FROM RESEARCH TO INDUSTRY

‘ACTIVITÉS’ ILC ACCÉLÉRATEUR

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GROUPES DE TRAVAIL ‘FRANCE-JAPON’

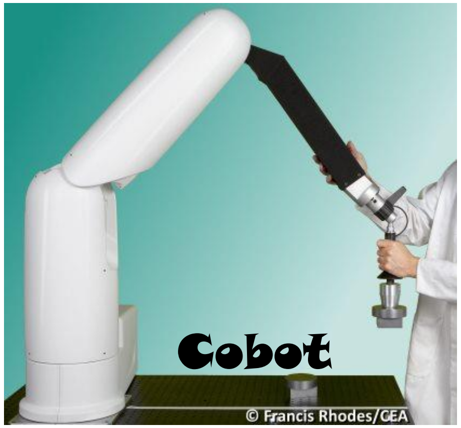
- Comité de Pilotage FJPPL, 5 septembre 2019
  - ATF2 Studies and preparation for ILC (Angeles Faus-Golfe, LAL)
  - R&D on innovative treatments and characterization of SRF surface for future accelerators (Kubo, Hayano, Eozénou, Proslier)
  - Robotics for clean room work (Michizono, Berry, Napoly)
- Discussions avec le ‘LAL’ pour ajouter une groupe de travail sur les ‘Coupleurs de puissance’.

ROBOTISATION EN SALLE BLANCHE

- Principe proposé par le CEA à LCWS2017, Morioka
  - Réduction des coûts de main d’œuvre
  - Elimination des erreurs d’assemblage et non-conformités
  - Uniformisation des procédures sur les centres régionaux d’assemblage.
  - ‘Plug compatibility’
- Démonstration du nettoyage des brides cavités à Saclay démontrées, sur un financement Irfu.
- Groupe de travail ‘officiel’ CEA-KEK, en veille.
- Groupe de travail ‘officieux’ CEA-CERN, actif.

CEA proposal to Japan-France collaboration

- To prevent performance degradation of SRF cavities due to metallic dust, it is necessary to clean with an ion gun.
- Robot cleaning contributes to work efficiency and cost reduction of the assembly.
- With the experience gained on the assembly of the cryomodules at European-XFEL, CEA-Saclay is pursuing R&D effort on robotization.



