Linac4 Project
Forthcoming industrial orders

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(in collaboration with M. Vretenar – AB/RF)

1. *Introduction, parameters*
2. *Project Planning*
3. *Linac4 R&D Collaborations*
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The present LHC Injector Chain

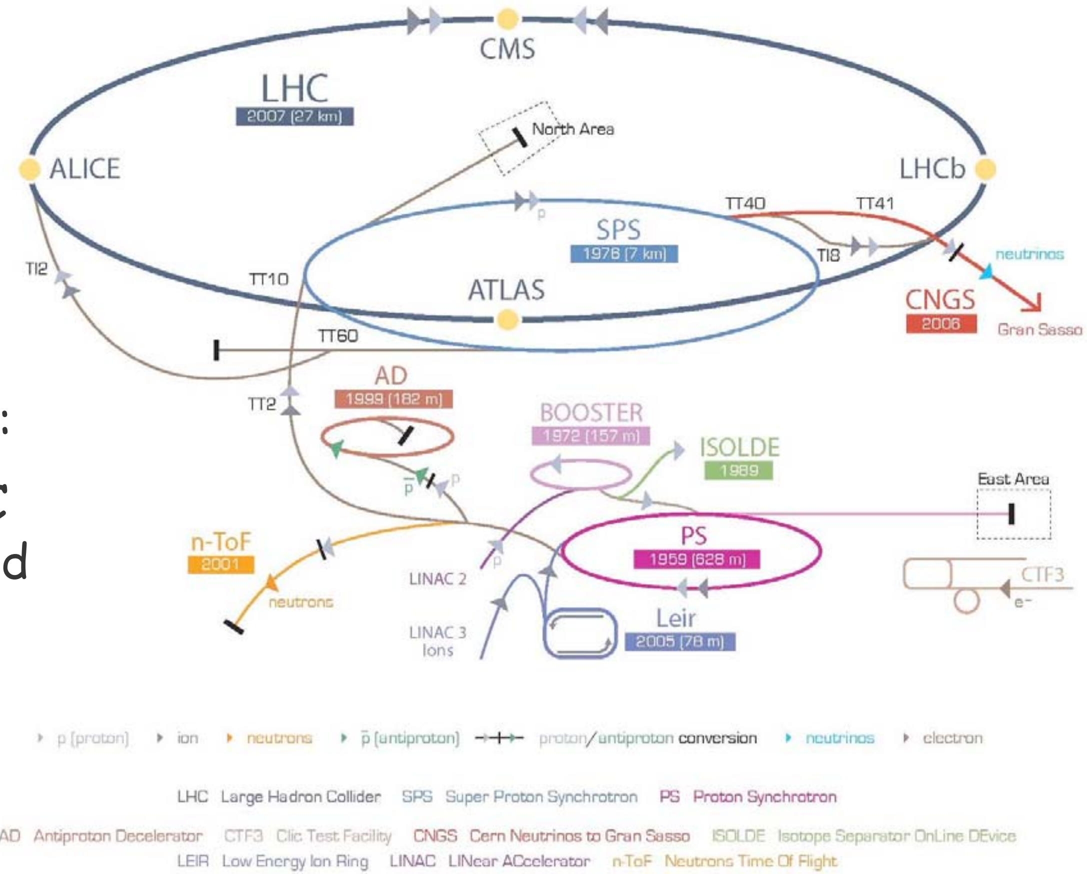
Present LHC Injectors

-Linac2 (p, 50 MeV, 1978)
-PSB (1.4 GeV, 1972)
-PS (28 GeV, 1959)
-SPS (450 GeV, 1976)

Two concerns for the future:

1. The reliability of the LHC relies upon a relatively old accelerator chain.

2. To fully exploit the LHC potential we will need to upgrade the injectors.



The “White Paper”

✦ At its June 2007 Meeting, the CERN Council has approved the “White Paper”, first presented to the Council in October 2006.

✦ The approved programme includes (2nd Theme, high priority programme to be achieved by 2011, in order to eliminate concerns about reliability and remove technical bottlenecks in the present injection line):

- ❑ construction of Linac4 (160 MeV, H-).
- ❑ design of the Superconducting Proton Linac (SPL).
- ❑ design of a new PS (PS2).

✦Construction of Linac4 is approved as a high priority project, and started in January 2008. The present planning foresees that the 2013 PSB start-up will be with the Linac4 beam. White Paper budget will cover the period 2008-11 (4 years).

