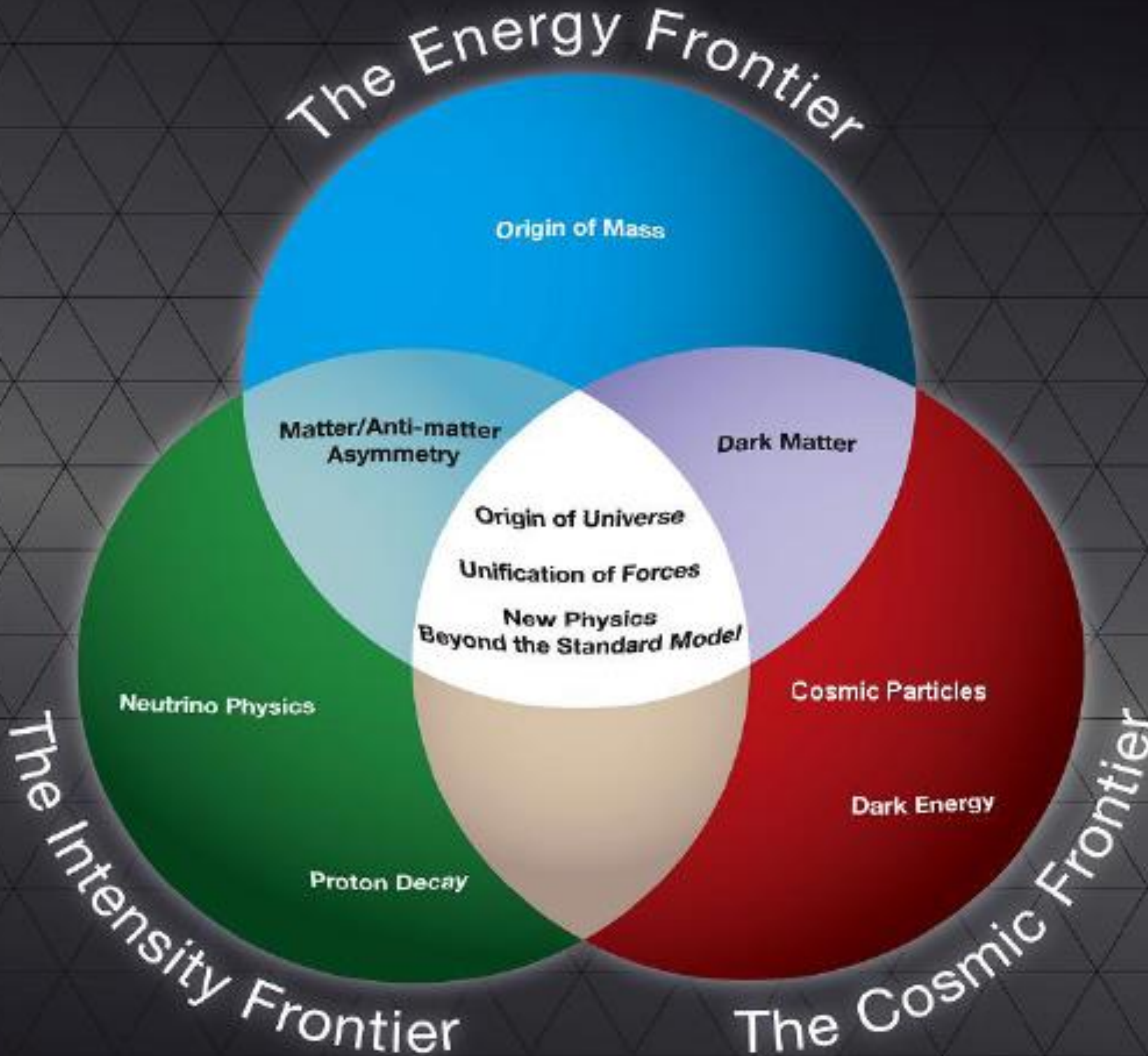
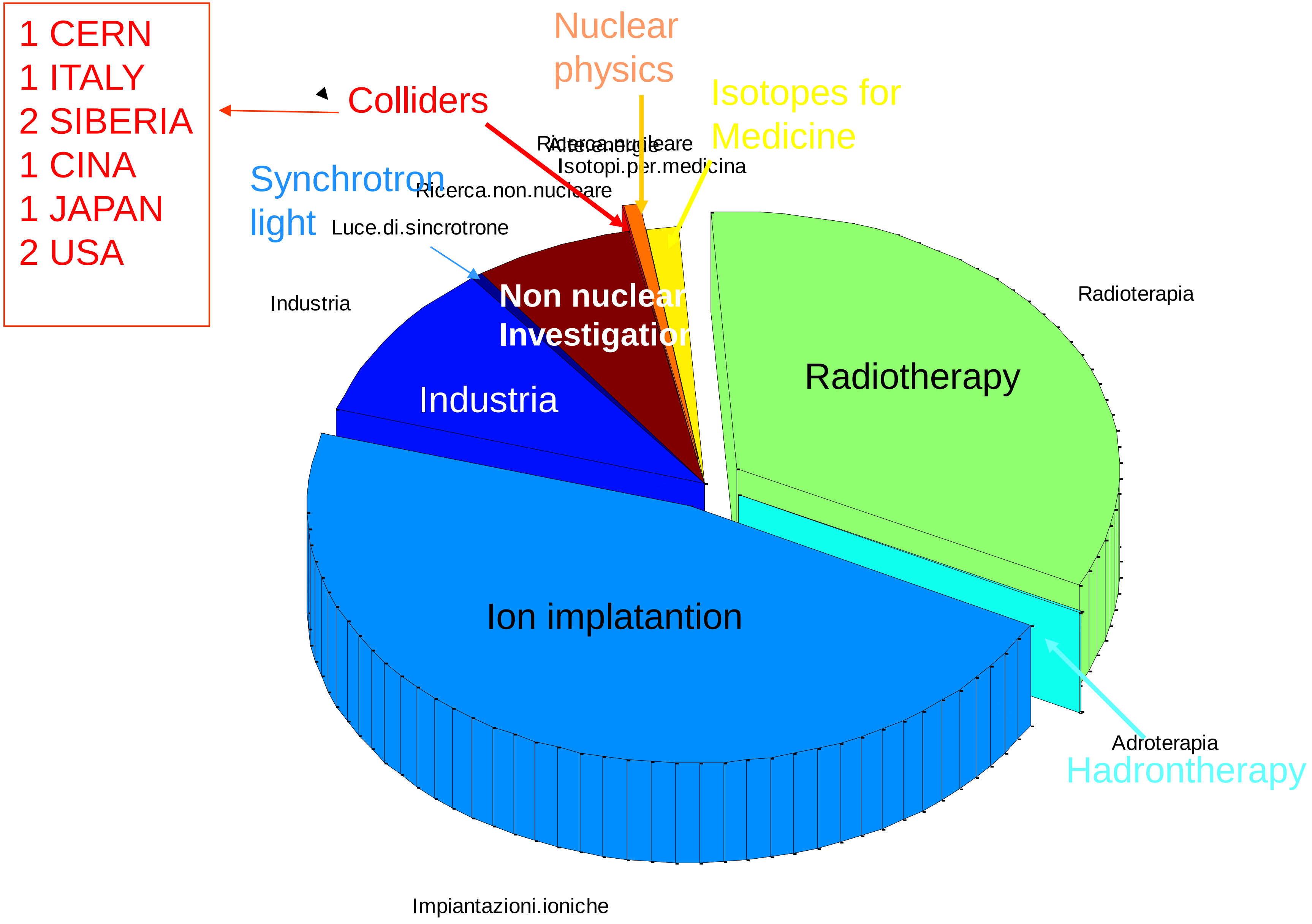
Budoucí projekty

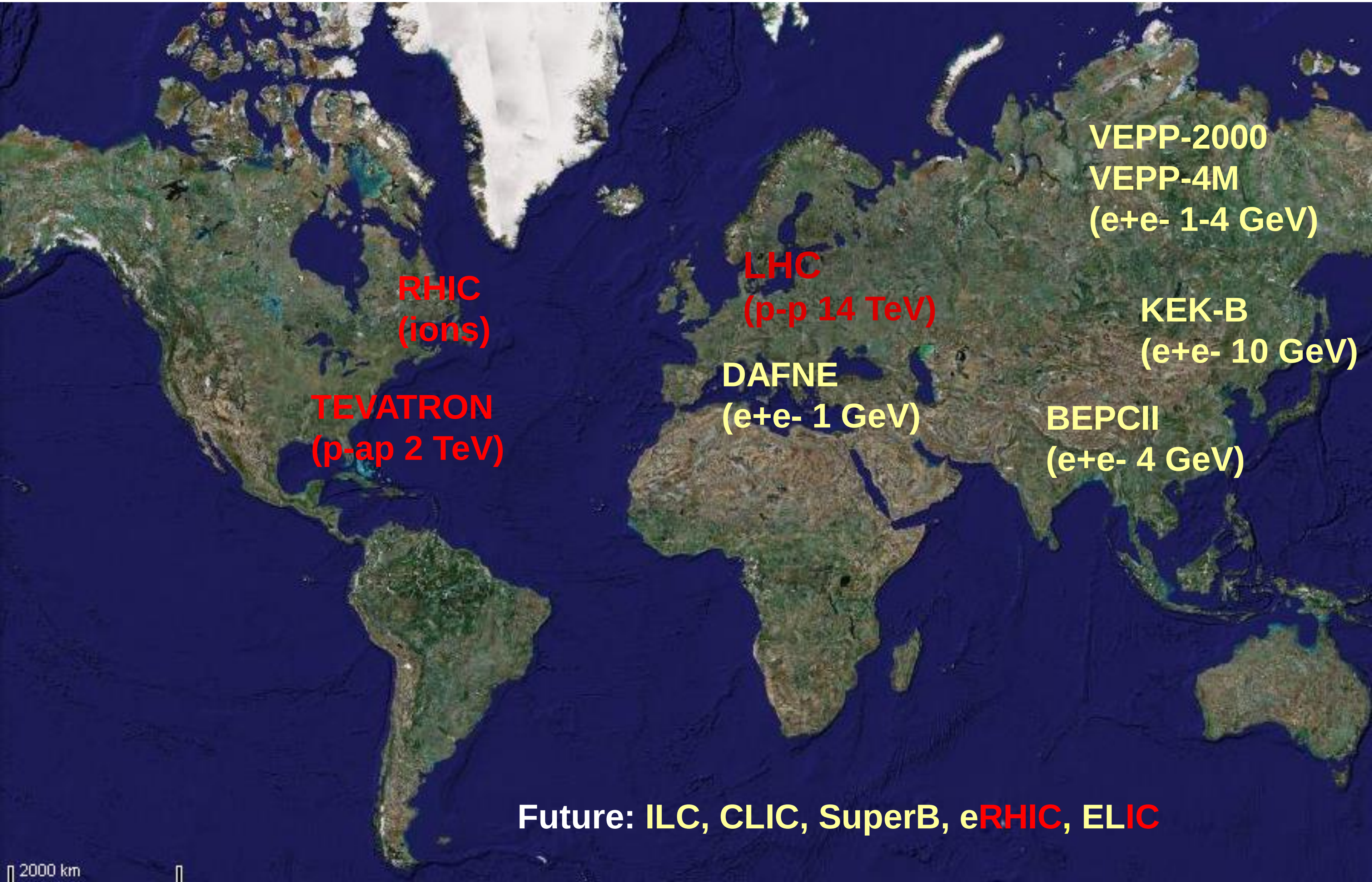
- Modernizace
  - SLHC
  - SuperKEKB
- Nové urychlovače
  - ILC
  - CLIC
  - Mionový urychlovač
  - SuperB
  - LHeC


The Energy Frontier
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Neutrino Physics
Cosmic Particles
Dark Energy
Proton Decay
The Intensity Frontier
The Cosmic Frontier