Cobot

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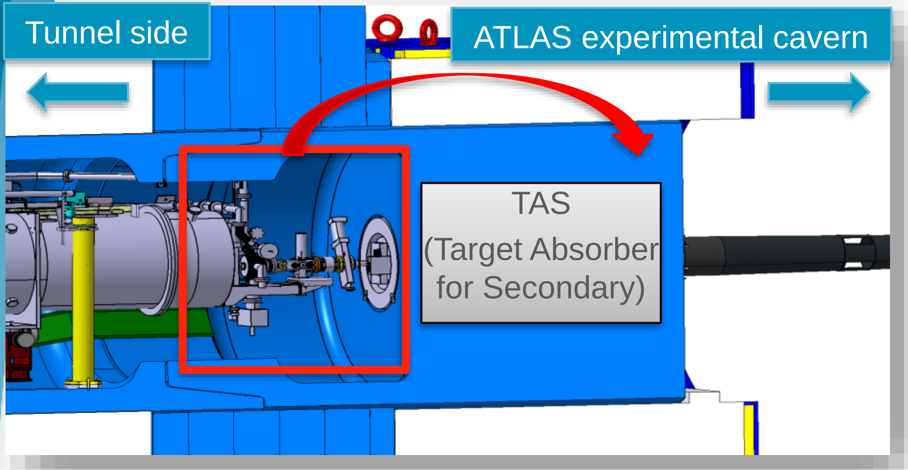
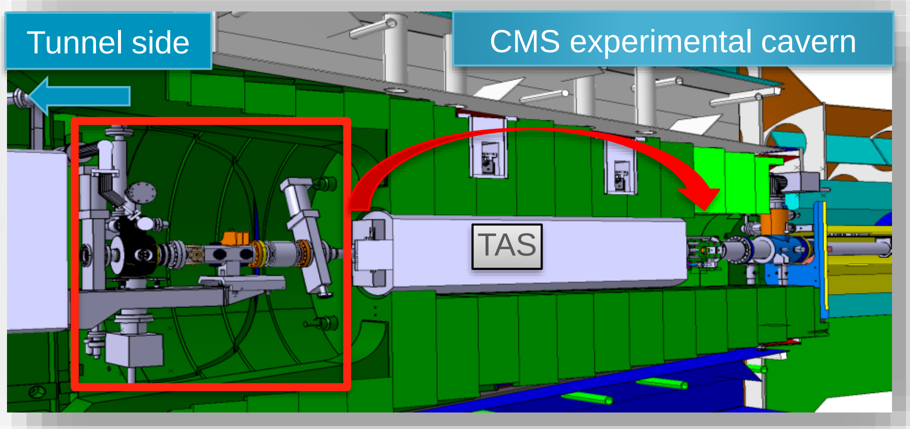
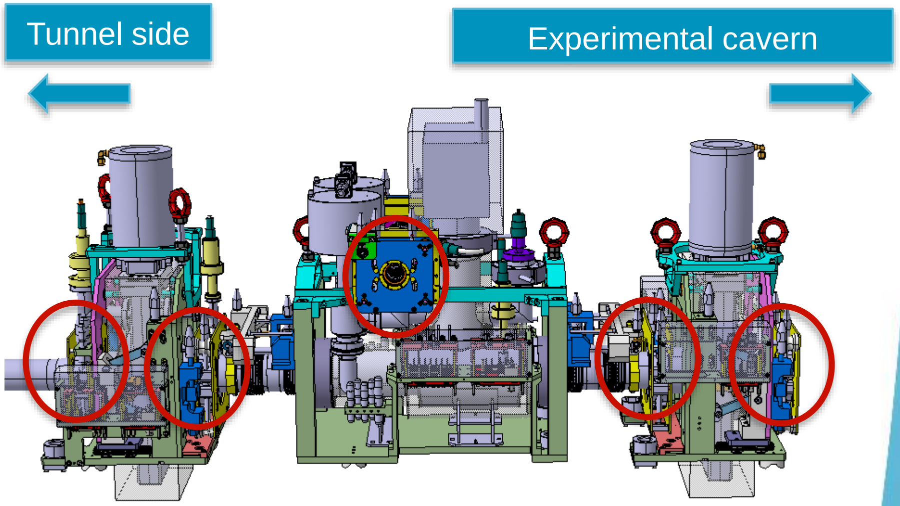
Cobot in Saclay ISO4 Clean Room

R&D plan (KEK/ CEA-Saclay)
JFY2020: (KEK) Robot introduction for dust removal of electrostatic remover
(CEA) Cobot tests for cleaning all flanges of two cavities,
Evaluation of cobot for flange assembly
JFY2021: (KEK) Development of robot operation program, learning of operation work
(CEA) Order Cobot and development of the flange assembly
JFY2022: (KEK) Operation confirmation by robotization of equipment
(CEA) Cobot tests on a cavity – bellow assembly

Vacuum Assembly for eXperimental areas (VAX)

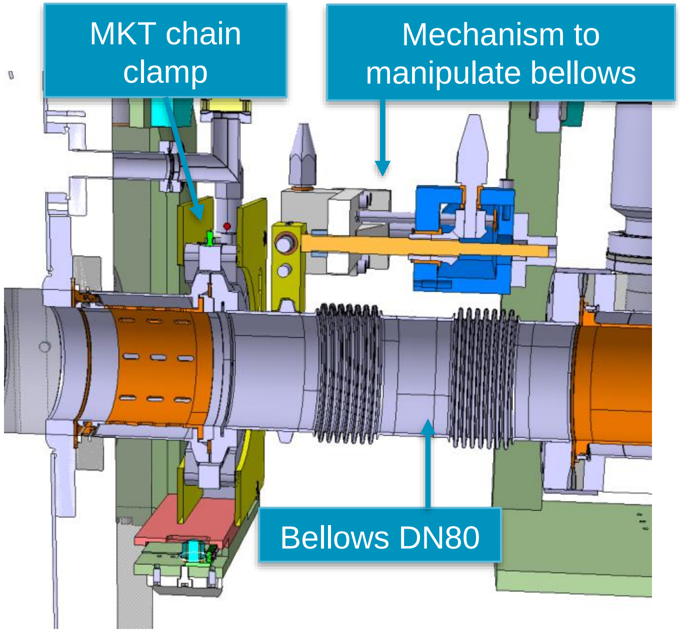






1. 3 separate modules
2. Vertical, remote operation
3. Standard interconnection QCF DN100 and QCF DN40