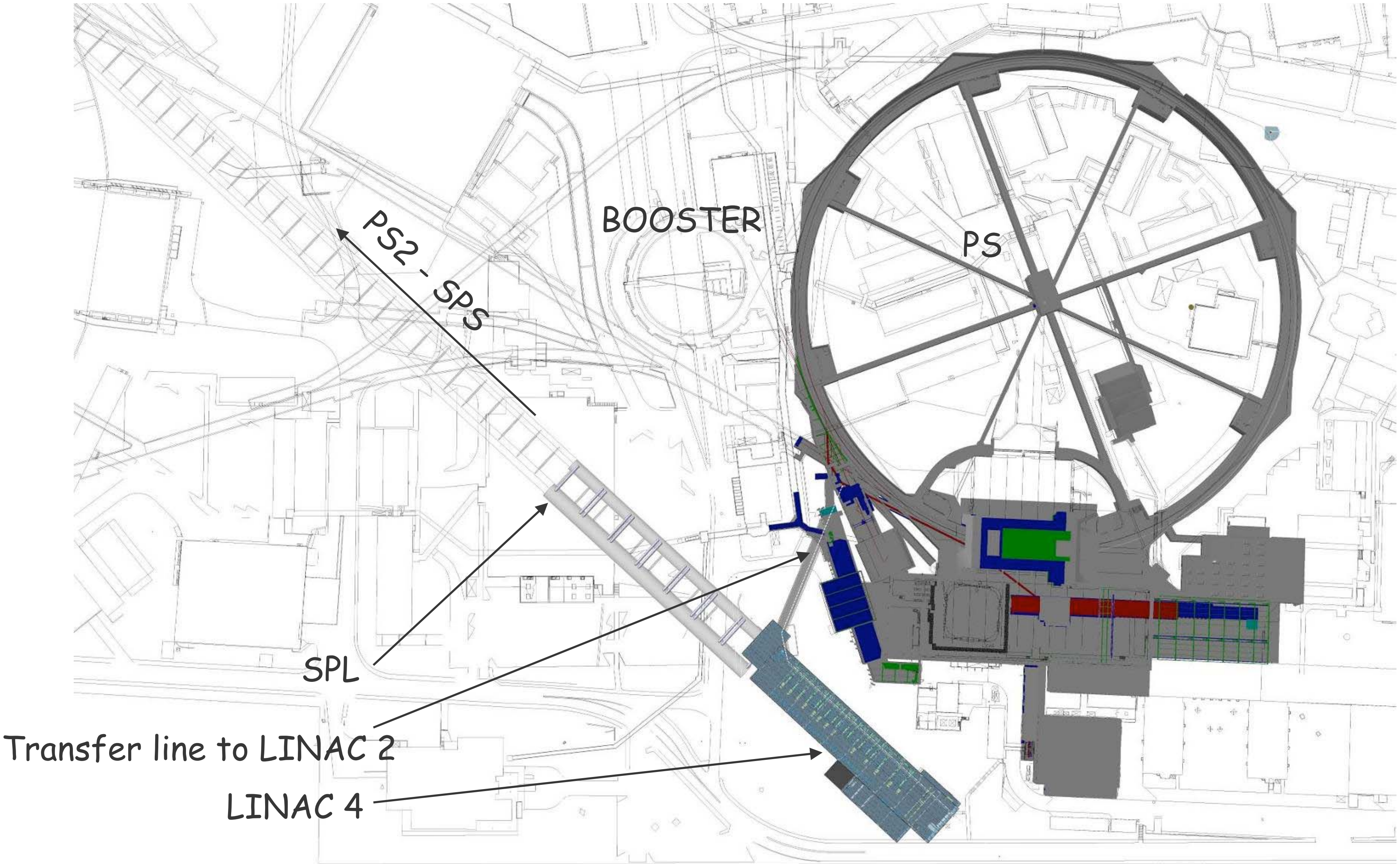
Three stages/modes of Linac4

Linac4 is foreseen to operate in 3 different modes:

1. Injector to PSB *(2013-2016?):* 160 MeV, 2 Hz, 40 mA, 400 ms.
2. Injector to Low Power SPL *(2016-2020?):* 180 MeV, 1 Hz, 20 mA, 1.2 ms
3. Injector to High Power SPL *(if approved, >2020):* 180 MeV, 50 Hz, 40 mA, 400 ms

The present design takes into account these three different modes and the future connection to the SPL