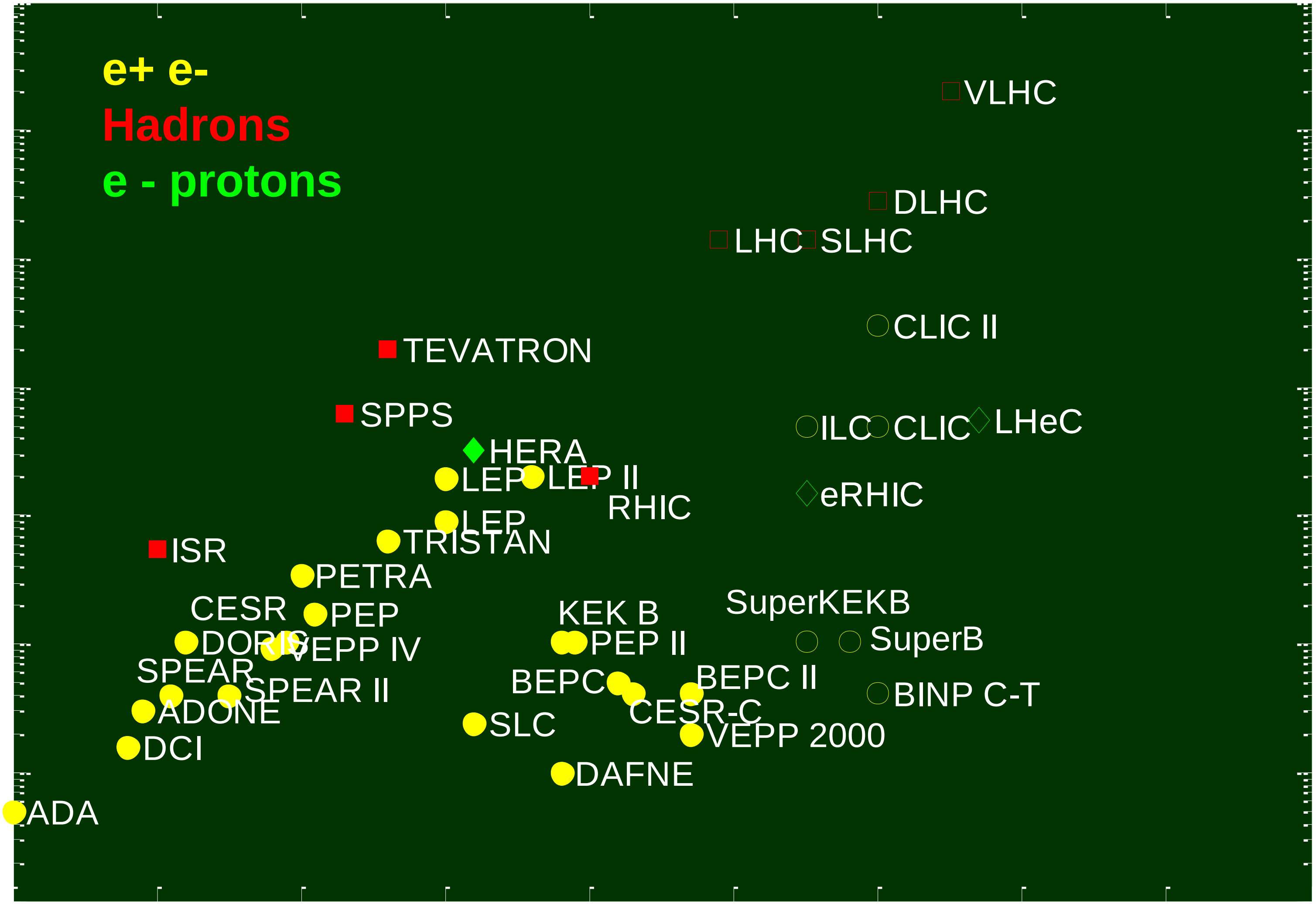

1 CERN
1 ITALY
2 SIBERIA
1 CINA
1 JAPAN
2 USA
Colliders
Nuclear physics
Isotopes for Medicine
Synchrotron light
Ricerca.nucleare
Alte.energie
Isotopi.per.medicina
Ricerca.non.nucleare
Luce.di.sincrotrone
Industria
Non nuclear Investigation
Industria
Radiotherapy
Radioterapia
Ion implatantion
Adroterapia
Hadrontherapy
Impiantazioni.ioniche