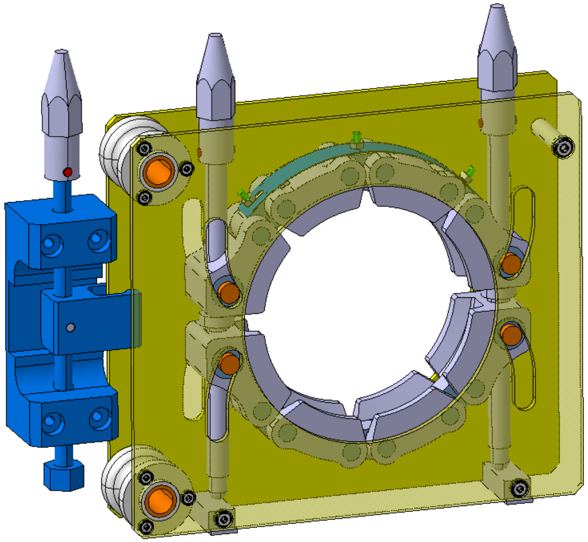
VAX QCF DN100 interconnection



MKT chain clamp

Mechanism to manipulate bellows

Bellows DN80



CM1 @ 40 MV/m

- Fermilab (Belomestnykh, Grasselino, Posen, TD) a pris l’initiative d’inviter le CEA, DESY, KEK et TRIUMF pour lancer une activité de développement d’un cryomodule démonstrateur ‘ILC’ à 40 MV/m.

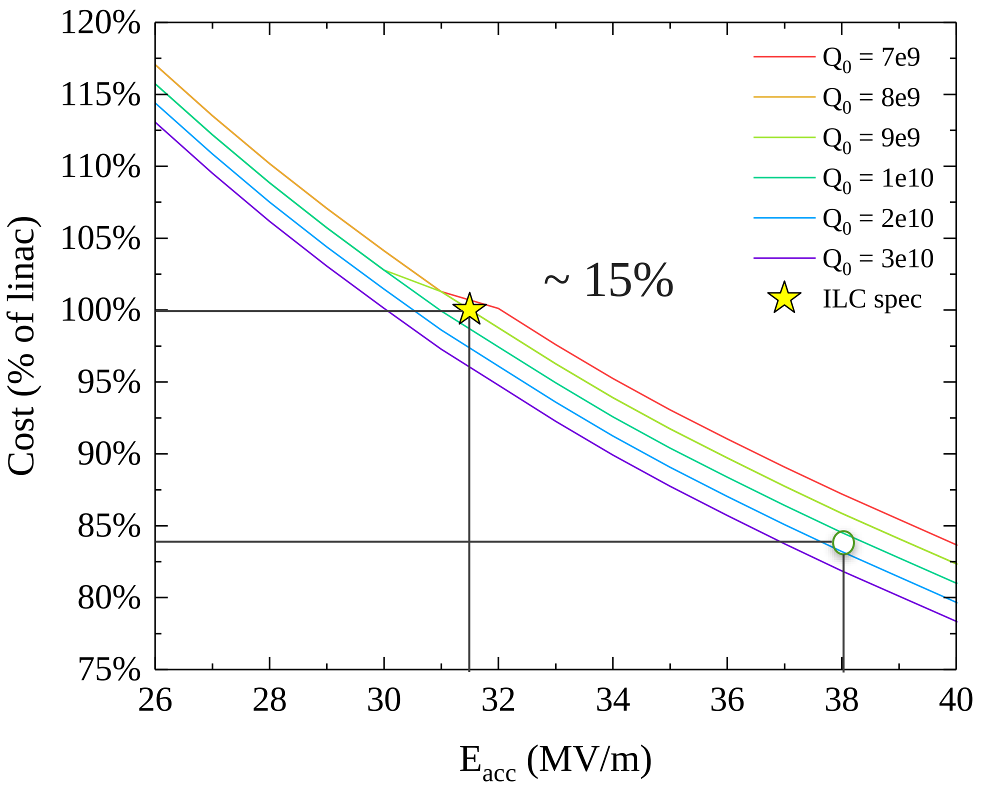
- Il s’agit du cryomodule CM1, le premier construit par DESY et Fermilab (en 2009), à Fermilab sur le modèle des cryomodules FLASH-XFEL (8 cavités).
- Le cryomodule CM2 équipe l’accélérateur FAST-IOTA à Fermilab. En cas de réussite, CM1@40 MV/m le remplacerait.