Linac4: connection to PSB and SPL



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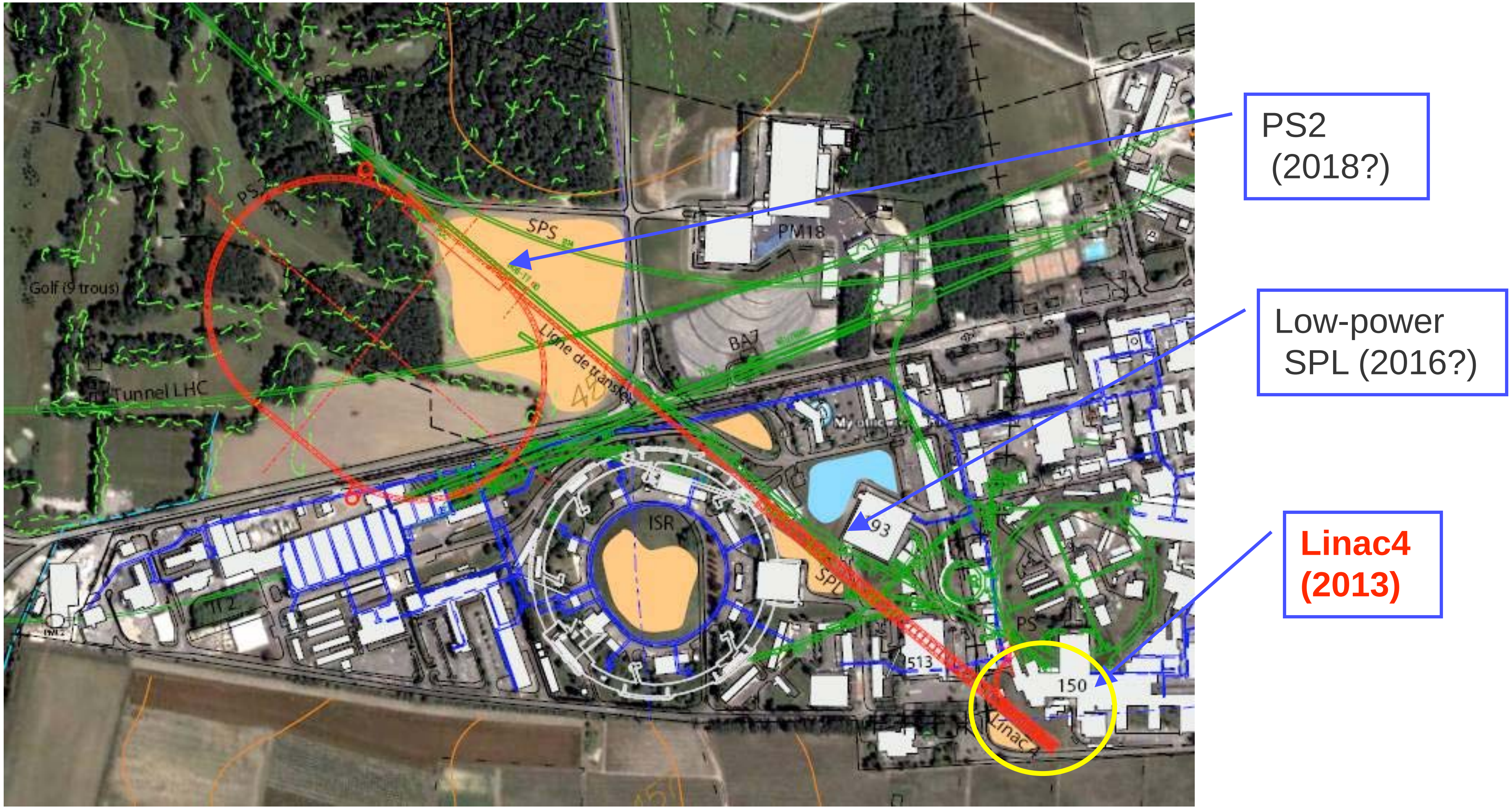
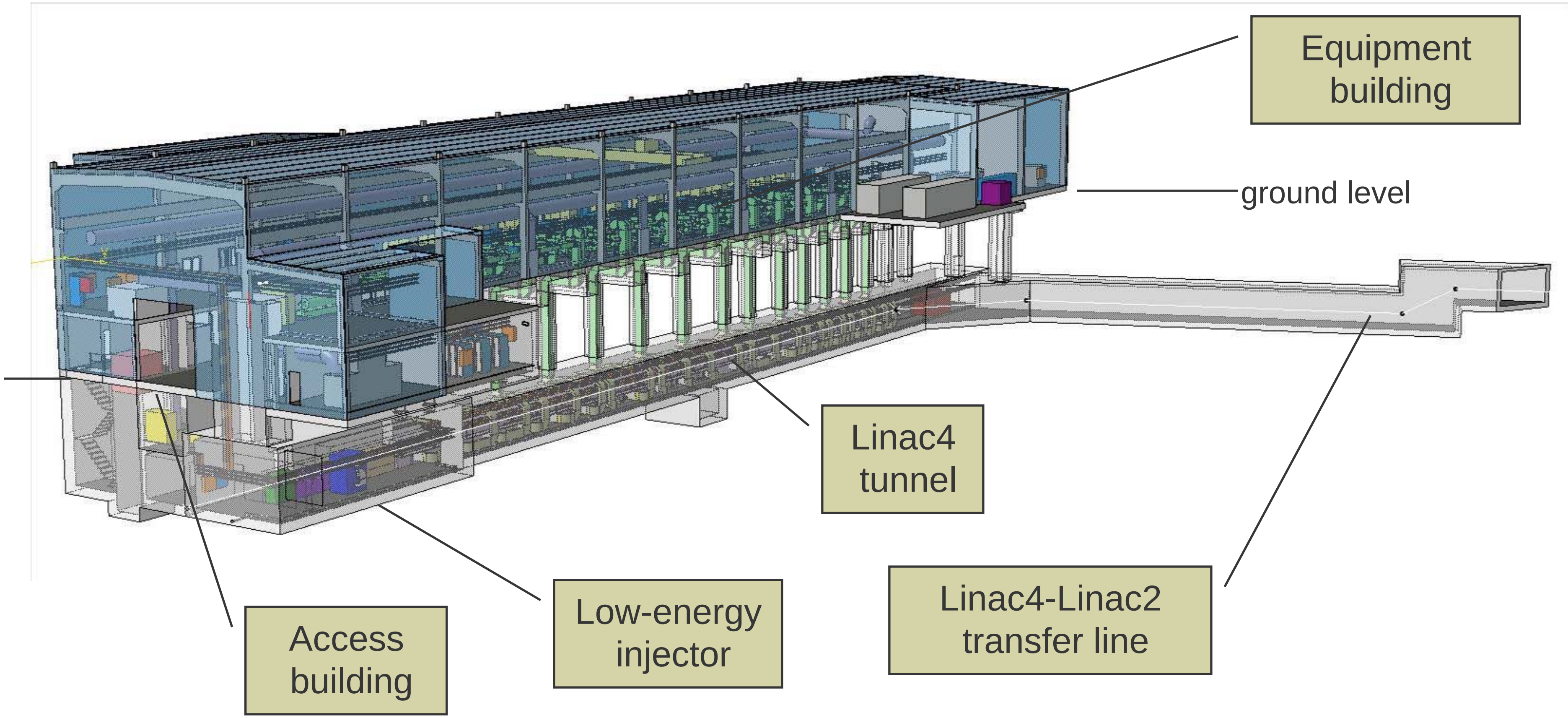
The new injectors on the CERN site



1st stage: Linac4 + PSB + PS + SPS

2nd stage: Linac4 + SPL + PS2 + SPS

Linac4 civil engineering



Pre-integration May – October 2007: definition of building dimensions and characteristics
Tendering drawings preparation November 2007 – April 2008
Integration continuing, for small modifications before start of works.

