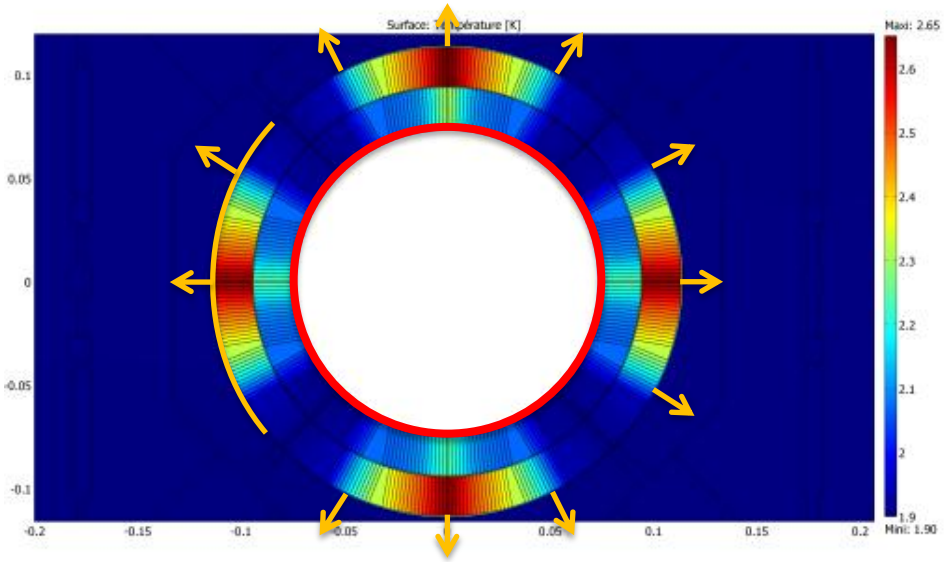
JULY 2: HABEMUS APERTURE! CL MM LATIS



Aperture versus time, and decision for HL LHC

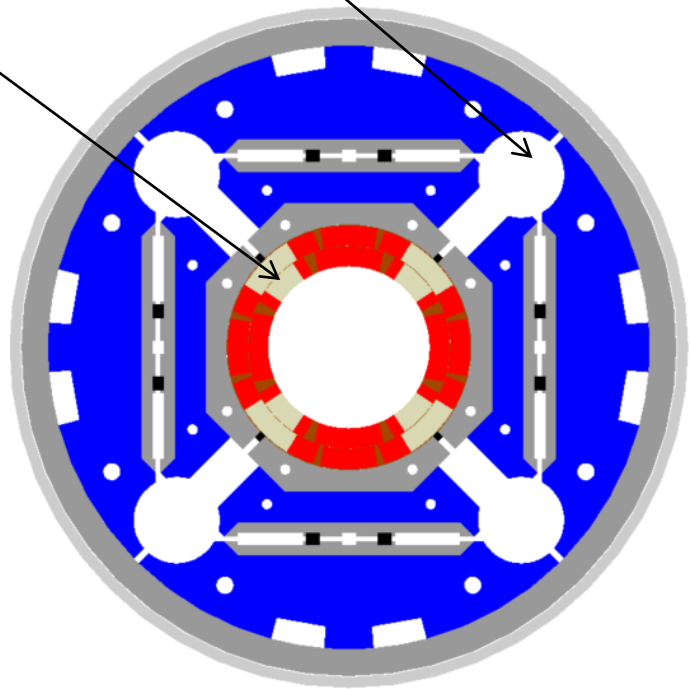
HEAT LOADS

- Features to be included in the cold mass design
  - Opening of the coil pole, size of the heat exchangers
- Heat removal: with beam screen, 400 W in the beam screen and 400 W in the triplet



85 % through the helium channels in the pole
15 % through the external insulation

Thermal model [H. Allain, R. Van Weelderen]