COLLIDERS - 2009

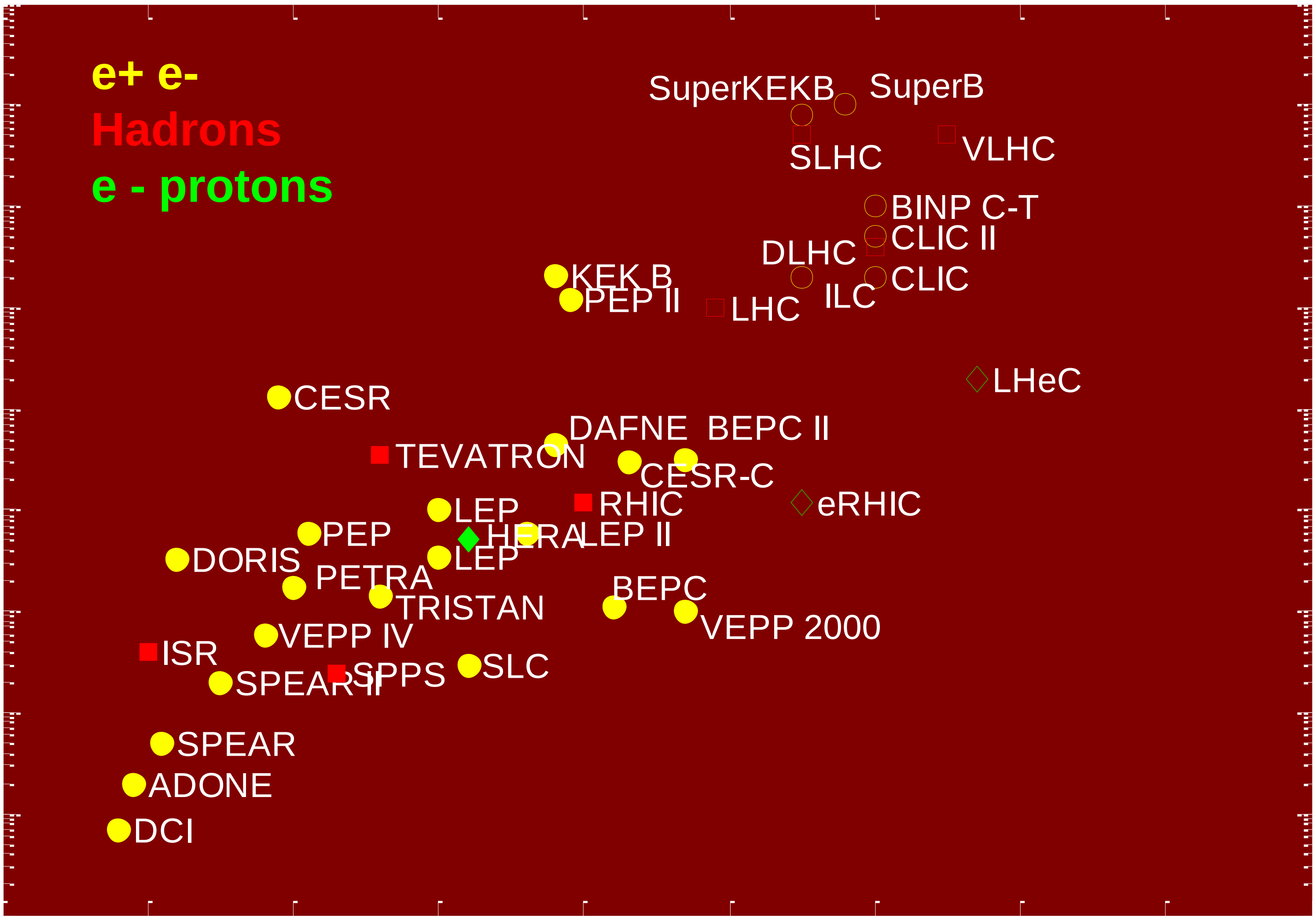
Leptons
Hadrons



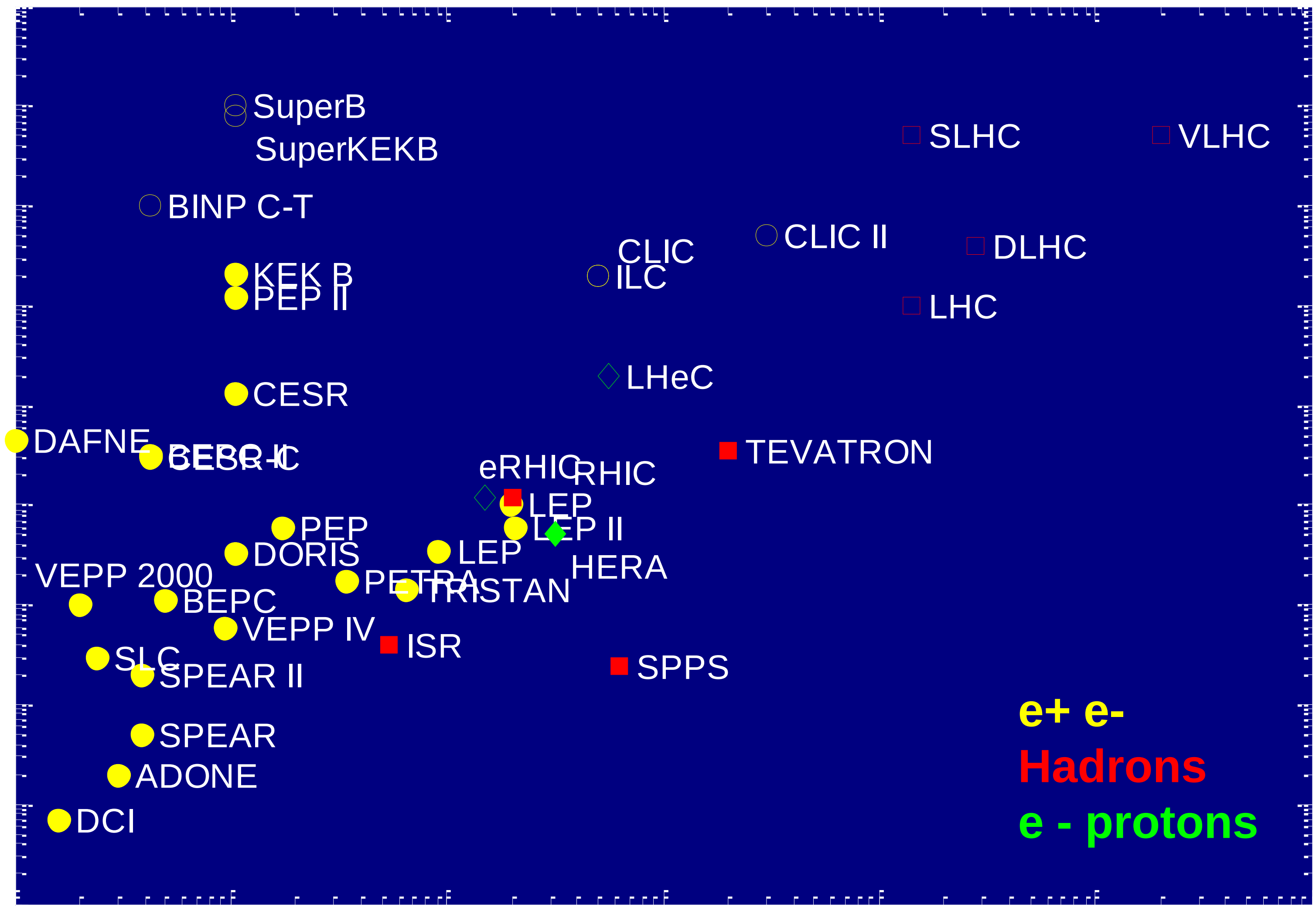
Collider energies



luminosities

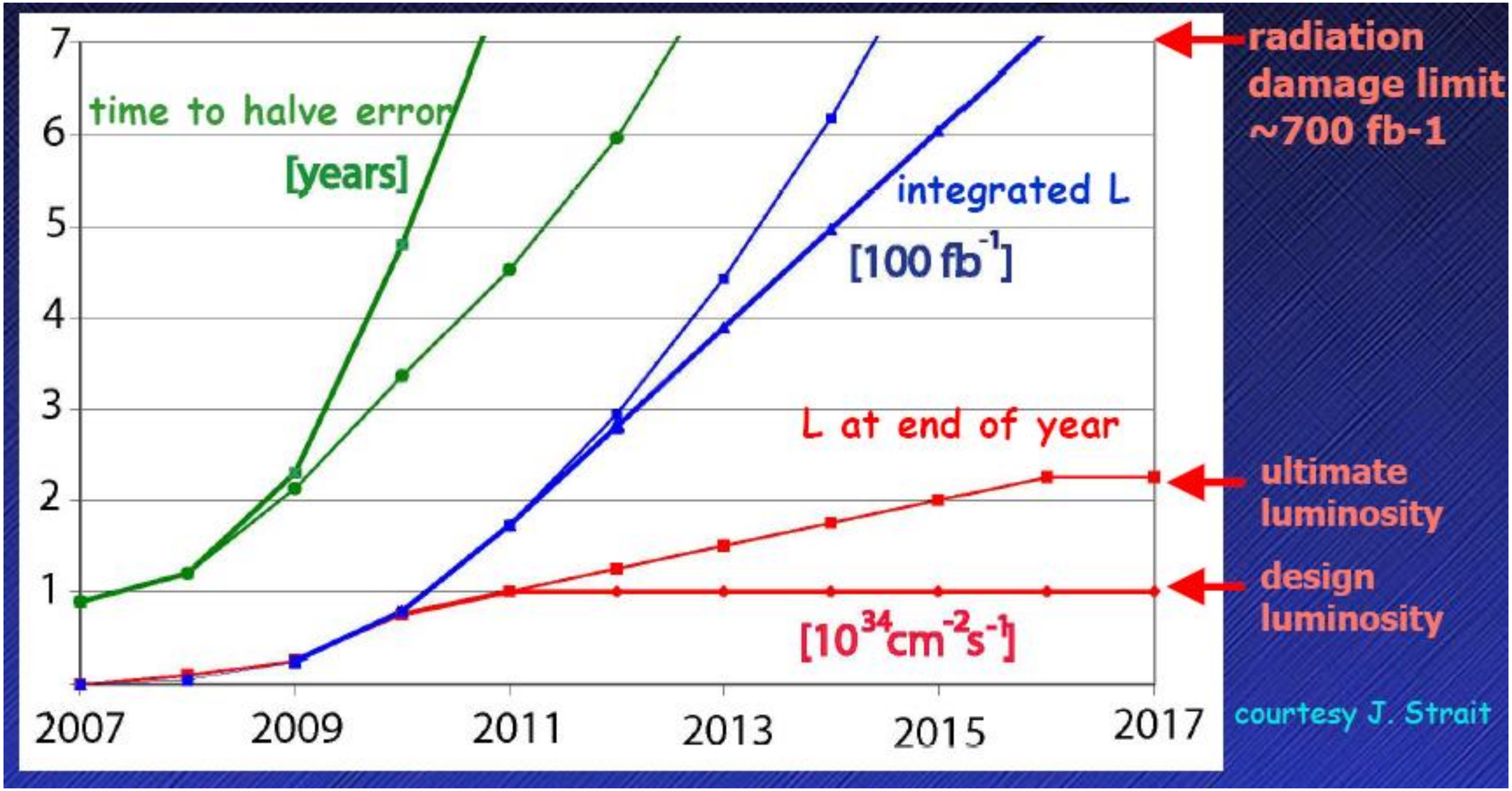


Collider luminosities versus energies

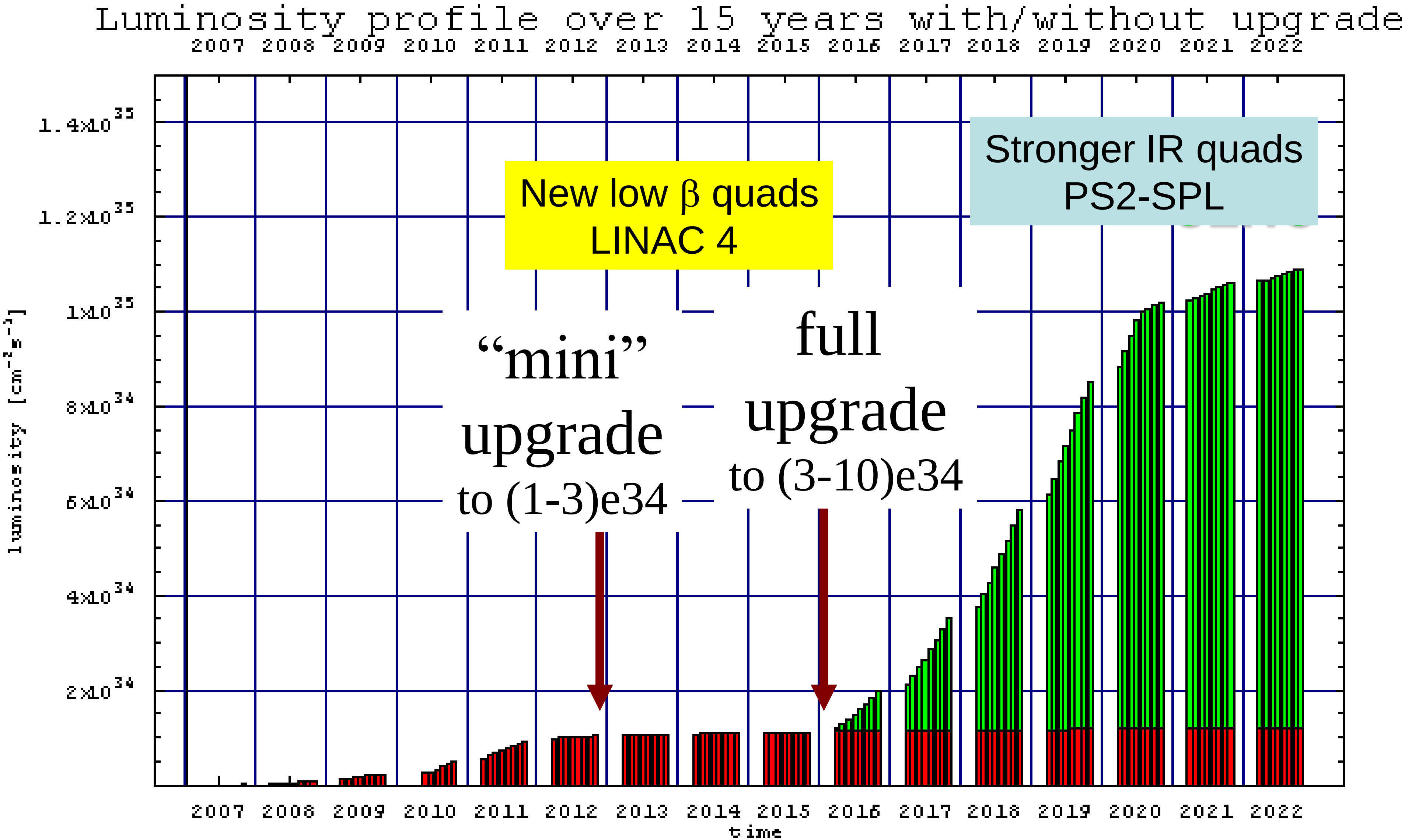


SLHC

- Uvažovaná modernizace LHC pro vyšší luminositu a energii



LHC/LHC *L*-Upgrade Schedule



Preliminary planning studies, J-P Koutchouk

Expected factors for the LHC luminosity upgrade

The peak LHC luminosity can be multiplied by:

- **factor 2.3** from nominal to ultimate beam intensity (0.58 $\Rightarrow$ 0.86 A)
- **factor 2** from new low-beta insertions with $\beta^*=0.25$ m

$T_{turnaround}$~10 h (HERA experience) $\Rightarrow$ $\int Ldt$ ~ 3 x nominal ~ 200/(fb*year)

Major hardware upgrades (LHC main ring and injectors) are needed to exceed ultimate beam intensity. The peak luminosity can be increased by:

- **factor 2** if we can double the number of bunches (maybe impossible due to electron cloud effects) or increase bunch intensity and bunch length

$T_{turnaround}$~10 h (HERA experience) $\Rightarrow$ $\int Ldt$ ~ 6 x nominal ~ 400/(fb*year)

A new Super-SPS injecting into the LHC at 1 TeV would yield:

- **factor ~2** in peak luminosity (2 x bunch intensity and 2 x emittance)
- **factor 1.4** in integrated luminosity from shorter $T_{turnaround}$~5 h

thus ensuring $L \sim 10^{35}$ cm^{-2} s^{-1} and $\int Ldt$ ~ 9 x nominal ~ 600/(fb*year)

Constraints for the luminosity upgrade

- In their present configuration, the ATLAS and CMS detectors can accept a maximum luminosity of $3 \div 5 \times 10^{34}$ cm^{-2} s^{-1}
- An increase in luminosity may require changing the IR layout and positioning the low-ß quadrupoles closer to the IP (e.g. at 12-13 m?)
- The ultimate bunch intensity of 1.7×10^{11} p/bunch is compatible with the present LHC beam dumping system. Further increases, e.g. to 2×10^{11} p/bunch or slightly higher, could still be tolerated accepting reduced safety margins or implementing moderate upgrades. Machine protection and collimation will be challenging.
- A possibility being considered also for CNGS beams is to upgrade the proton linac from 50 to 120 ÷ 160 MeV (LINAC 4), to overcome space charge limitations at injection in the booster. Then the ultimate LHC intensity would become easy to achieve and a further 30% increase would be possible with same emittance and same LHC filling time.
- If nominal (ultimate) luminosity is reached by 2011, the radiation damage limit for IR quads (700 fb^{-1}) is reached by 2017 (2013).

Možné scénáře

- Maximální luminosita bez HW změn (fáze 0)
  - Jen 2 IP
  - Zvýšení N_b
  - Max. pole dipólu 9 T
- Pouze změny interakční oblasti (fáze 1)
- Podstatné HW změny (fáze 2)

Experimental conditions at 10^{35} cm^{-2} s^{-1} (12.5ns)

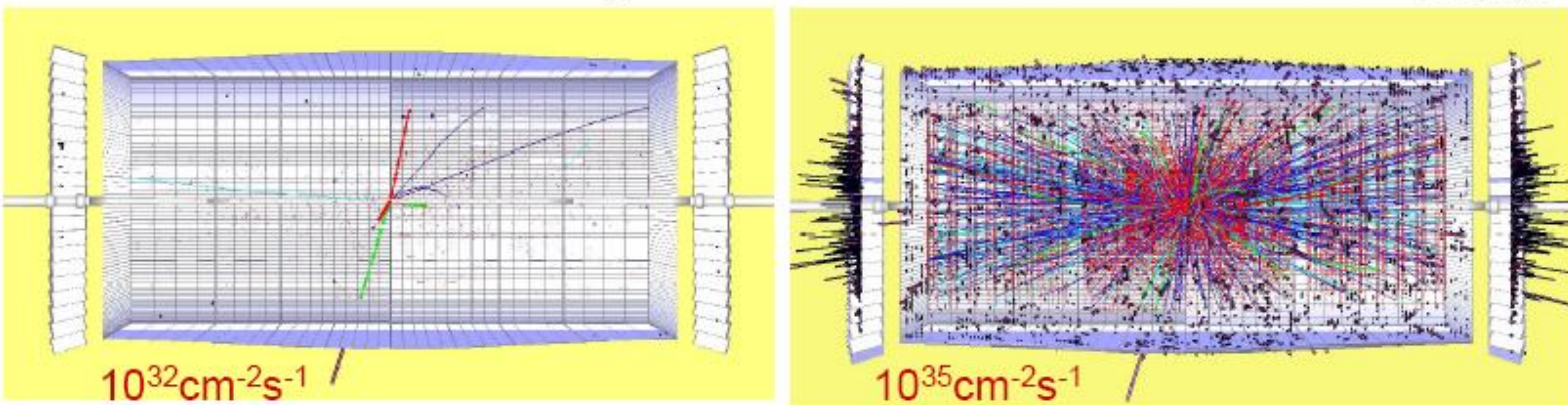
~ 100 pile-up events per bunch crossing - if 12.5 nsec bunch spacing - compared to ~ 20 for operation at $10^{34} cm^{-2} s^{-1}$ and 25 nsec (nominal LHC regime),