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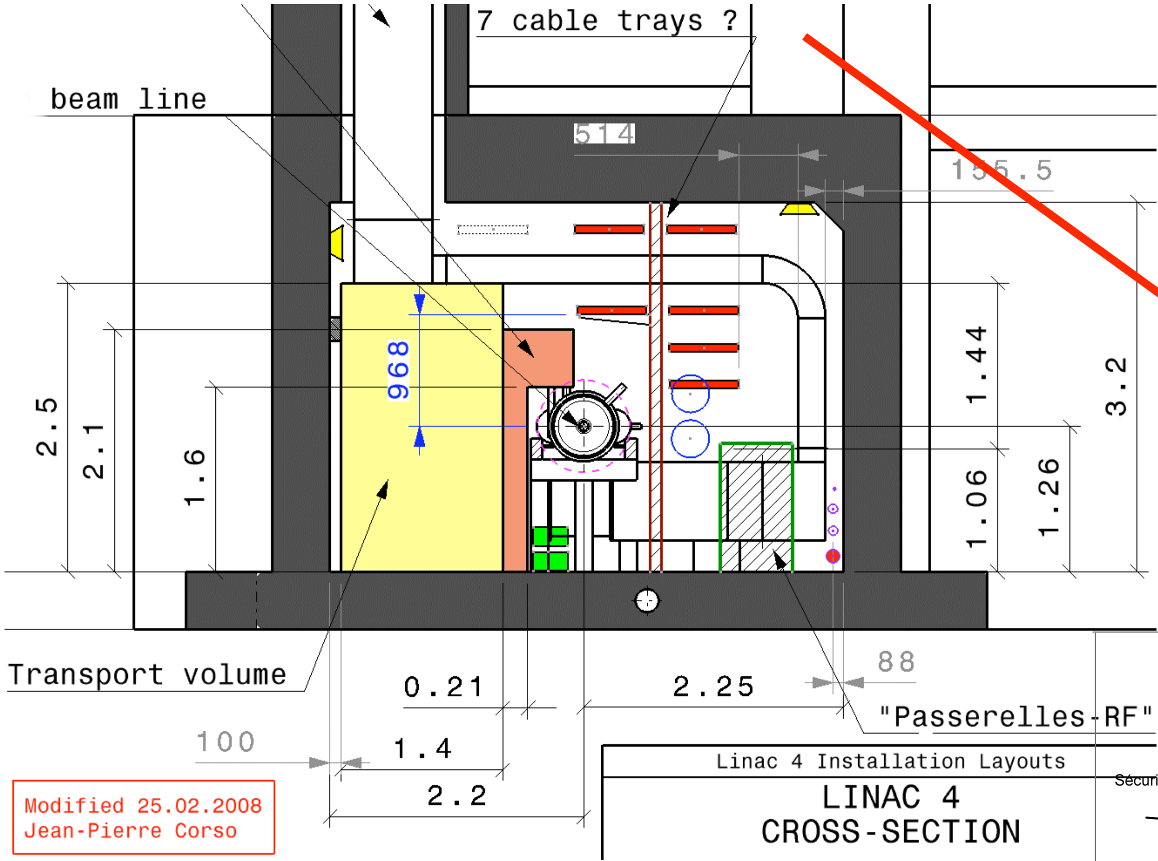
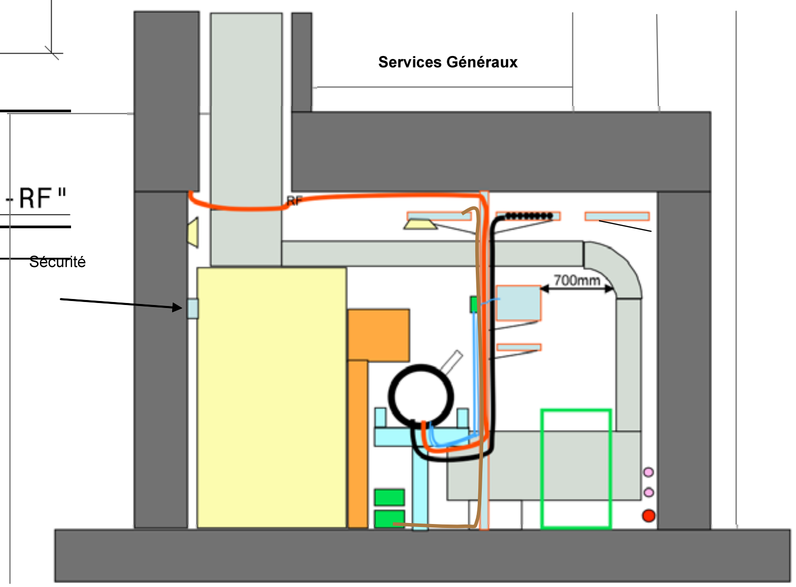
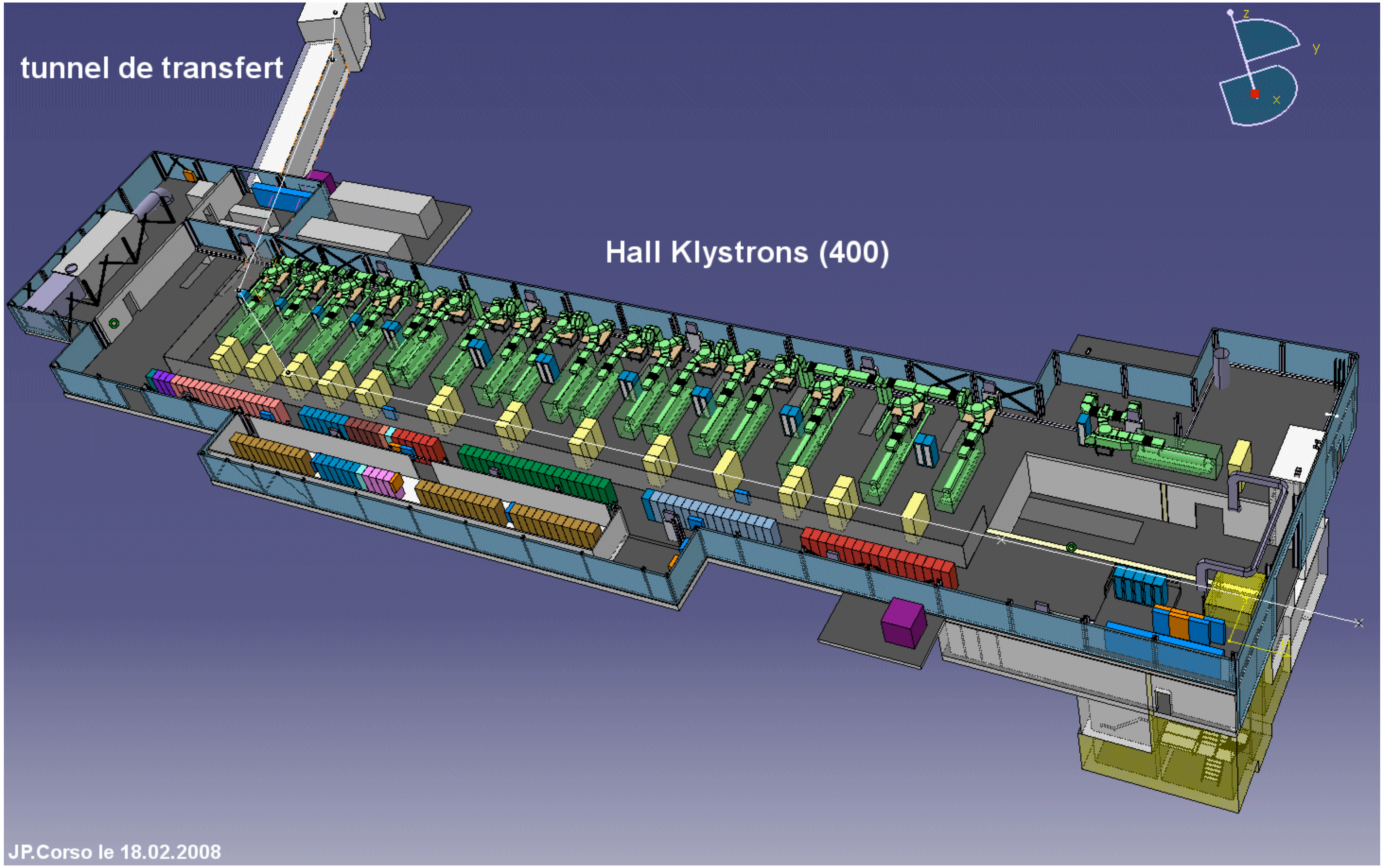
Tunnel cross-section