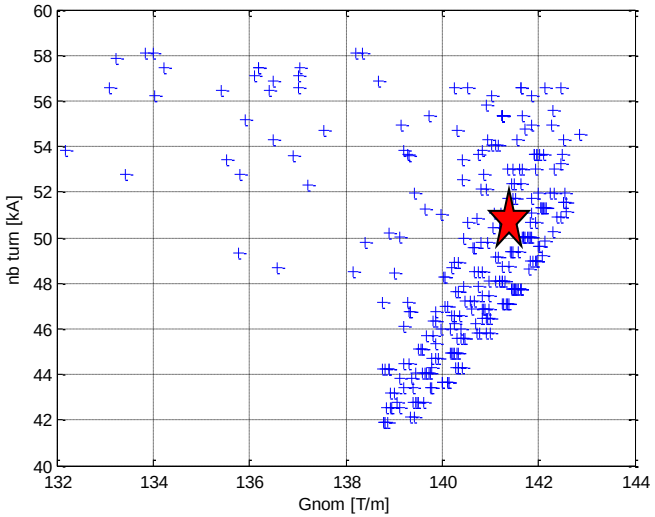


Tentative cold mass design [P. Ferracin]

MQXF: CABLE CHOICE

- Management has been defined: G. Ambrosio, P. Ferracin
- Cable choice is on the critical path
  - Strand: from 0.8 to 0.85 mm
  - Number of strands: from 35 to 40
  - We will have a 18.5 mm width cable, two layers
  - 80% margin on loadline, ~140 T/m operational gradient
  - Cored cable is the baseline

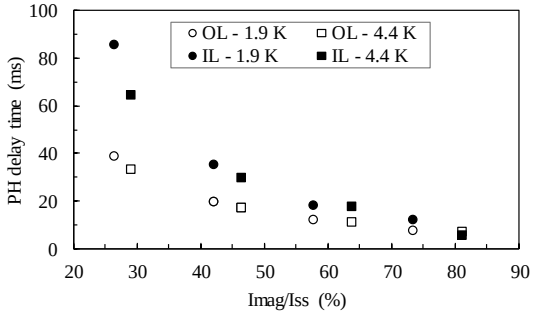
- Strand
  - RRP and OST
  - J_c is ~there: 1400 A/mm^2 at 15 T
  - RRR>100
  - Filament possibly ~40 μm



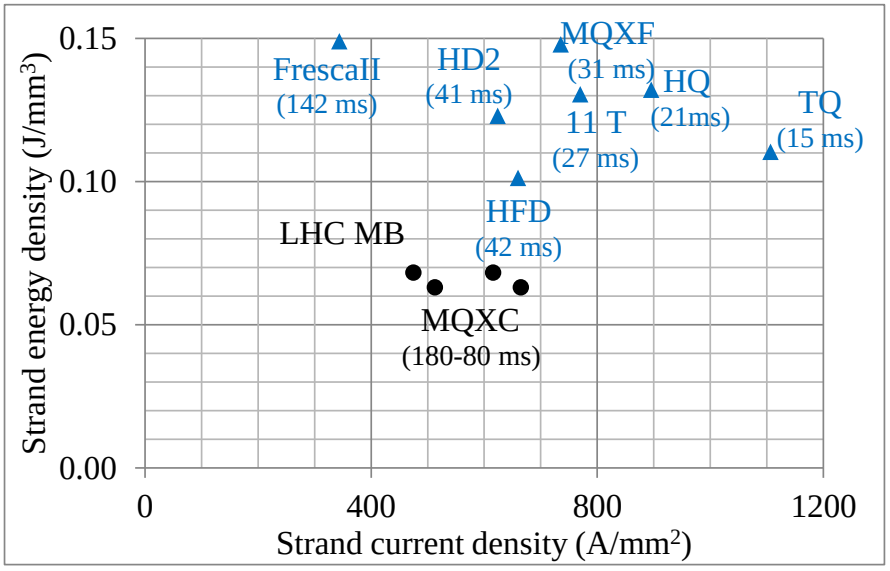
Expolring different cross-sections [P. Ferracin, F. Borgnolutti, H. Felice]