➡ $dn^{ch}/d\eta$/crossing ≈ 600 and ≈ 3000 tracks in tracker acceptance

$H \rightarrow ZZ \rightarrow ee\mu\mu$, m_H = 300 GeV, in CMS

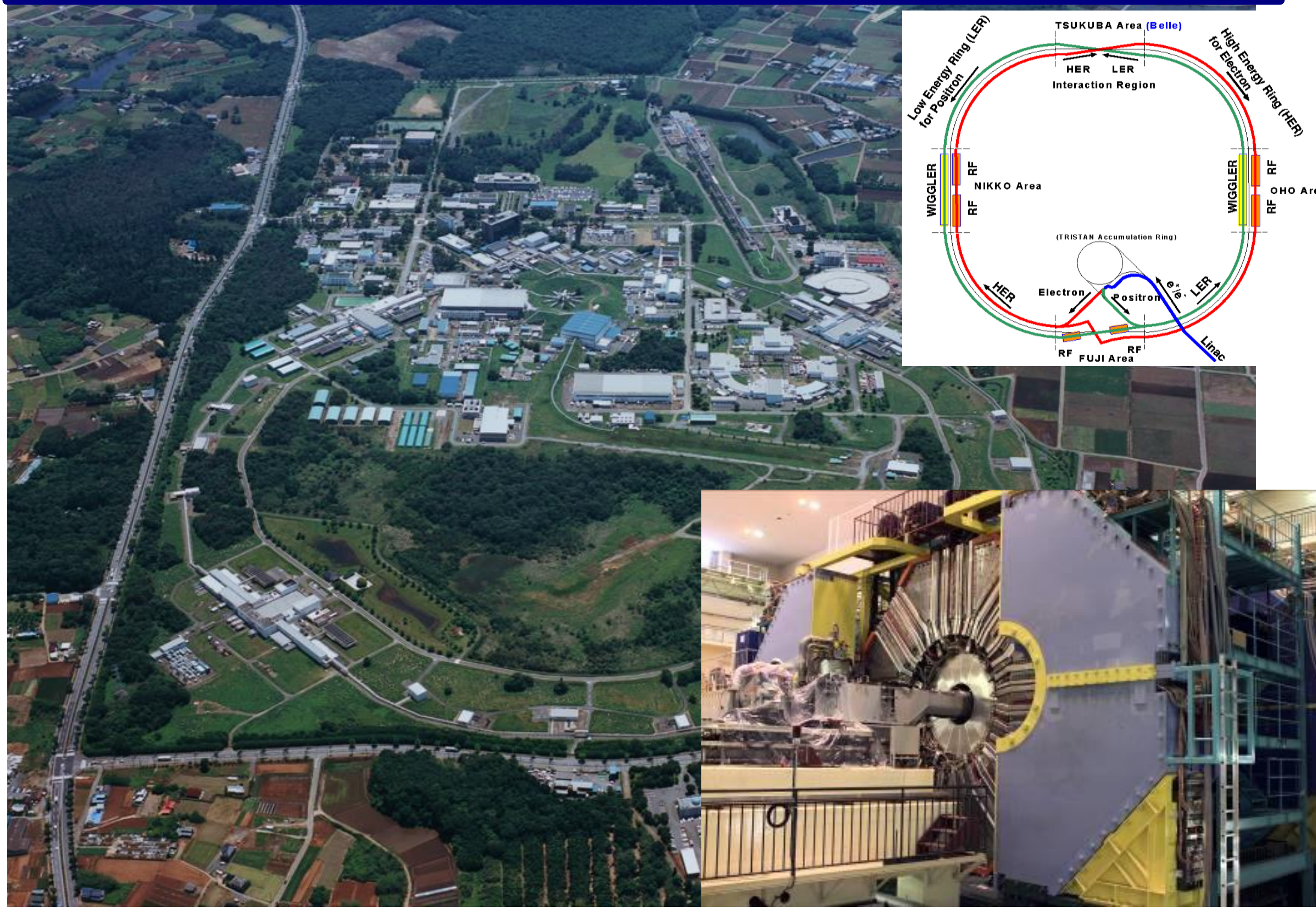
Generated tracks, p_t > 1 GeV/c cut, i.e. all soft tracks removed!

I. Osborne



➡ If same granularity and integration time as now: tracker occupancy and radiation dose in central detectors increases by factor ~10, pile-up noise in calorimeters by ~ 3 relative to 10^{34}

How to do it? Upgrade KEKB & Belle

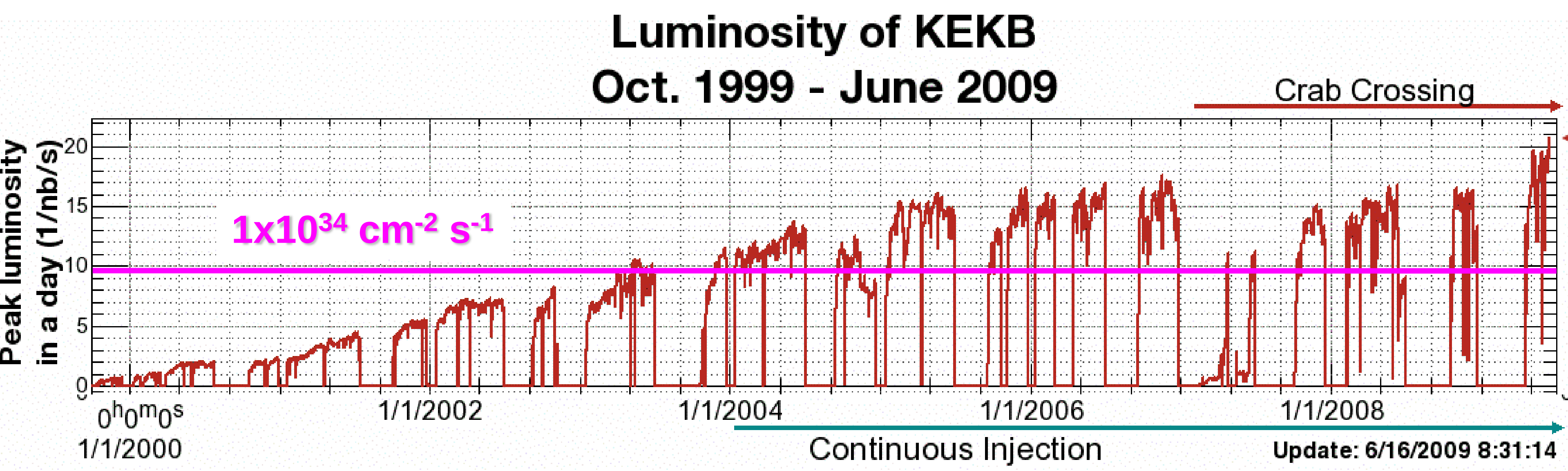


The KEKB Performance

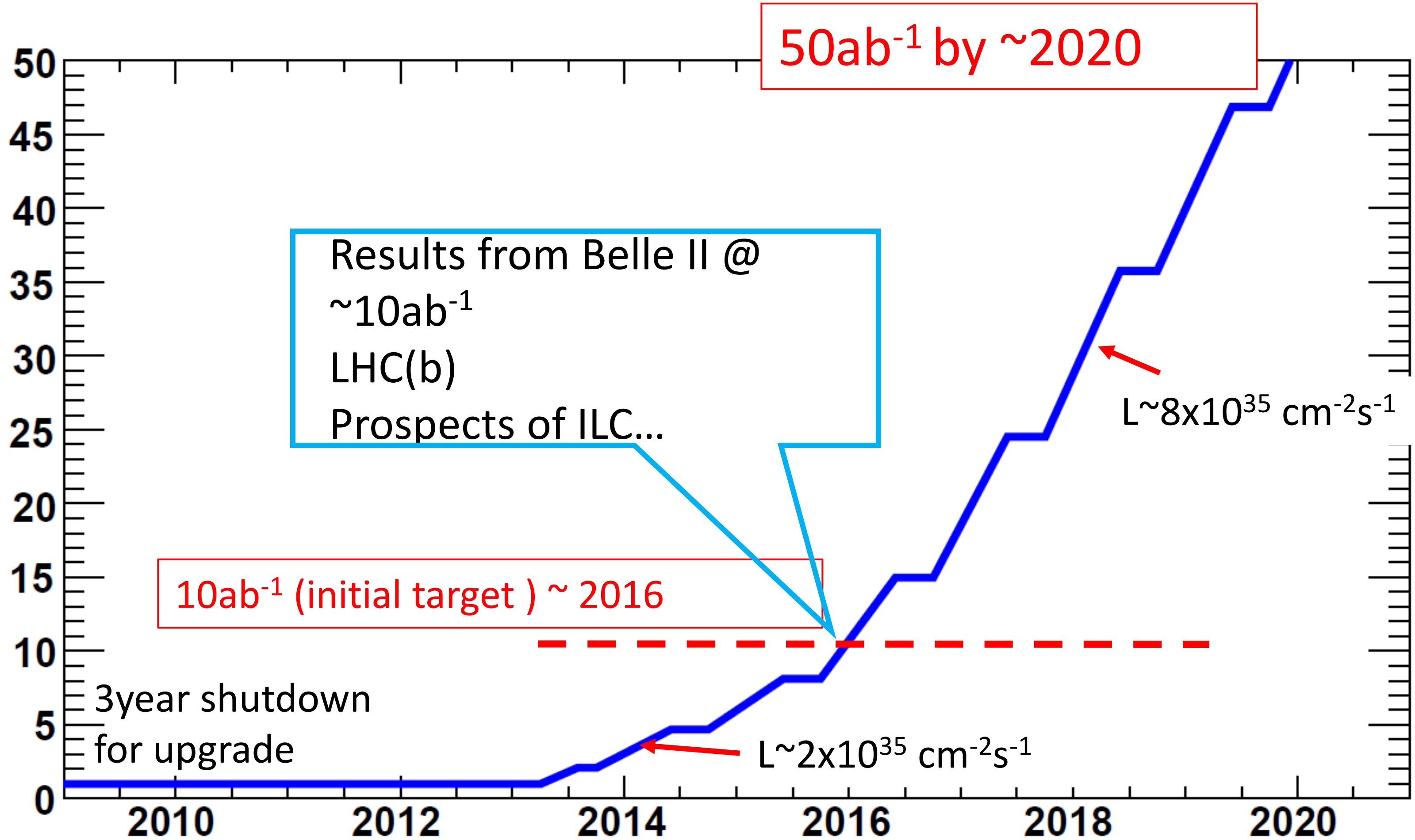
Luminosity Records:

- **Peak L = 2.1x10^{34} cm^{-2} s^{-1}** (2x the design value)
- **Daily ∫Ldt = 1.5 fb^{-1}** (2.5 x the design value)
- **Total ∫Ldt ~ 950 fb^{-1}** (as of July 2009)

70 x TeVatron
1,7 x PEPII
210 x LEP
2 x LHC
1 x ILC



Luminosity Prospects



Strategies for Increasing Luminosity

Accelerator Physics: Basic terms:

Betatron functions: $u(s) = \sqrt{\epsilon}\sqrt{\beta(s)}\cos[\psi(s) - \psi_0]$