Final position of cable trays:



Equipment Hall (Bld. 400)



Linac4 Project - Organization, Information

- Project Leader: Maurizio Vretenar – AB/RF

- Technical information about the Project:
  - Linac4 web site: http://linac4.web.cern.ch/linac4/
    (accessible from the CERN web page)
  - LINAC4 Machine Review Committee - January 2008 (see Linac4 web site).
  - "Linac4 Technical Design Report", CERN-AB-2006-084 ABP/RF (but some changes in the design since then!)

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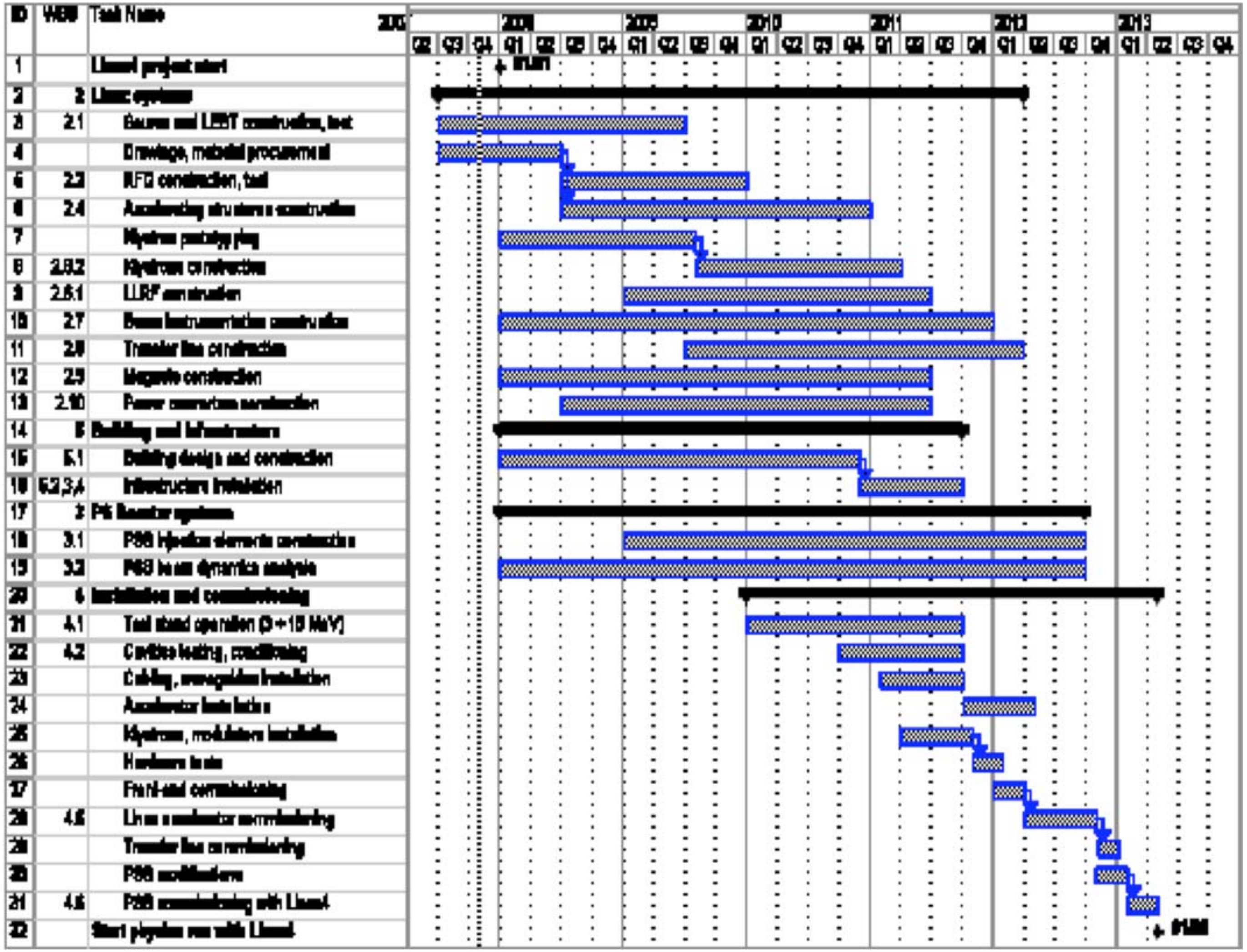
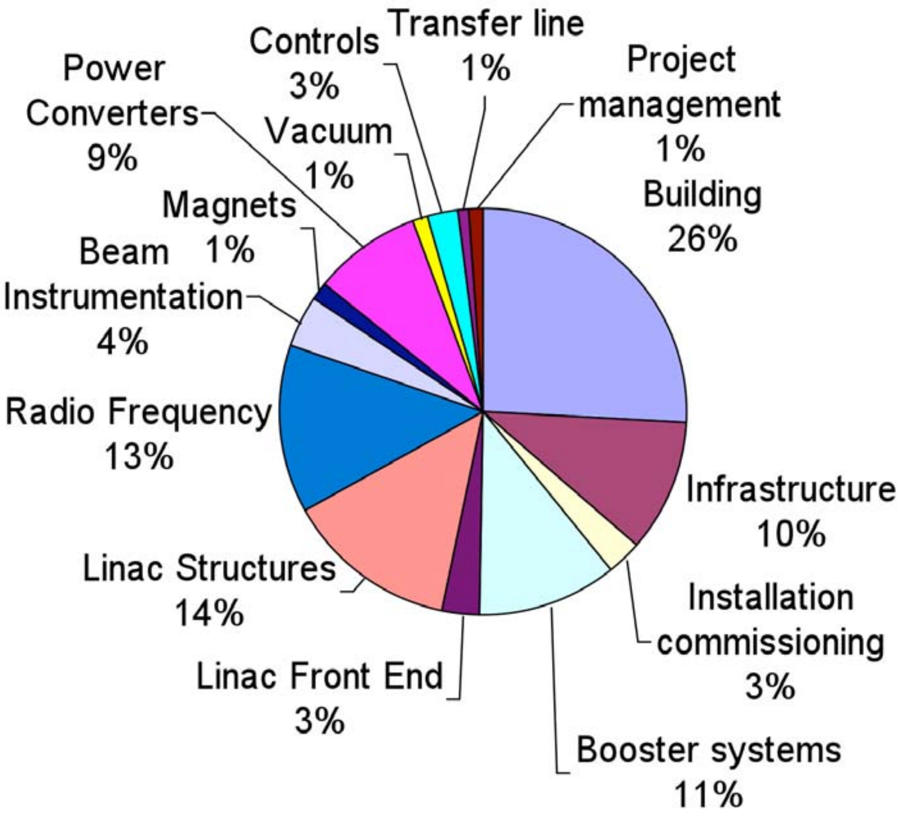
Linac4 Master Plan