MQXF: PROTECTION

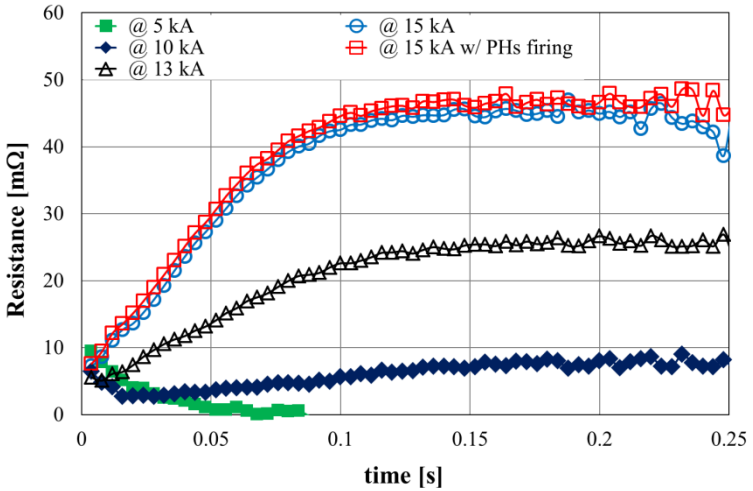
- Protection is very critical
  - New regime of energy density: 0.130 J/mm^3
  - We have about 30 ms to quench all magnet
  - HQ: good short delay of heaters,
    but (and?) evidence of quench back
  - Test of magnets with cored cable are relevant (synergy with 11 T)



Heater delay [H. Felice, T. Salmi]