ILC Cost Reduction Demonstration

- Many new advances in SRF technology since ILC TDR
- New treatments may enable significant reduction in ILC cost:
  - Flux expulsion
  - Two step bake (75/120)
  - Cold EP
- This year with ILC Cost Reduction R&D funds from DOE, Fermilab plans to assemble a cryomodule with cavities with new treatments
- Goal is to reach higher gradient than has ever been demonstrated in CM test.

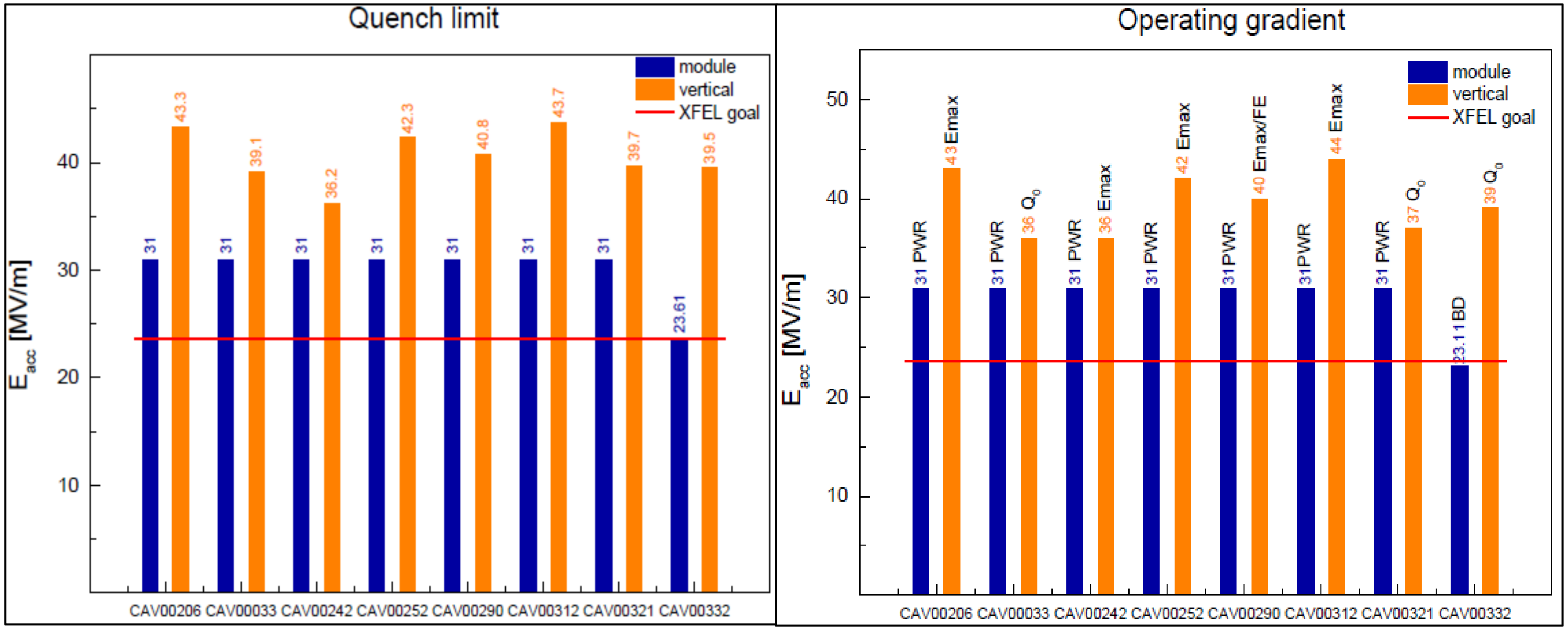
ILC Cost Reduction Demonstration

- Aim will be 38 MV/m average gradient with a stretch goal of 40 MV/m. The Q_0 goal will be 1.0×10^{10} at 38 MV/m
- Achieving this would be a key demonstration of the potential for cost reduction for ILC.