- ✦End CE works: December 2010
- ✦ Installation: 2011
- ✦ Linac commissioning: 2012
- ✦ Modifications PSB: shut-down 2012/13 (6 months)
- ✦ Beam from PSB: 1.5.2013

Linac4 Budget

TS (building, infrastructure): 34.85 MCHF
AT (magnets, vacuum): 2.26 MCHF
AB (all the rest): 54.40 MCHF



Linac4 – Technical Aspects

- Technologies and know-how of the main accelerating Linac4 structures and the RF equipment only available in specialized physics Institutes, and -without essential R&D investments- rarely in the industry,
- Final design of the main Linac4 elements has been therefore preceded by extensive R&D Collaboration with Member and Non-Member States laboratories (2004-2008) which will contribute to the production of certain elements,
- Several critical accelerating elements will be produced by CERN.

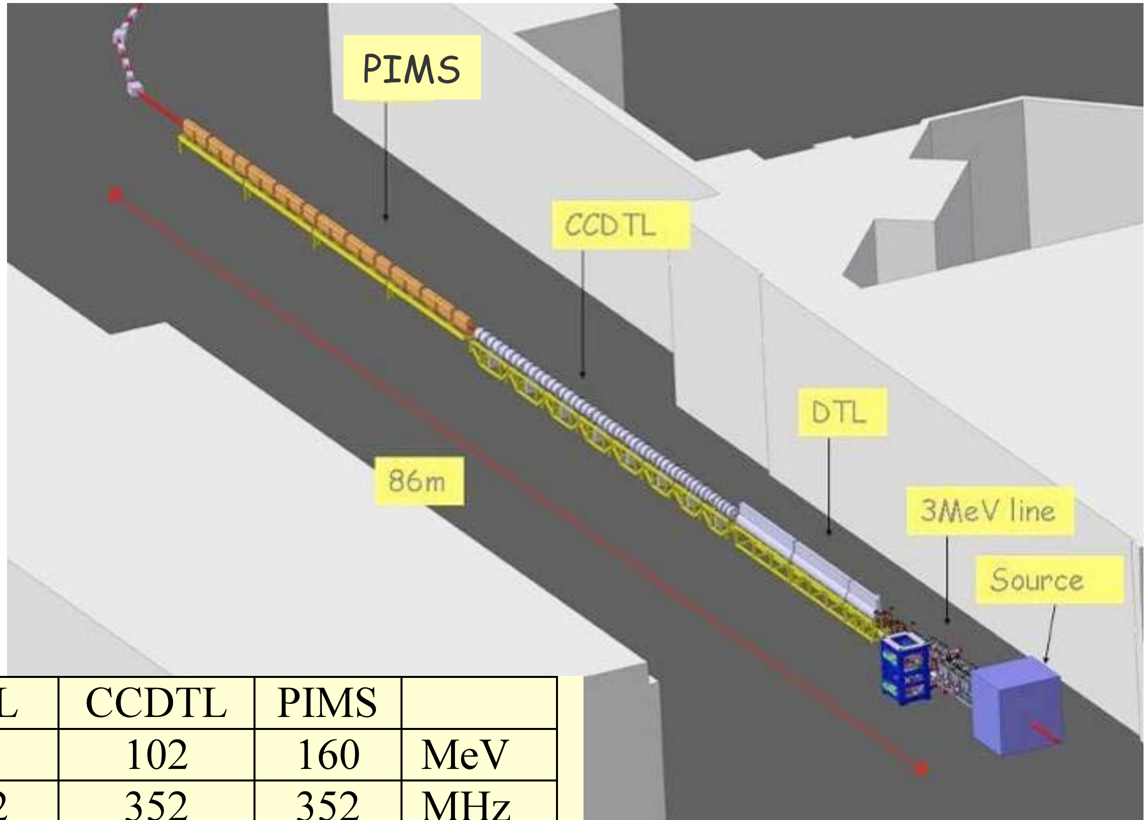
Linac4 – Key Technologies

- Precision machining of steel and copper (0.02 – 0.1);
- Electron Beam Welding (EBM), brazing, copper plating of steel:
- Radio-frequency components for high peak power and low average power;
- Conventional electro-magnets of small dimensions and high precision;
- Permanent Magnet Quadrupoles (PMQ);
- High Voltage (100 – 120 kV) pulse transformers and switches.