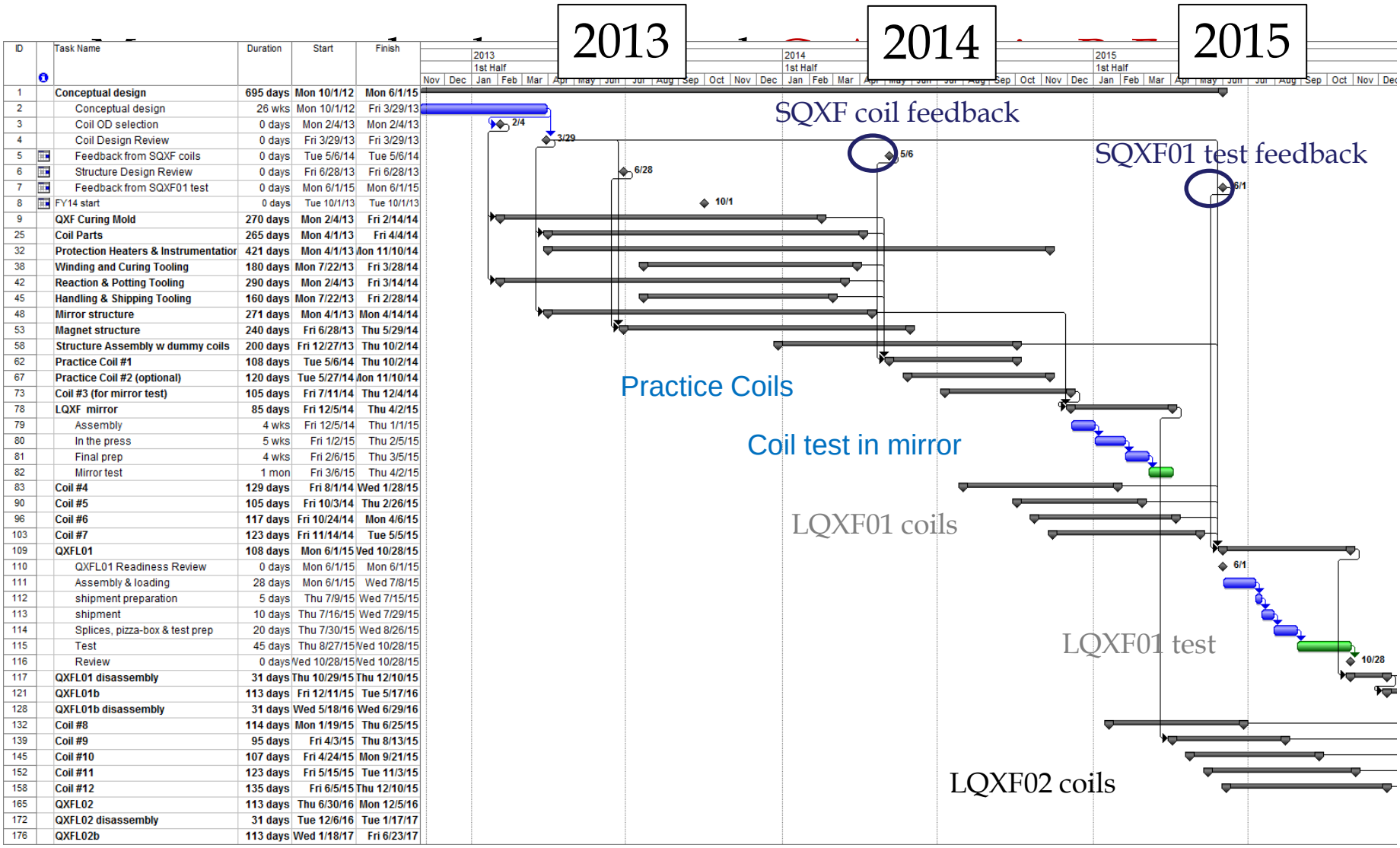


Estimate of time margin [E. Todescoi, H. Felice]



Evidence of quench-back [M. Bajko, H. Bajasi]