Luminosity: $L = \frac{N}{\sigma} \quad [\mathrm{cm}^{-2}\mathrm{s}^{-1}]$

Luminosity: $L = \frac{fbN_1N_2}{4\pi\sigma_x\sigma_y}$

Strategies for Increasing Luminosity

$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

- Lorentz factor: $\gamma_{e\pm}$
- Classical electron radius: r_e
- Beam size ratio@IP: 1 ~ 2 % (flat beam)
- Beam current: $I_{e\pm}$
- Beam-beam parameter: $\xi_y^{e\pm}$
- Vertical beta function@IP: β_y^*
- Lumi. reduction factor (crossing angle)& Tune shift reduction factor (hour glass effect): 0.8 ~ 1 (short bunch)

High-Current Option → (1), (2), (3)

Nano-Beam Option → (1), (2)

(1) Smaller β_y^*

(2) Increase beam currents

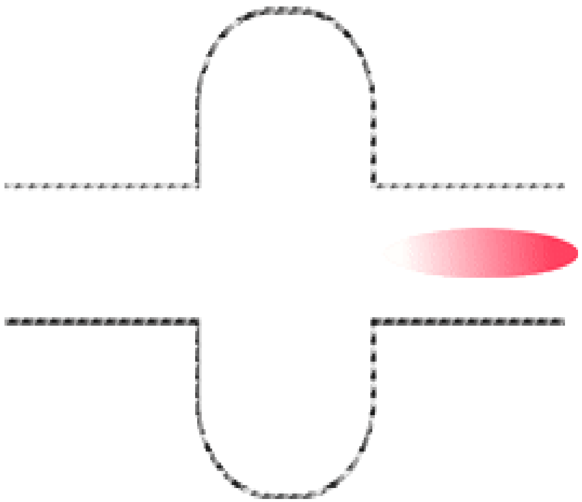
(3) Increase ξ_y

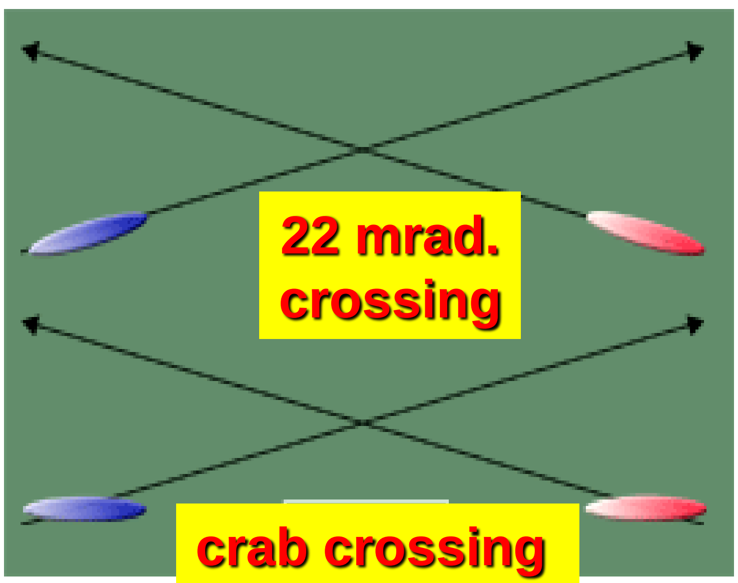
Comparison of Parameters

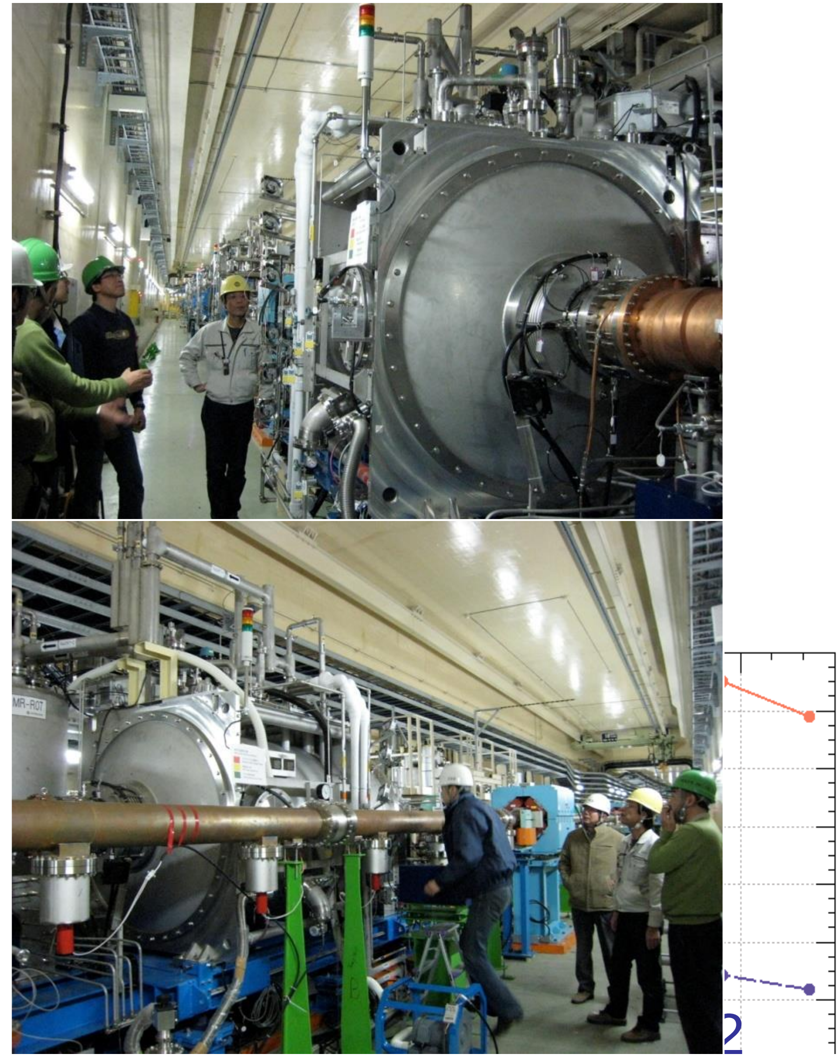
Preliminary

	KEKB Design	KEKB Achieved (): with crab	SuperKEKB Nano-Beam Scheme	LHC
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	0.24/0.37	550
ε_x (nm)	18/18	18(15)/24	2.8/2.0	0.5
σ_y(μm)	1.9	1.1	0.084/0.072	16
ξ_y	0.052	0.108/0.056 (0.101/0.096)	0.09/0.09	0.0034
σ_z (mm)	4	~ 7	5	75
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.62/1.15)	3.6/2.1	0.6
$N_{bunches}$	5000	~1500	2119	2808
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 (2.08)	80	1

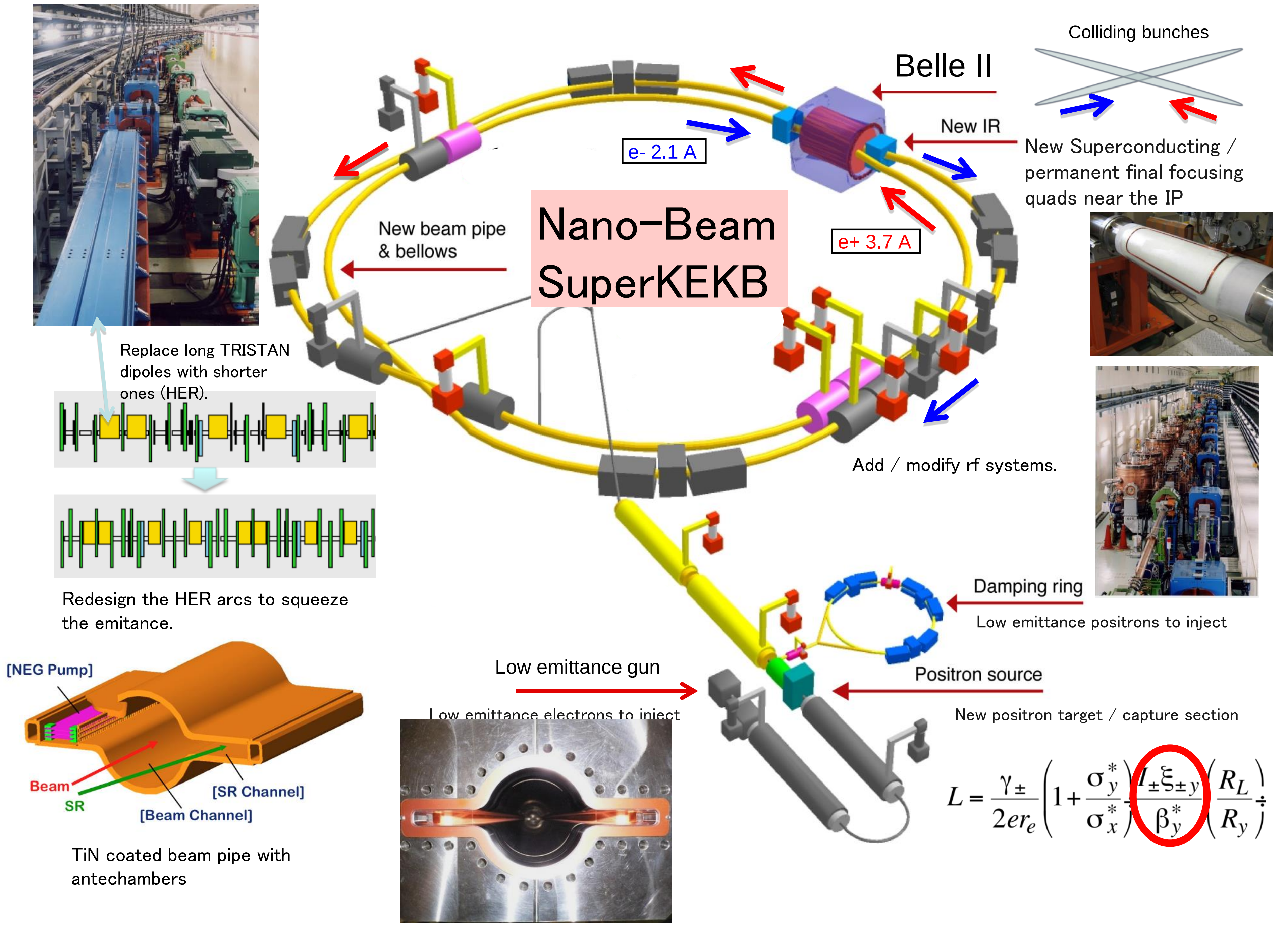
Crab Cavities







Installed in KEKB (Feb. 2007)


Colliding bunches
Belle II
New IR
New Superconducting / permanent final focusing quads near the IP
e- 2.1 A
e+ 3.7 A
Nano-Beam SuperKEKB
New beam pipe & bellows
Replace long TRISTAN dipoles with shorter ones (HER).
Redesign the HER arcs to squeeze the emitance.
Add / modify rf systems.
Damping ring
Low emittance positrons to inject
Positron source
New positron target / capture section
Low emittance gun
Low emittance electrons to inject
[NEG Pump]
Beam
SR
[SR Channel]
[Beam Channel]
TiN coated beam pipe with antechambers
$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$

Project Status

- SuperKEKB is a lab priority, part of the KEK Roadmap.
- The Japanese government has partially approved the project
- Funding in other countries on the way (D,SLO, CZ)
- We are proceeding with R&D while awaiting full approval of the construction budget request.