Linac4 accelerating structures

Linac4 accelerates H- ions up to 160 MeV energy:

- ❑ in about 80 m length
- ❑ using 4 different accelerating structures, all at 352 MHz
- ❑ the Radio-Frequency power is produced by 19 klystrons
- ❑ focusing of the beam is provided by 111 Permanent Magnet Quadrupoles and 33 Electromagnetic Quadrupoles



	RFQ	DTL	CCDTL	PIMS	
Output energy	3	50	102	160	MeV
Frequency	352	352	352	352	MHz
No. of resonators	1	3	7	12	
Gradient E_0	-	3.2	2.8-3.9	4.0	MV/m
Max. field	1.95	1.6	1.7	1.8	Kilp.
RF power	0.5	4.7	6.4	11.9	MW
No. of klystrons	1	1+2	7	4+4	
Length	6	18.7	25.2	21.5	m

A 70 m long transfer line connects to the existing line Linac2 - PS Booster

Linac4 Layout

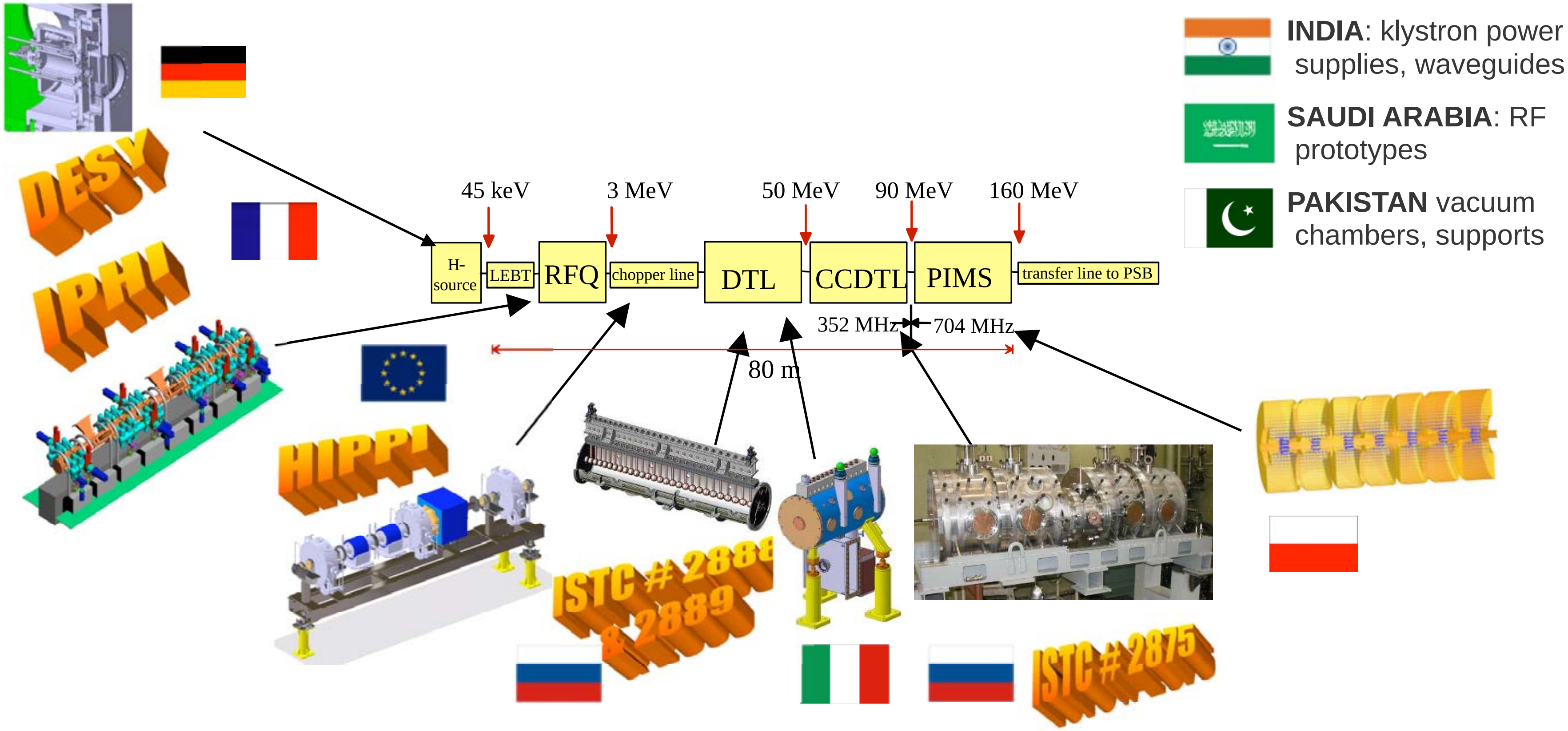
H-	RFQ	CHOPPER	DTL	CCDTL	PIMS
→ 95keV	→ 3MeV		3MeV →	50MeV →	94MeV → 160MeV
RF volume source (DESY)	Radio Frequency Quadrupole (IPHI)	Chopper	Drift Tube Linac	Cell-Coupled Drift Tube Linac	Pi-Mode Structure
35 kV Extrac.	352 MHz	352 MHz	352 MHz	352 MHz	352 MHz
+60kV Postacc.	6 m	3.6 m	18.7 m	25 m	22 m
	1 Klystron	11 EMquad	3 tanks	21 tanks	12 tanks
	1 MW	3 cavities	3 klystrons	7 klystrons	8 klystrons
			4 MW	6.5 MW	~12 MW
			111 PMQs	21 EMQuads	12 EMQuads

Total Linac4:
80 m, 18 klystrons

4 different acc. Structures:
RFQ, DTL, CCDTL, PIMS

Ion current: 40 mA (avg. in pulse), 65 mA (bunch)

Linac4 R&D collaborations (2004-2008)