MQXF: PLAN

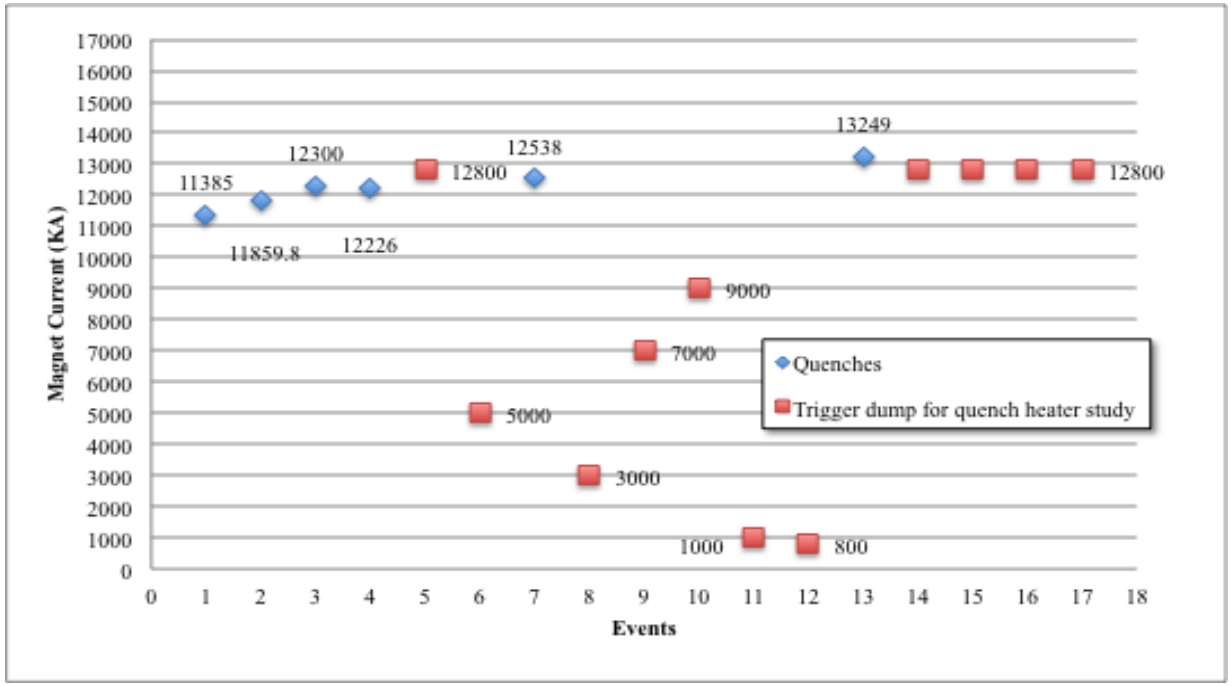


ID	Task Name	Duration	Start	Finish
1	**Conceptual design**	**695 days**	**Mon 10/1/12**	**Mon 6/1/15**
2	Conceptual design	26 wks	Mon 10/1/12	Fri 3/29/13
3	Coil OD selection	0 days	Mon 2/4/13	Mon 2/4/13
4	Coil Design Review	0 days	Fri 3/29/13	Fri 3/29/13
5	Feedback from SQXF coils	0 days	Tue 5/6/14	Tue 5/6/14
6	Structure Design Review	0 days	Fri 6/28/13	Fri 6/28/13
7	Feedback from SQXF01 test	0 days	Mon 6/1/15	Mon 6/1/15
8	FY14 start	0 days	Tue 10/1/13	Tue 10/1/13
9	**QXF Curing Mold**	**270 days**	**Mon 2/4/13**	**Fri 2/14/14**
25	**Coil Parts**	**265 days**	**Mon 4/1/13**	**Fri 4/4/14**
32	**Protection Heaters & Instrumentatior**	**421 days**	**Mon 4/1/13**	**Mon 11/10/14**
38	**Winding and Curing Tooling**	**180 days**	**Mon 7/22/13**	**Fri 3/28/14**
42	**Reaction & Potting Tooling**	**290 days**	**Mon 2/4/13**	**Fri 3/14/14**
45	**Handling & Shipping Tooling**	**160 days**	**Mon 7/22/13**	**Fri 2/28/14**
48	**Mirror structure**	**271 days**	**Mon 4/1/13**	**Mon 4/14/14**
53	**Magnet structure**	**240 days**	**Fri 6/28/13**	**Thu 5/29/14**
58	**Structure Assembly w dummy coils**	**200 days**	**Fri 12/27/13**	**Thu 10/2/14**
62	**Practice Coil #1**	**108 days**	**Tue 5/6/14**	**Thu 10/2/14**
67	**Practice Coil #2 (optional)**	**120 days**	**Tue 5/27/14**	**Mon 11/10/14**
73	**Coil #3 (for mirror test)**	**105 days**	**Fri 7/11/14**	**Thu 12/4/14**
78	**LQXF mirror**	**85 days**	**Fri 12/5/14**	**Thu 4/2/15**
79	Assembly	4 wks	Fri 12/5/14	Thu 1/1/15
80	In the press	5 wks	Fri 1/2/15	Thu 2/5/15
81	Final prep	4 wks	Fri 2/6/15	Thu 3/5/15
82	Mirror test	1 mon	Fri 3/6/15	Thu 4/2/15
83	**Coil #4**	**129 days**	**Fri 8/1/14**	**Wed 1/28/15**
90	**Coil #5**	**105 days**	**Fri 10/3/14**	**Thu 2/26/15**
96	**Coil #6**	**117 days**	**Fri 10/24/14**	**Mon 4/6/15**
103	**Coil #7**	**123 days**	**Fri 11/14/14**	**Tue 5/5/15**
109	**QXFL01**	**108 days**	**Mon 6/1/15**	**Wed 10/28/15**
110	QXFL01 Readiness Review	0 days	Mon 6/1/15	Mon 6/1/15
111	Assembly & loading	28 days	Mon 6/1/15	Wed 7/8/15
112	shipment preparation	5 days	Thu 7/9/15	Wed 7/15/15
113	shipment	10 days	Thu 7/16/15	Wed 7/29/15
114	Splices, pizza-box & test prep	20 days	Thu 7/30/15	Wed 8/26/15
115	Test	45 days	Thu 8/27/15	Wed 10/28/15
116	Review	0 days	Wed 10/28/15	Wed 10/28/15
117	**QXFL01 disassembly**	**31 days**	**Thu 10/29/15**	**Thu 12/10/15**
121	**QXFL01b**	**113 days**	**Fri 12/11/15**	**Tue 5/17/16**
128	**QXFL01b disassembly**	**31 days**	**Wed 5/18/16**	**Wed 6/29/16**
132	**Coil #8**	**114 days**	**Mon 1/19/15**	**Thu 6/25/15**
139	**Coil #9**	**95 days**	**Fri 4/3/15**	**Thu 8/13/15**
145	**Coil #10**	**107 days**	**Fri 4/24/15**	**Mon 9/21/15**
152	**Coil #11**	**123 days**	**Fri 5/15/15**	**Tue 11/3/15**
158	**Coil #12**	**135 days**	**Fri 6/5/15**	**Thu 12/10/15**
165	**QXFL02**	**113 days**	**Thu 6/30/16**	**Mon 12/5/16**
172	**QXFL02 disassembly**	**31 days**	**Tue 12/6/16**	**Tue 1/17/17**
176	**QXFL02b**	**113 days**	**Wed 1/18/17**	**Fri 6/23/17**