SuperB: Itálie

Accelerator basic concepts (1)

- B-Factories (PEP-II and KEKB) have reached high luminosity ($>10^{34}$ cm^{-2} s^{-1}) but, to increase L of ~ 2 orders of magnitude, bordeline parameters are needed such as:
  - Very high currents ➡ HOM in beam pipe
    - *overheating, instabilities, power costs*
    - *detector backgrounds increase*
  - Very short bunches ➡ RF voltage increases
    - *costs, instabilities*
  - Smaller damping times ➡ Wiggler magnets
    - *costs, instabilities*
  - Crab cavities for head-on collision
    - KEKB experience

Difficult and costly operation

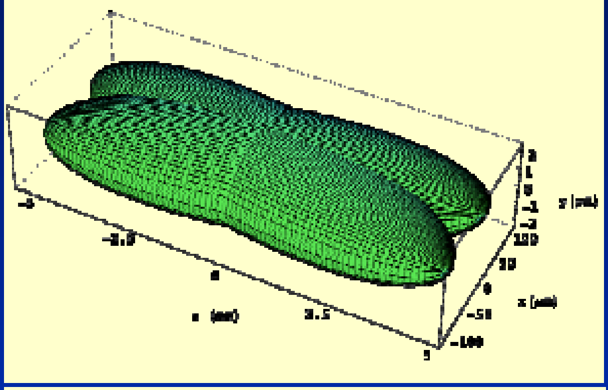
SuperB

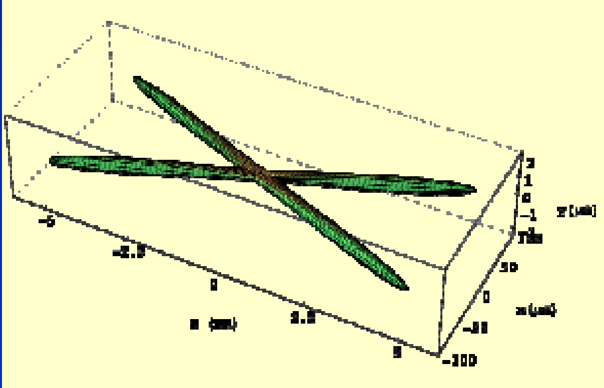
SuperB

Comparison of SuperB to Super-KEKB

Parameter	Units	*SuperB*	Super-KEKB
Energy	GeV	4x7	3.5x8
Luminosity	10^{36}/ cm^2/s	1.0 to 2.0	0.5 to 0.8
Beam currents	A	1.9x1.9	9.4x4.1
β_y*	mm	0.22	3.
β_x*	cm	3.5x2.0	20.
Crossing angle (full)	mrad	48.	30. to 0.
RF power (AC line)	MW	20 to 25	80 to 90
Tune shifts	(x/y)	0.0004/0.2	0.27/0.3

IP beam distributions for KEKB





IP beam distributions for *SuperB*

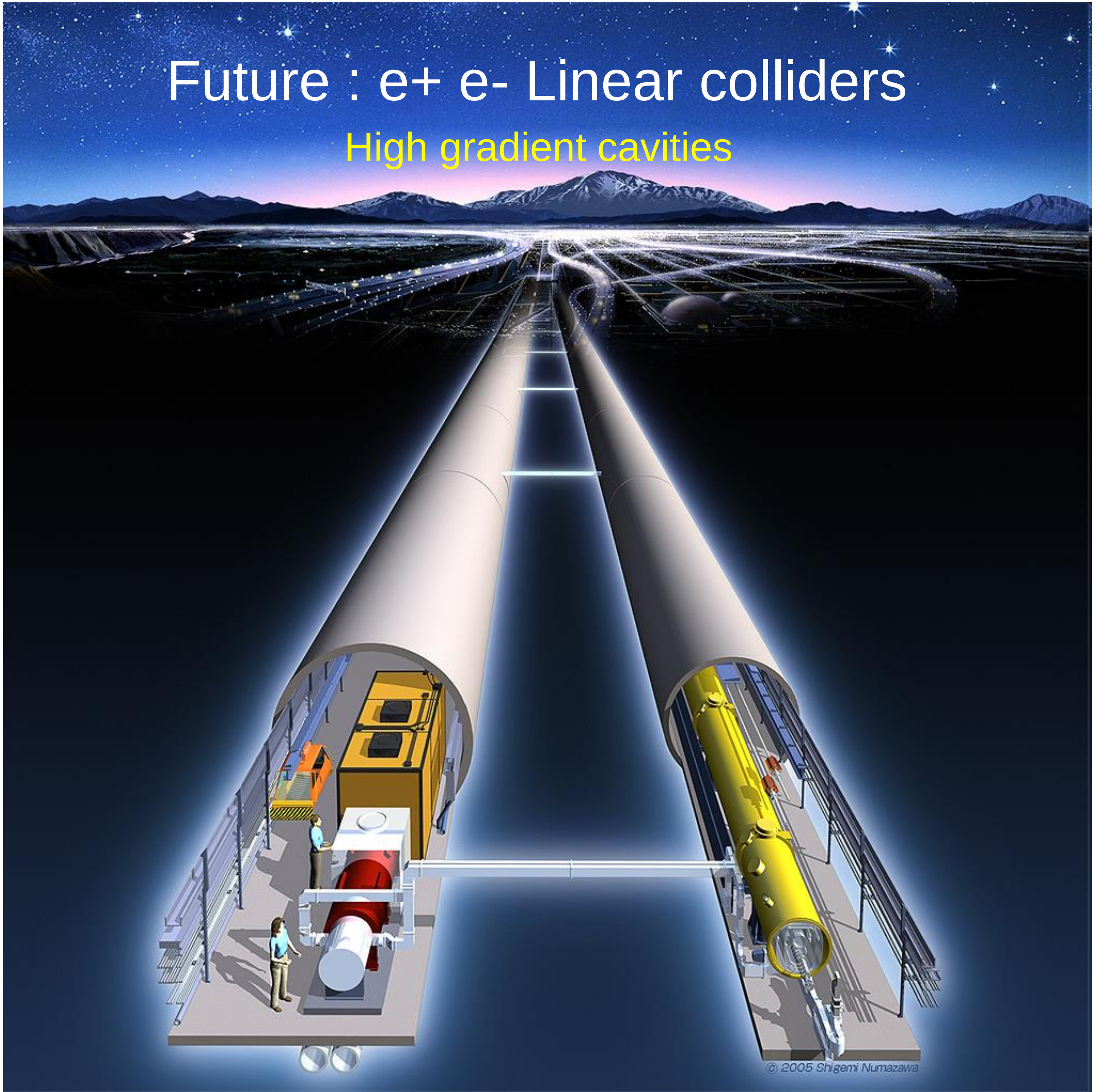
Lineární urychlovač e^+e^-

Motivace

- Další fundamentální výsledky lze dosáhnout při E_{CM}~ stovky GeV
- LHC: 7 TeV
- Podle shodného mínění nestačí jen jeden urychlovač
- Ke komplementárním měřením (EW) je třeba e^+e^-
- LEP: poslední kruhový urychlovač, po něm musí být elektrony urychlovány lineárně

Future : e+ e- Linear colliders

High gradient cavities



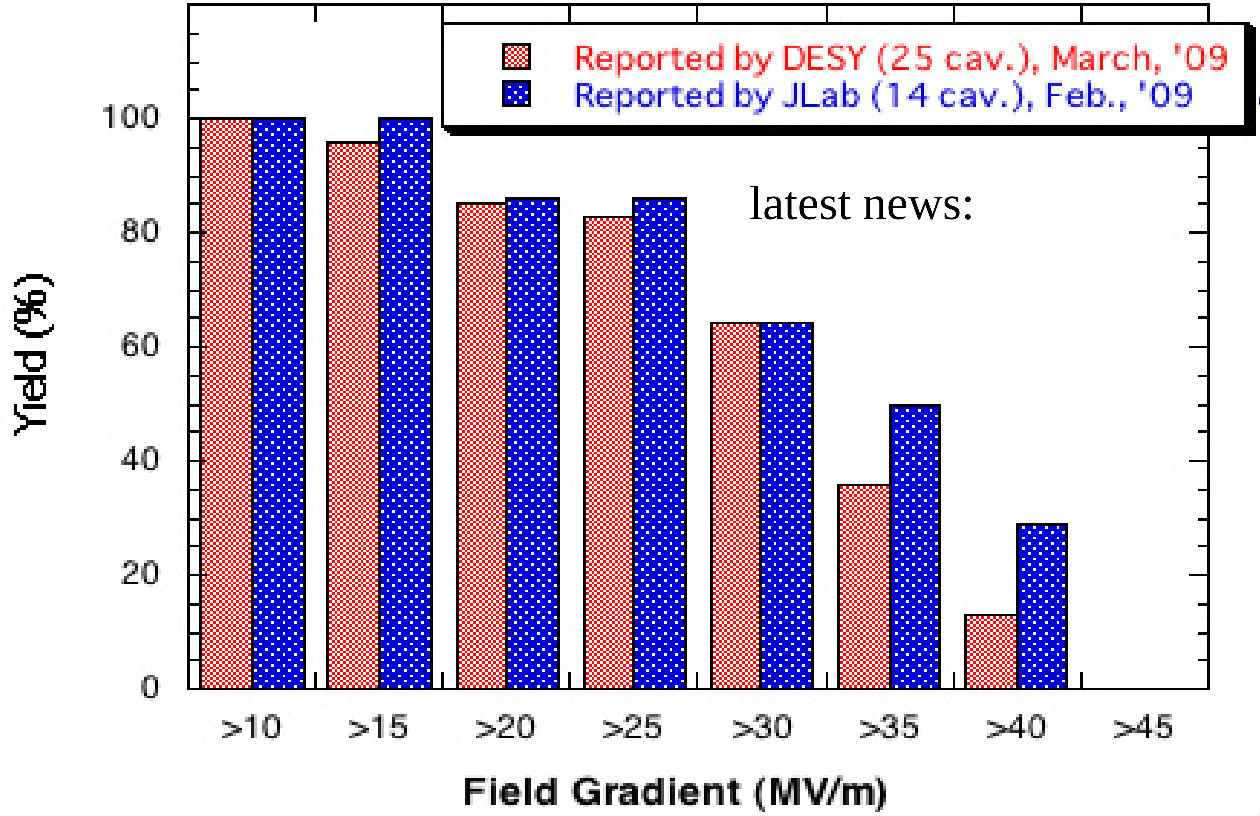
CLIC

- Dual beam acceleration technology
- R&D at CERN ~ 20 y
- Normal conducting cavities
- 12 GHz, 100 MV/m
- Maximum energy 3 TeV cm – Phase I at 0.5 TeV

ILC

- Well extablished SC rf technology (TESLA, FLASH, XFEL…)
- Decision in 2004
- Rf cavities ~ TESLA like
- 1.3 GHz, 31.5 MV/m
- Maximum energy 1 TeV cm - Phase I at 0.5 TeV
- GDE (Global Design Effort) - International

Cryomodule Gradient Progress



latest news:

LC operation :

<31.5> MV/m spec

(27 MV/m achieved at DESY/FLASH)

(29 MV/m achieved DESY test stand)

- 20 % improvement required for ILC

B.Barish

Lineární urychlovač e^+e^-

Historie: 3 podobné projekty 0,5-1 TeV

- TESLA (Hamburg)
- NLC (USA, patrně SLAC)
- JLC (Japonsko)
- CLIC (CERN) 3 TeV, výhled

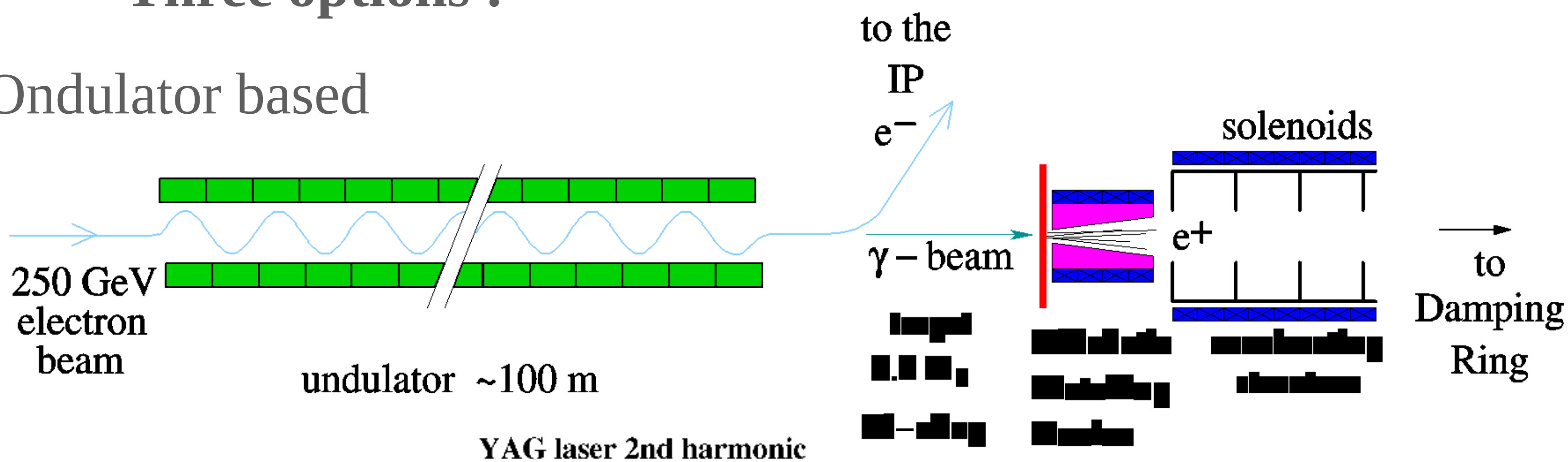
Mezinárodní dohoda o přípravě 1 urychlovače ILC