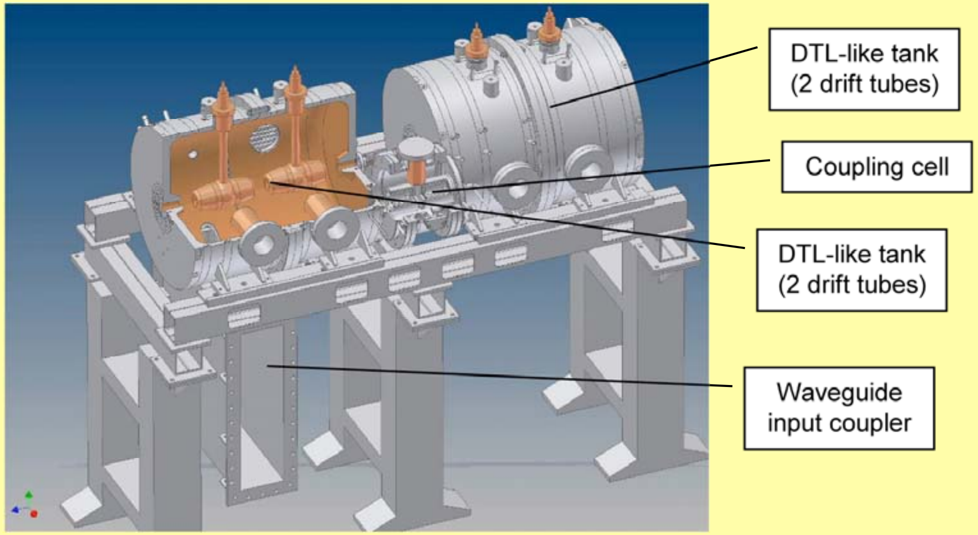


Network of collaborations for the R&D phase, via EU-FP6, CERN-CEA/IN2P3, ISTC (CERN -Russia), CERN-India and CERN-Pakistan agreements.

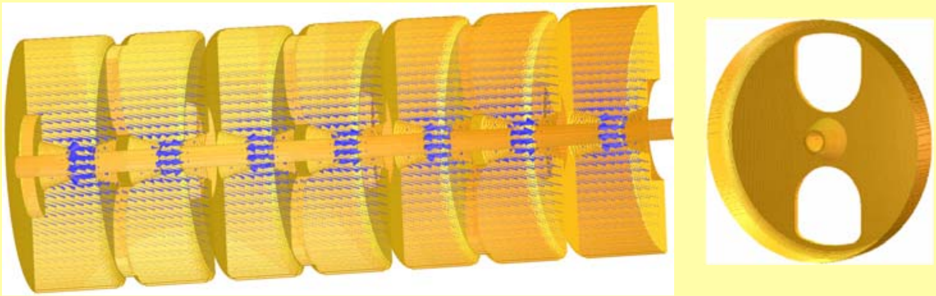
Support by EU – FP6: HIPPI JRA within CARE (Coordinated Accelerator Research in Europe)

International participations to the construction of Linac4 to be defined during 2008 (Russia, France, Poland, India, Pakistan, Saudi Arabia, Spain, USA….)

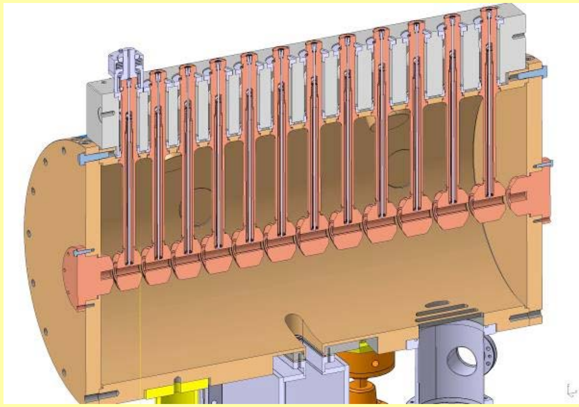
The Linac4 accelerating structures



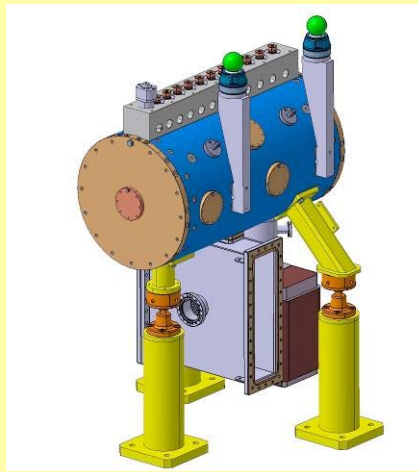
CCDTL: 2 prototypes built and tested



PIMS (7-cell pi-mode cavities): advanced design, prototype being designed



DTL: prototype in construction



Linac4 - Forthcoming industrial orders

- A. Accelerating structures

Description	Parameters, technologies, number of units	Estimated cost range MCHF	Remarks
Drift Tube Linac (DTL) - tanks	Φ500, L~1.5 m 11 units	≈ 0.2	
Drift Tube Linac (DTL) – drift tubes	Copper, EBW ?, 120 units	0.4 – 0.6	
RF Windows	1 MW peak, 24 units	0.7 - 1.3	

Linac4 - Forthcoming industrial orders

- B. RF equipment

Description	Parameters, technologies, number of units	Estimated cost range MCHF	Remarks
Klystrons	2.6 MW peak, 7 units	3.5 - 4.0	One European producer only?
Loads	Ferrite or water absorbing medium, 19 units	0.8 – 1.2	One European producer only?
Amplifiers	30 kW peak, 3 units	0.5	

Linac4 - Forthcoming industrial orders

- C. Power converters

Description	Parameters, technologies, number of units	Estimated cost range MCHF	Remarks
HV pulse transformers	120 kV, 13 units	1.0 – 2.0	MS done, but no interest from European companies
HV switches	120 kV, 13 units	1.0	
Power converters	Various types (5-10 different?), 100 units	2.0 - 2.5	

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Linac4 - Forthcoming industrial orders

- D. Magnets

Description	Parameters, technologies, number of units	Estimated cost range MCHF	Remarks
PMQ (Permanent Magnet Quadrupoles)	High gradient (100 T/m), 120 units	0.35 – 0.45	**No European producer**
Conventional quadrupoles	Electromagnets, 60 units	0.5 – 0.7	
Bending magnets	Electromagnets, 7 units	0.4 – 0.6	

Linac4 - Forthcoming industrial orders

- E. Other equipment

Description	Parameters, technologies number of units	Estimated cost range MCHF	Remarks
Programmable Logic Controllers (PLC)		0.2	
Vacuum pumps	Two or three different types	0.4 – 0.6	

Final remarks

- A detailed schedule of the industrial tenders for Linac4 is in preparation,
- The tendering document forms and accompanying technical and commercial documents are now being reviewed to update them and adjust to the new stage of the LHC.