Cavités RF @ 40 MV/m

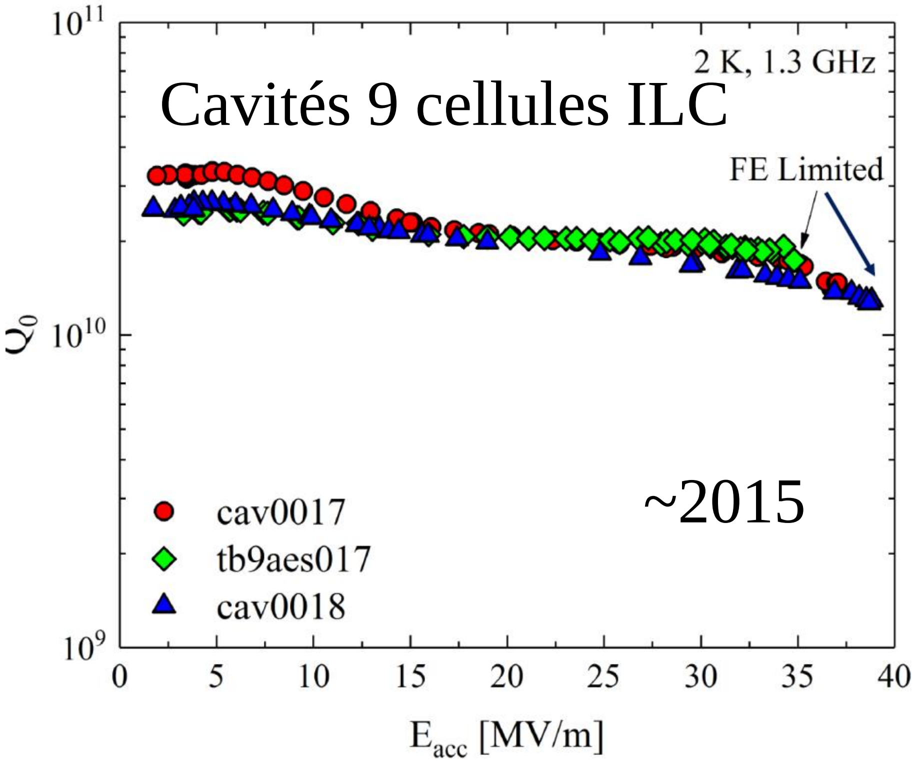
- De telles cavités sont présentes dans l’accélérateur XFEL, e.g. XM67

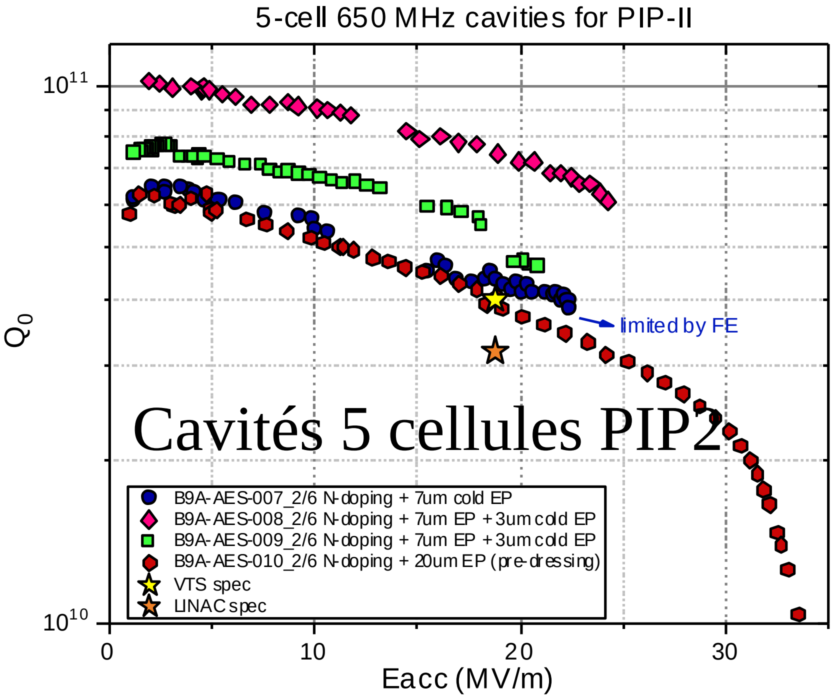


- La préparation des cavités à Fermilab fait appel à la combinaison de traitements de surface: traitement thermique à 800°C, dopage N_2, étuvage, électro-polissage à 13°C, d’hygiène magnétique incluant démagnétisation et blindages, et de refroidissement rapide < 40K pour éviter les gradients thermiques sources de courants électriques.