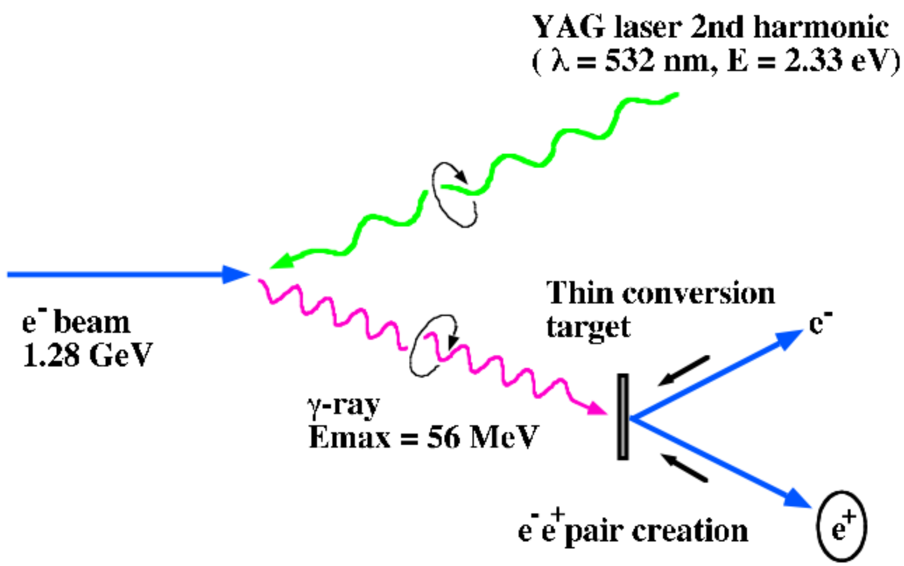
- 2004 výběr technologie (supravodivá)
- 2005 vytvořena rada Global Design Enterprise (GDE)
- 2006 cenový strop (7 M$)
- 2007: šok ve financování v USA a UK
- 200? výběr místa (DESY, USA, Japonsko, Čína,???)
- 200?-?? stavba, ...

Positron source

Three options :

1) Ondulator based





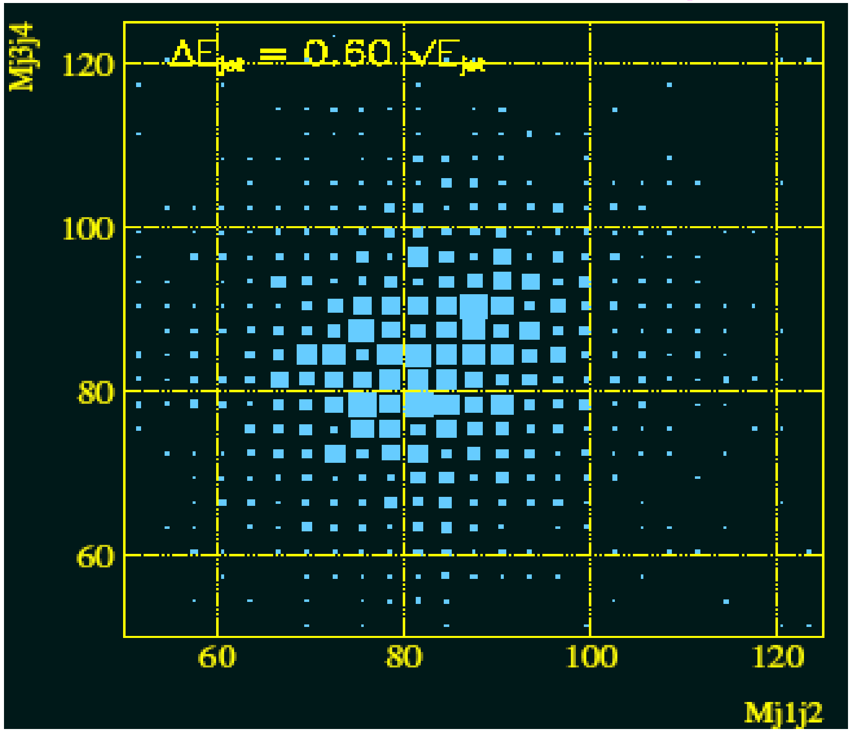
2) Compton backscattering

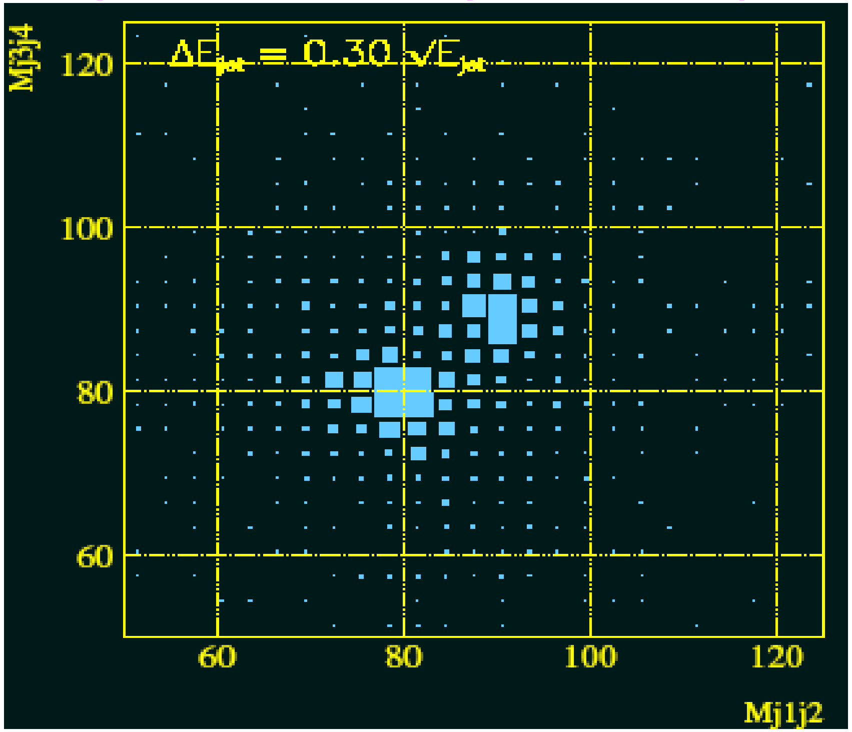
3) SLC source $e^- W$

Potřeba lepšího energetického rozlišení

- Some processes where WW and ZZ need to be separated without beam constraints (e.g. $e^+e^- \to \nu\nu WW$, $\nu\nu ZZ$)
- This requires a resolution of about $\Delta E/E = 30\%/\sqrt{E}$

WW-ZZ separation for $\Delta E/E = 60\%/\sqrt{E}$ and $\Delta E/E = 30\%/\sqrt{E}$





Nový koncept: Tok částic (Particle Flow)

How to measure the energy of a jet?

- Classical method: Calorimetry
  - typical event: 30% electromagnetic and 70% hadronic energy
  - typical resolution: $10\%/\sqrt{E}$ for Ecal and $50\%/\sqrt{E}$ for Hcal

  ➠ $\Delta E/E > 45\%/\sqrt{E}$ for jets
- The particle flow method
  - typical event: 60% charged tracks 30% electromagnetic and 10% neutral hadronic energy
  - tracking resolution negligible on this scale

  ➠ $\Delta E/E = 20\%/\sqrt{E}$ for jets possible in principle

Particle Flow

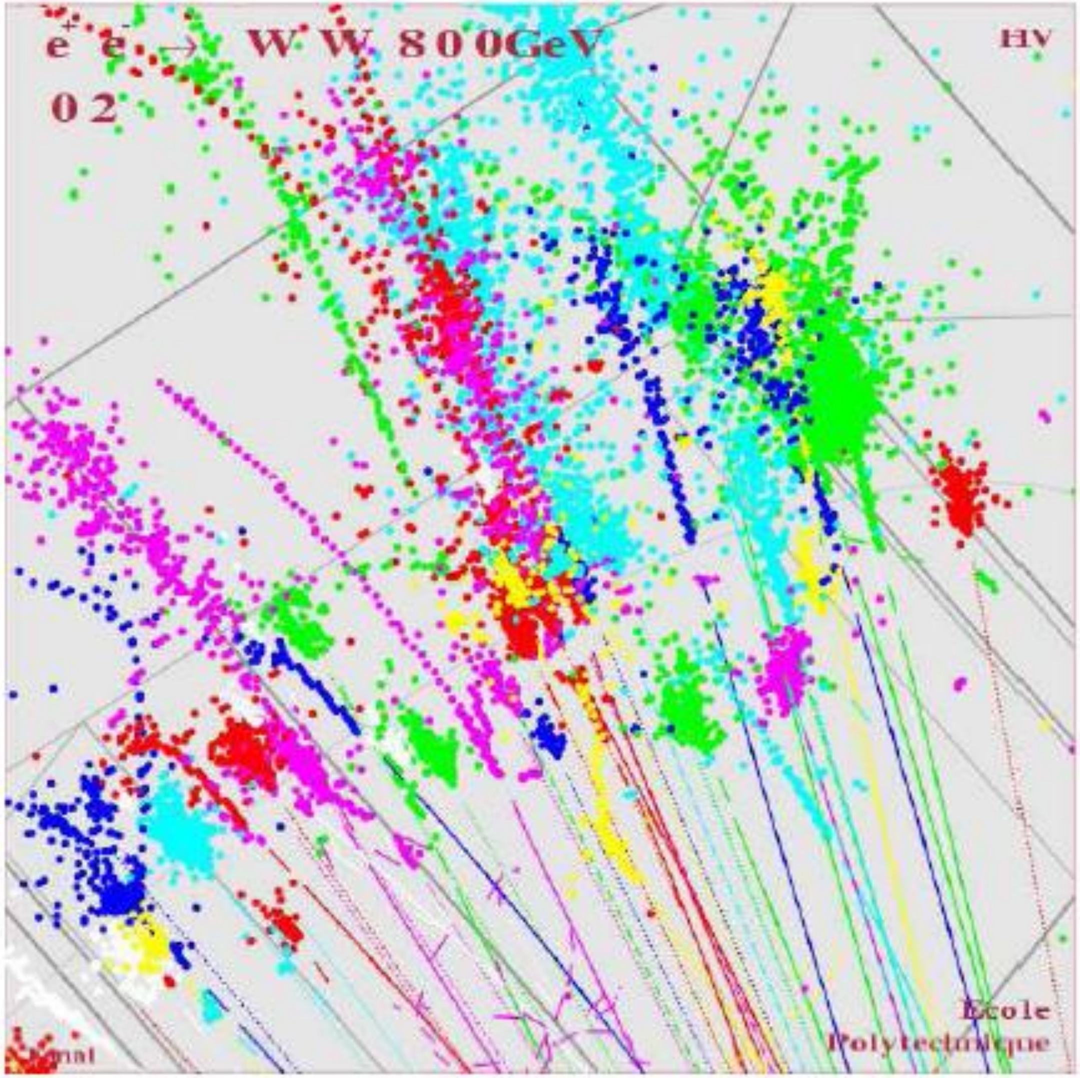
Main problem: Confusion

- At high energy jets are very narrow

➡ Tracks are very close at the calorimeter

- Need very fine granularity of calorimeter and sophisticated software to separate showers

