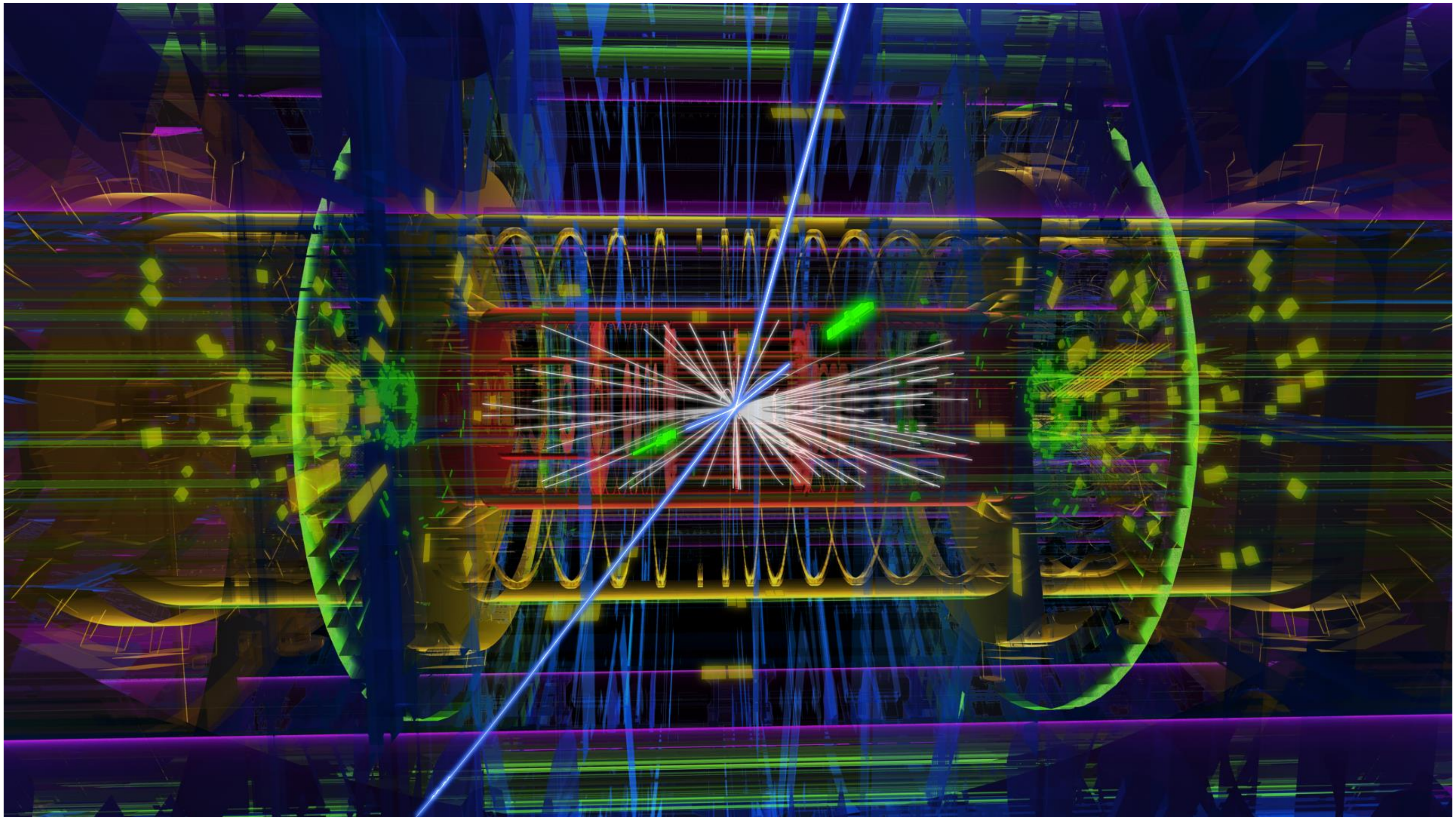
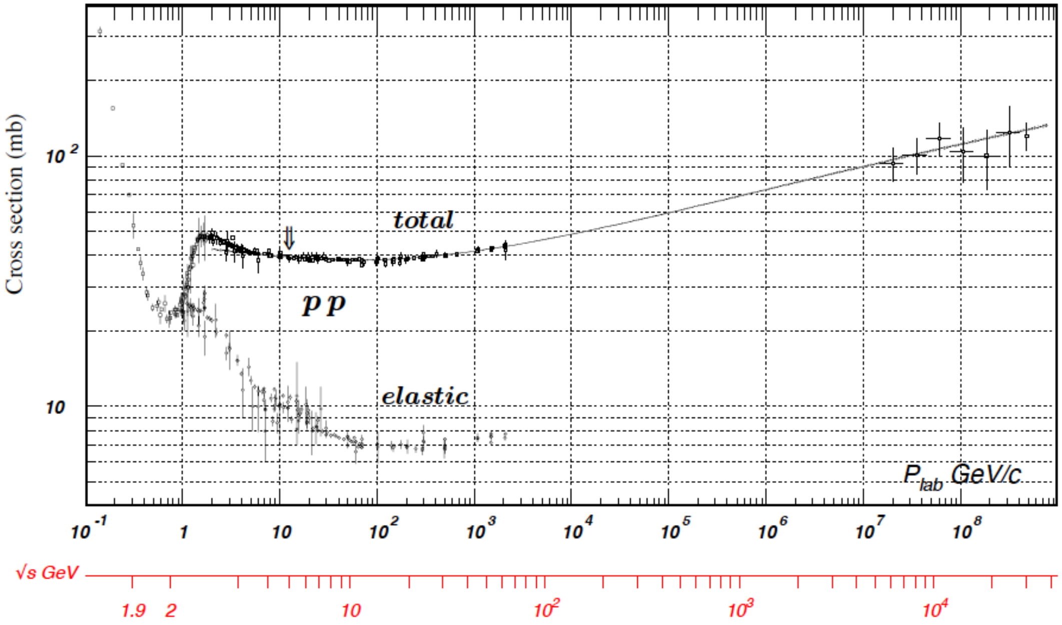
High Light of the HEP-Year