Tentative plan and schedule of MQXF [G. Ambrosio, P. Ferracin]

MQXC

- MQXC (120 mm aperture Nb-Ti quadrupole ex phase-1) has been assembled and tested – enhanced insulation
  - New technology that could be used in D1 and Q4, [plan B for triplet]
  - 4 quenches to nominal, 1 after thermal cycle, not pushed yet to max
  - Evidence of heat extraction of 50 mW/cm^3



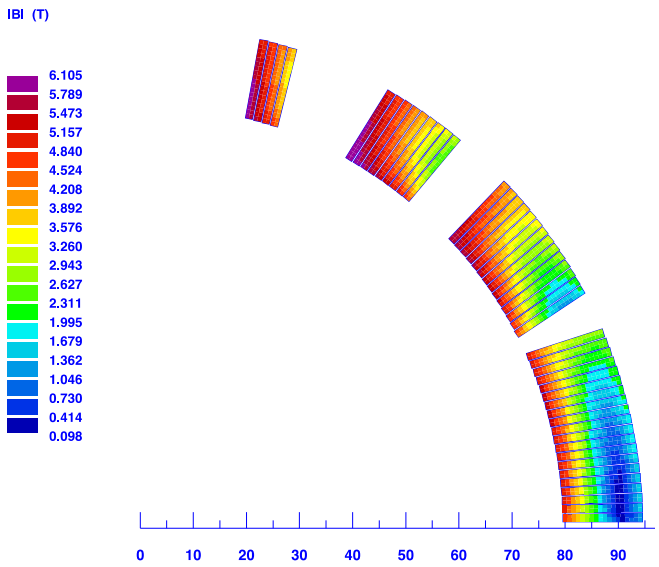
MQXC training [G. Kirby, J. Perez, N. Bourcey, J. Mazet, M. Bajko, et al.]

SEPARATION DIPOLES D1

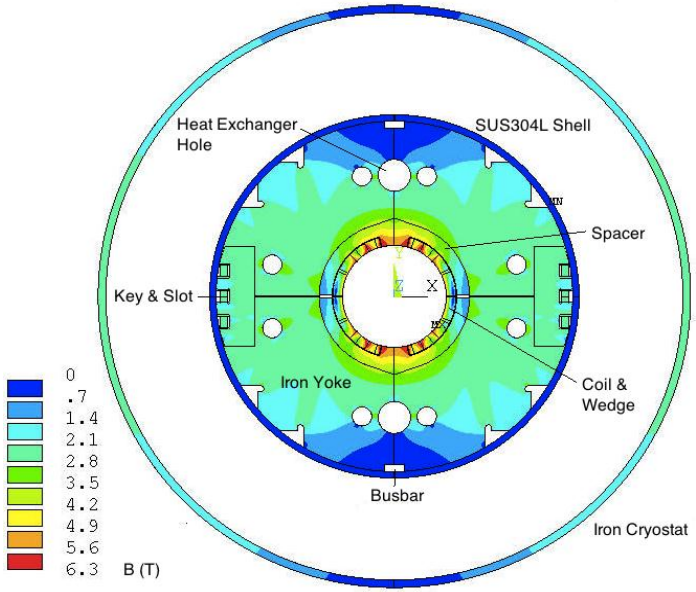
Nb-Ti separation dipole – decision to go from two to one layer

[Q. Xu, T. Nakamoto]

- Small reduction of operation field (from 6.5 to 5.2 T) – 7.6 m length
- 70% on loadline – possibly go to 75%-80% if we want shorter length
- Higher current density but OK with forces (<100 MPa)
- Lower fringe field