Cavités RF @ 40 MV/m

- Ces méthodes de préparation sont encore perfectibles et optimisables.
- Il est prévu de les utiliser pour les cavités PIP-II (650 MHz).





- Pour CM1, Fermilab fournira 8 cavités à 40 MV/m. Il faudra les assembler avec soin !

CM1 @ 40 MV/m

- Pour le DACM, j'ai évoqué trois sujets possibles de collaboration :
  - la préparation en électro-polissage 'froid' et la qualification en CV d'une ou deux cavités (pour le projet il est important de démontrer que la méthode de préparation des cavités est exportable)
  - la fourniture de blindages magnétiques (8 unités)
  - la participation à l'assemblage et au test de CM1.1 à Fermilab.
- Le calendrier est 2020, avant l'arrivée des 10 cryomodules LCLS-II HE.
- CM1 est déjà installé dans le hall de montage de LCLS-II à Fermilab, prêt à être démonté.

Paramètres ILC à haute luminosité

- Proposition H. Padamsee:
  - Taux d'interaction × 3 : 5 → 15 Hz
  - Nombre de paquets × 2 : 1312 → 2624
  - Aucune modification des paramètres faisceaux de collision

$\Rightarrow$

  - Luminosité × 6 : 1.3 → 7.7 10^{34} $cm^{-2}.s^{-1}$
  - Puissance faisceaux × 6 : 5.3 → 31.5 MW
  - Puissance totale × 6 : < 300 MW
  - Coût de construction : 5.5 B + 1.34 B = 6.84 B

- Trois pages suivantes de H. Padamsee @ Fermilab Workshop on ILC HL-HG. https://indico.fnal.gov/event/20759/

Goals: Keep ILC 250 high visibility in European Plan and Snowmass

- One argument for FCCee is that with rings and high beam current, luminosity for Higgs Factory can be much higher (6X) than ILC 250
- Also FCCee will have 2 detectors (=>Lum is 12X ILC 250)
  - But ILC 250 will have polarized e- and e+
  - So OK to shoot for 6X ILC250
  - We also explore 10X ILC 250 to make ILC super attractive!
- 2X higher Lumi explored before (next slide), but not 6 X, or 10X
- Develop parameters for ILC high luminosity (6X) to compare with FCC ee Higgs
  - Rough estimate of costs to compare with FCCee Higgs
  - Rough estimate AC power to compare with 300 MW FCCee
  - Starting from ILC 250 costs
- Develop Parameters for 380 GeV ILC
  - Rough Estimate costs and AC power
- Cost Estimates are FIRST PASS ONLY, NEED TO BE STUDIED MORE
- Friendly

Path #1 to Higher Luminosity

$$\mathrm{Lum} := N^2 \cdot f \cdot \frac{HD}{4 \cdot \pi \cdot \sigma x \cdot \sigma y} \qquad f := nb \cdot rep \qquad Pb := N \cdot e \cdot f \cdot E$$

- Keep beam parameters like N and σx, σy, βx, βy same to preserve advantages of ILC, example final spot size is 7.6 nm, and background same
- Path chosen here
  - Increase rep rate 3X (from 5 to 15 Hz)
  - Increase nb, number of bunches x2
  - Keep same bunch spacing to increase duty factor, and increase RF pulse length
    - Longer RF pulse length increases duty factor, to keep peak RF power same
    - Longer RF pulse length raises unit cost of klystron and modulator
    - Longer RF pulse raises total cost of refrigeration (more dynamic heat load)
- Increase Q X2
  - Brings down refrigeration cost
  - Further increase of Q to $3X10^{10}$ will bring down cost by another 0.15 B
- Answer: ILC250 6X lumi cost is 1.34 B above 5.5 B
  - total 6.84 B from start
- Compared to FCC 10.5 B total
- With Lower AC power
  - 267 MW for ILC-6X lumi vs. 300 MW for FCC