ATLAS event display: Higgs => two electrons & two muons

pp Cross Section and event rate



Activity: ***$A(t)=-dN/dt=1/\tau*N(t)$, where τ = lifetime, $A(t)$ = events per second***

Lumi ***= $7*10^{33}cm^{-2}s^{-1}$, total cross section (see fig) = Σ = $100mb=10^{-25}cm^2$***
Event Rate ***= $L*\Sigma = 7*10^{33}cm^{-2}s^{-1} * 10^{-25}cm^2 = 7*10^8s^{-1}$ per IP.***

This is automatically the proton loss rate due to lumi.

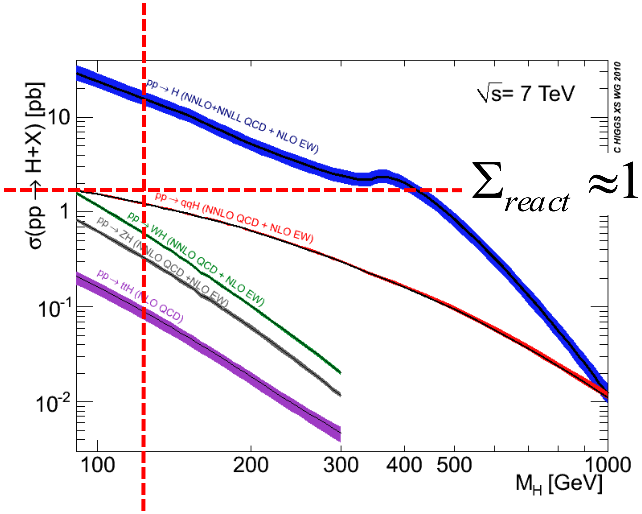
Now $\tau = N(t) / A(t)$ = 1380 bunches * 10^{11} protons per bunch / $7*10^8s^{-1}$
$\approx 1.4*10^{14}$ protons /2* $7*10^8s^{-1} \approx$ 28 h

which fits amazingly wellllll !!

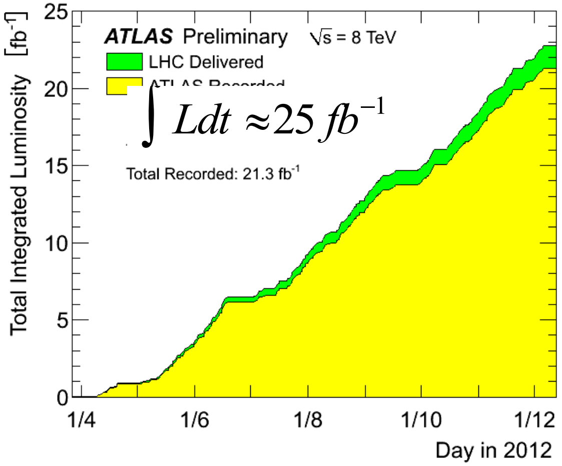
The High light of the year

production rate of events is determined by the cross section Σ_{react} and a parameter L that is given by the design of the accelerator: … the luminosity

$$R = L * \Sigma_{react} \quad \approx 10^{-12} b \cdot 25 \frac{1}{10^{-15} b} = some\, 1000\ H$$



$$\Sigma_{react} \approx 1 pb$$



$$\int Ldt \approx 25\ fb^{-1}$$

remember:
$1b = 10^{-24}\ cm^2$

The luminosity is a storage ring quality parameter and depends on beam size (β !!) and stored current