Previous two-layers version[Q. Xu, T. Nakamoto]



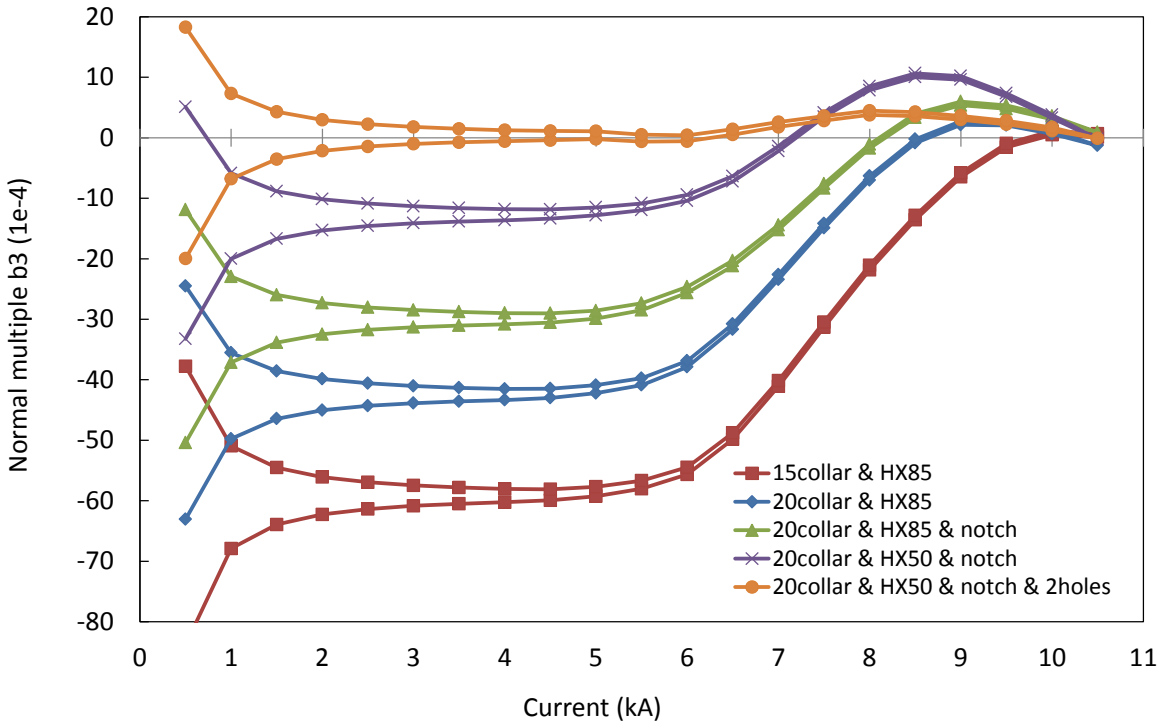
One layer version [Q. Xu, T. Nakamoto]

SEPARATION DIPOLES D1

Aperture of 160 mm – decision to go from two to one layer

[Q. Xu, T. Nakamoto]

- Strong regime of saturation (10% of transfer function at nominal)
- Careful iron shape optimization to reduce multipoles

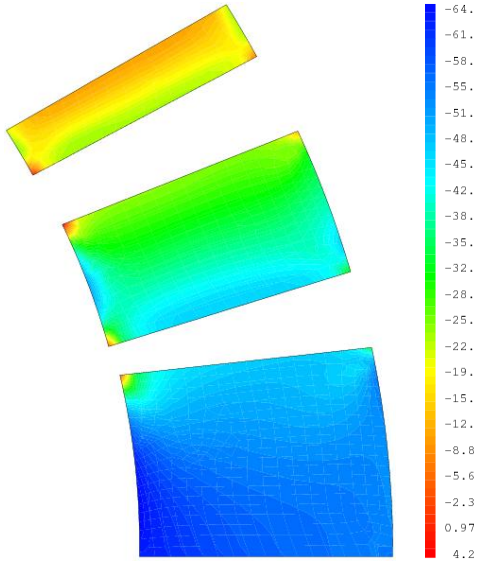


Optinization of b3 versus current[Q. Xu, T. Nakamoto]