Compare ILC 250 GeV and 6X LUM parameters

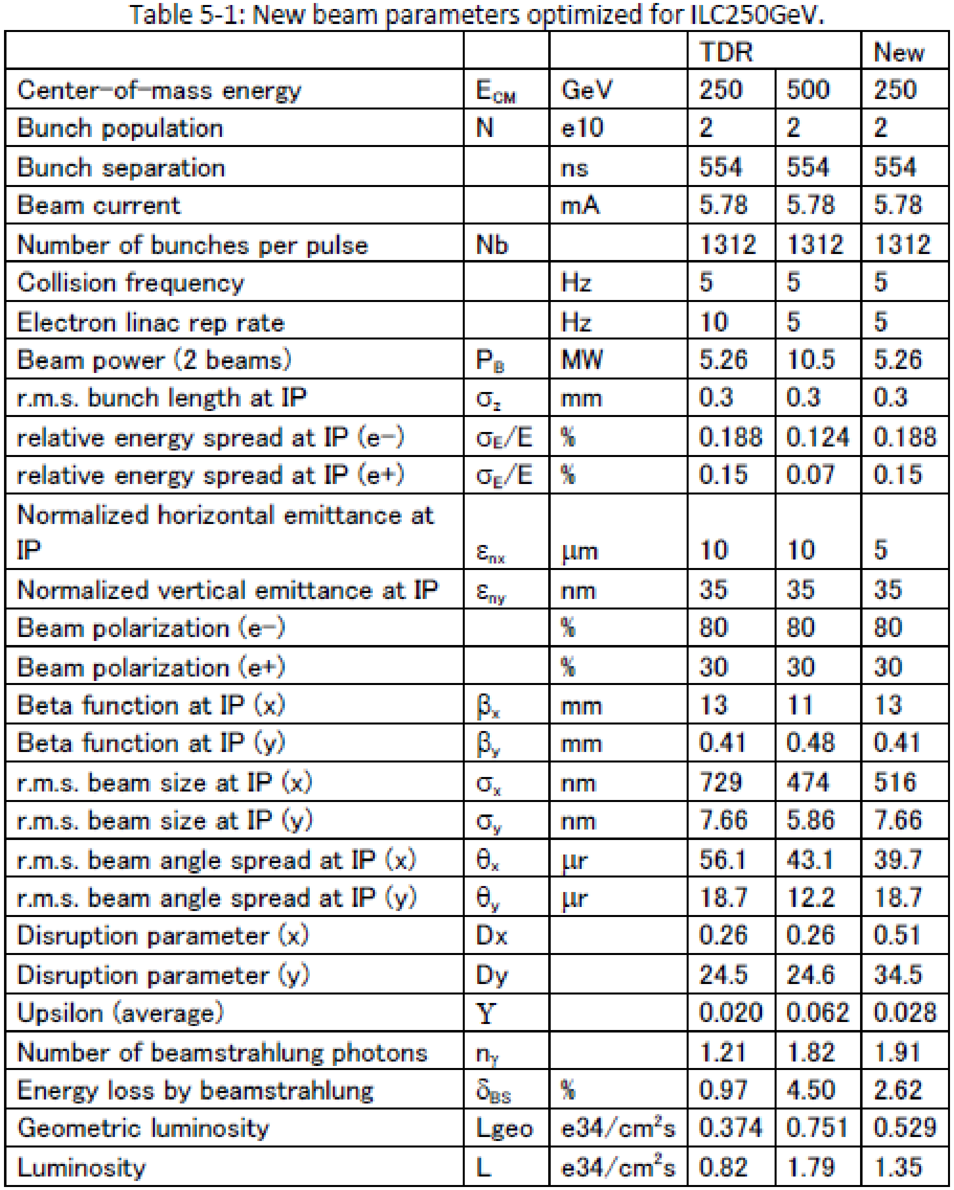


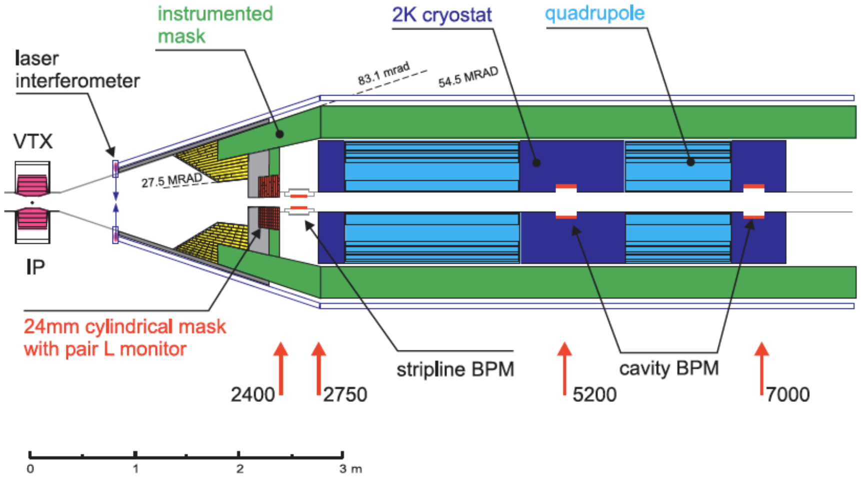
Table 5-1: New beam parameters optimized for ILC250GeV.

			TDR		New	6x Lum
Center-of-mass energy	E_{CM}	GeV	250	500	250	
Bunch population	N	e10	2	2	2	same
Bunch separation		ns	554	554	554	same
Beam current		mA	5.78	5.78	5.78	Same peak
Number of bunches per pulse	Nb		1312	1312	1312	2624
Collision frequency		Hz	5	5	5	15
Electron linac rep rate		Hz	10	5	5	15
Beam power (2 beams)	P_B	MW	5.26	10.5	5.26	31.5 MW
r.m.s. bunch length at IP	σ_z	mm	0.3	0.3	0.3	same
relative energy spread at IP (e−)	σ_E/E	%	0.188	0.124	0.188	
relative energy spread at IP (e+)	σ_E/E	%	0.15	0.07	0.15	
Normalized horizontal emittance at IP	ε_{nx}	μm	10	10	5	same
Normalized vertical emittance at IP	ε_{ny}	nm	35	35	35	same
Beam polarization (e−)		%	80	80	80	
Beam polarization (e+)		%	30	30	30	
Beta function at IP (x)	β_x	mm	13	11	13	same
Beta function at IP (y)	β_y	mm	0.41	0.48	0.41	same
r.m.s. beam size at IP (x)	σ_x	nm	729	474	516	same
r.m.s. beam size at IP (y)	σ_y	nm	7.66	5.86	7.66	same
r.m.s. beam angle spread at IP (x)	θ_x	μr	56.1	43.1	39.7	