- Energy resolution still dominated by confusion term

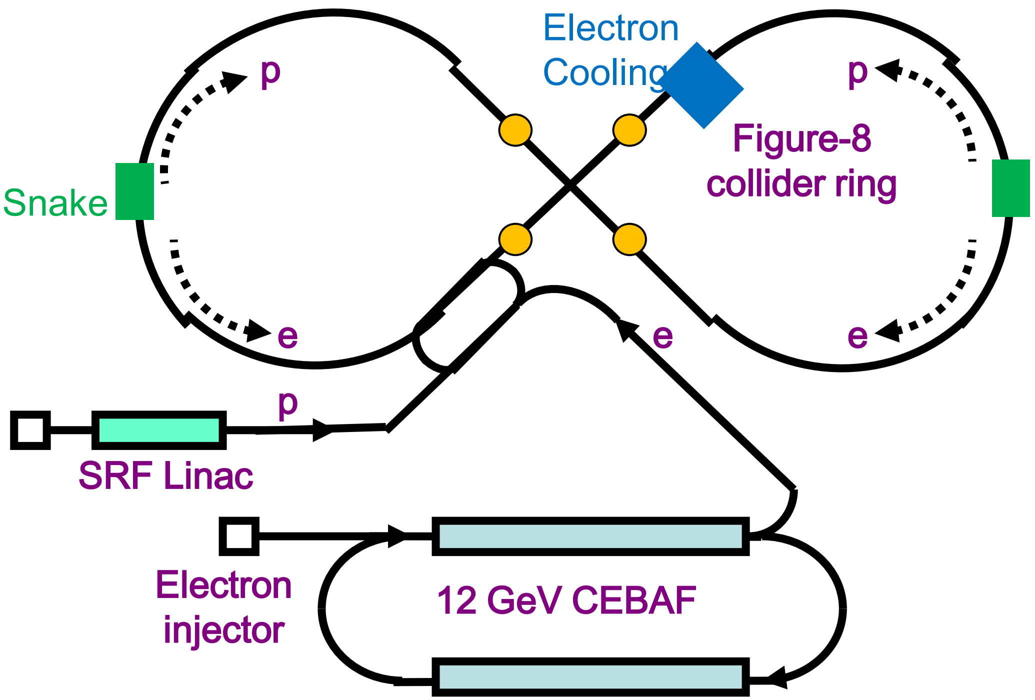


The three Detector concepts

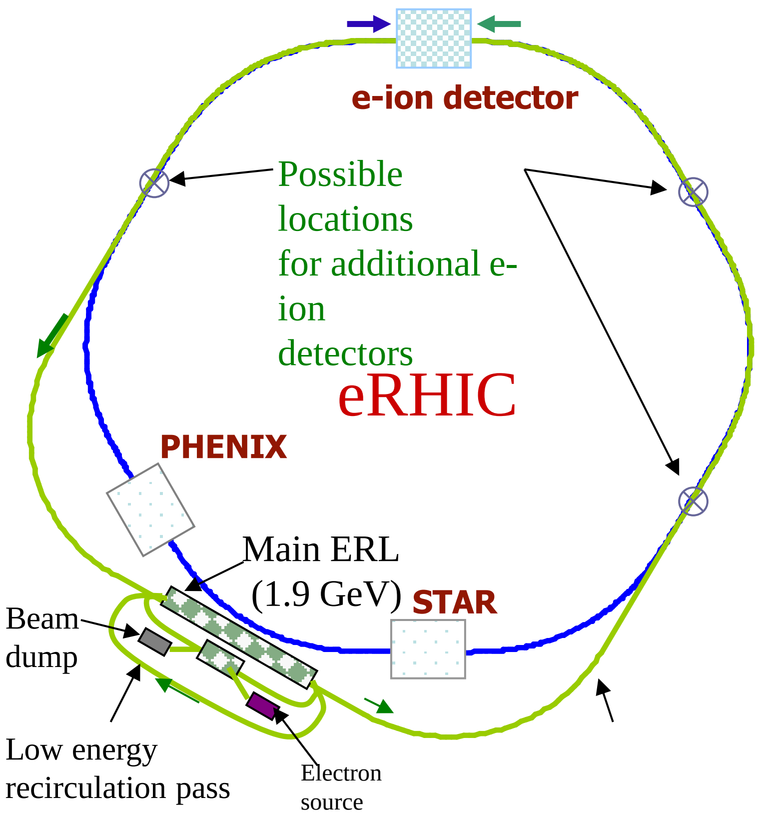
- SiD:
  - Small radius with high field ($R = 1.3\,\mathrm{m}$, $B = 5\,\mathrm{T}$, $BR^2 = 8.5\mathrm{Tm}^2$)
  - Few track measurements with high resolution (Si)
  - SiW calorimetry
  - $r_{\mathrm{min}}(\mathrm{VXD}) = 1.4\,\mathrm{cm}$
- LDC:
  - Medium R with medium field ($R = 1.7\,\mathrm{m}$, $B = 4\,\mathrm{T}$, $BR^2 = 11.6\mathrm{Tm}^2$)
  - Many track measurements with medium resolution (TPC)
  - SiW calorimetry
  - $r_{\mathrm{min}}(\mathrm{VXD}) = 1.5\,\mathrm{cm}$
- GLD:
  - Large radius with low field ($R = 2.1\,\mathrm{m}$, $B = 3\,\mathrm{T}$, $BR^2 = 13.2\mathrm{Tm}^2$)
  - Many track measurements with medium resolution (TPC)
  - Scintillator-W calorimetry
  - $r_{\mathrm{min}}(\mathrm{VXD}) = 1.7\,\mathrm{cm}$

e-ion colliders

USA Initiatives

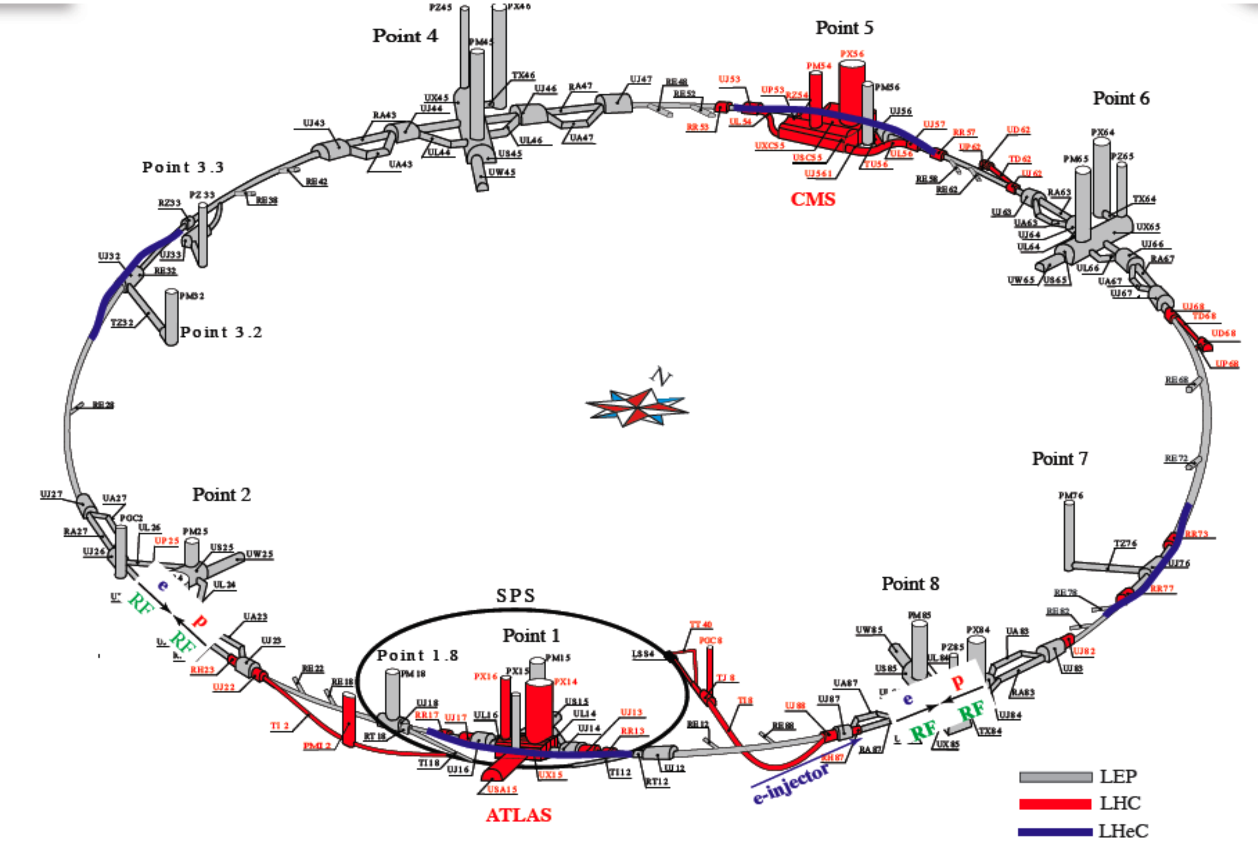


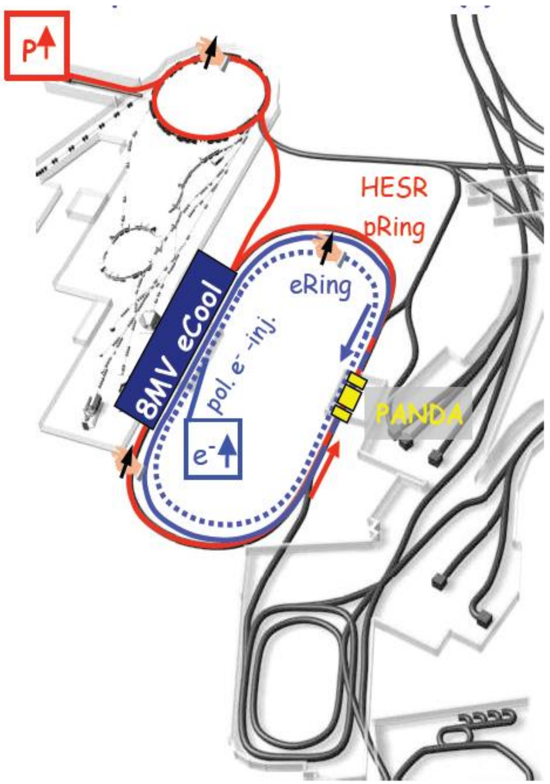
ELIC at CEBAF
5 GeV e- 5/10/30 GeV p
L 0.4/2.1/4.4 10^{33}



eRHIC at BNL
3/10 GeV e- 50/250 GeV p
L 0.5/2.6 10^{33}

European initiatives





LHeC at CERN (RING-RING or LINAC-RING)
60/140 GeV e- 7000 GeV p
L ~10^{33}

ENC at FAIR
Ecm ~ 13 GeV
L ~10^{33}

	TEST facilities TESTBENCHS	2010	2015	2020	2025	2030	
DAFNE							v
VEPP 2000							
BEPC-II							
TAU-CHARM BINP	DAFNE						
KEKB							v
SUPERKEKB	KEKB DAFNE						v
SUPERB	DAFNE						v
TEVATRON							v
LHC							v
SLHC							v
DLHC	LURP						v
LHeC							
RHIC							
eRHIC	RHIC						
eLIC	CEBAF						
ILC	ATF2-XFEL						
CLIC 0.5 GeV	CTF3						v
CLIC 3 GeV	CTF3 CLIC 0.5						v
NEUTRINO FACTORY	MICE MERIT						v
MUON COLLIDER	MICE MERIT μcool EMMA						v
PROJECT X							
LWFA LC	FACET						v

Approximate dates

RDR (CDR) TDR R&D Operation Construction

Proposed

approved