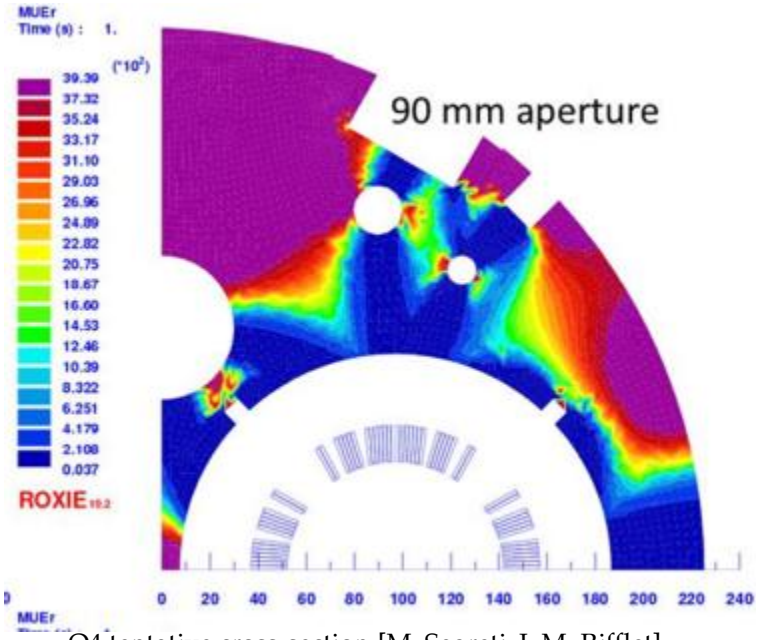
TWO-IN-ONE LARGE APERTURE QUADRUPOLE: Q4

Aperture of 90 mm

- Many options considered, one layer with MQ cable most attractive
  - Short pole length of 150 m, could be wound with LHC MB outer cables too short for the dipoles (reserve not affected)
- 120 T/m, 16 kA, 4.5-m-long, stress < 100 MPa
  - Protection could be viable with dump resistor only (no quench heaters)



Azimuthal stress at nominal [M. Segreti, J. M. Rifflet]



Q4 tentative cross-section [M. Segreti, J. M. Rifflet]

NEXT STEPS

- Have a baseline for correctors to be able to model heat deposition up to D1 for the 150 mm (March 2013?)
- Define powering scheme
  - Individually powered or in series ?
- Have a baseline for D2, for the TAN and model up to Q4 (September 2013?)
- QXF cable finalized in March 2013, then start tooling
  - Plan: two short model SQXF, one long LQXF within 2015
- Start for Q4 and D1 engineering design
  - Enhanced insulation or not ?
- In 2013 test of HQ and 11 T with cored cable – very important for protection and dynamic effects

www.cern.ch/hilumi/wp3

- KEK: Q. Xu, T. Nakamoto, A. Yamamoto, T. Ogitsu
- INFN LASA: M. Sorbi, G. Volpini
- CERN: H. Bajas, M. Bajko, J. Feuvrier, E. Fornasiere, P. Ferracin, S. Bermudez, P. Fessia, J. C. Perez, N. Bourcey, J. Mazet, D. Cote, P. Galbraith, G. Kirby, P. Hagen, L. Fiscarelli, S. Russenschuck, M. Karppinen, A. Ballarino, L. Oberli, L. Bottura, G. De Rijk, L. Rossi, S. Fartoukh, R. De Maria, O. Bruning, M. Giovannozzi, F. Cerutti, L Esposito, A. Herve, P.P. Granieri, R. Van Weelderen. R. Kersevan
- CEA Saclay: M. Segreti, J.-M. Rifflet
- BNL: P. Wanderer, M. Annarella
- FNAL: G. Ambrosio, X. Miau, N. Mokhov
- LBL: H. Felice, F. Borgnolutti, T. Salmi, S. Caspi, S. Prestemon, A. Godeke, X. Wang, Y. Miao, D. Dietderich

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