r.m.s. beam angle spread at IP (y)	θ_y	μr	18.7	12.2	18.7	
Disruption parameter (x)	Dx		0.26	0.26	0.51	same
Disruption parameter (y)	Dy		24.5	24.6	34.5	same
Upsilon (average)	Υ		0.020	0.062	0.028	
Number of beamstrahlung photons	n_γ		1.21	1.82	1.91	same
Energy loss by beamstrahlung	δ_{BS}	%	0.97	4.50	2.62	
Geometric luminosity	Lgeo	e34/cm²s	0.374	0.751	0.529	
Luminosity	L	e34/cm²s	0.82	1.79	1.35	7.7

Etude d’un retour aux collision frontales (comme LEP et SLC), A. Seryi

Head-on scheme

- TESLA 500 GeV CM head-on scheme relied on 20m magneto-electrostatic separator with 50kV/cm to separate head-on colliding beams [1]
  - TESLA 800 GeV CM upgrade required 80 kV/cm - beyond what was achieved at LEP
- Problem found in 2002: SR losses on septum blade of head-on scheme [2] => eventual elimination of head-on scheme



- For ILC250 head-on scheme may again become feasible
- Head-on may also be more suitable for reduction of L^* from 3.5-4m in ILC to about 2m
- One of consequences – unclear path to energy upgrade

Refs: [1] TESLA TDR, Part II, Chapter 7, 2001
[2] A. Seryi, Beamstrahlung Photon Load on the TESLA Extraction Septum Blade, LCC-104, 2002