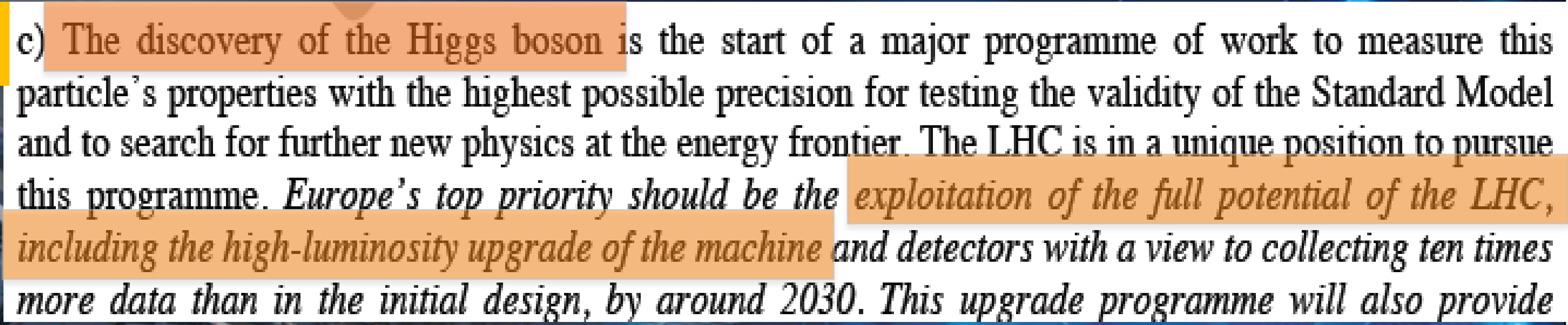
$$L = \frac{1}{4\pi e^2 f_0 b} * \frac{I_1 * I_2}{\sigma^*_x * \sigma^*_y}$$

$$\Delta p/p = 5*10^{-4}$$

Future Projects

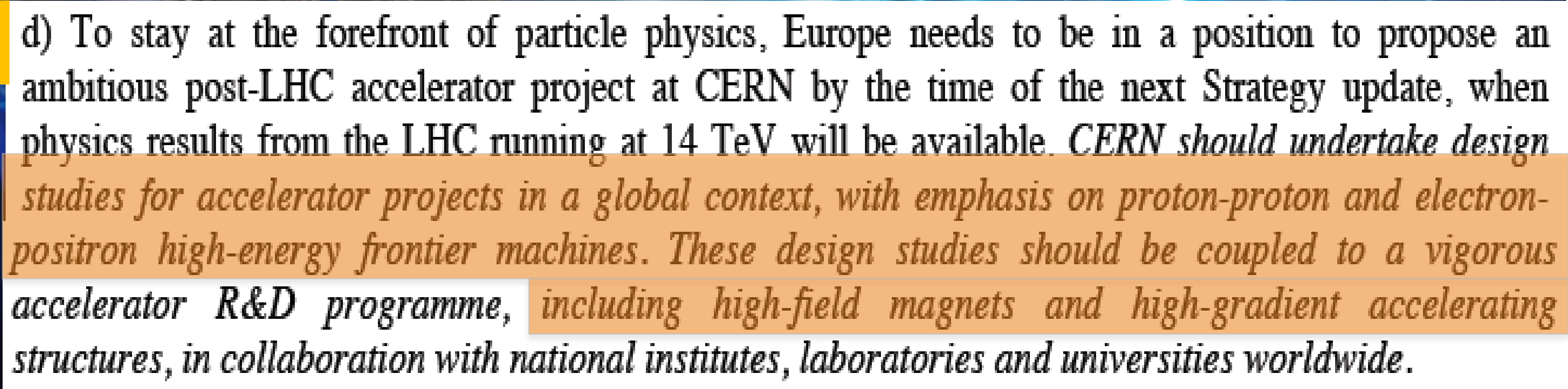
Recommendations from European Strategy Group

#1



c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide*

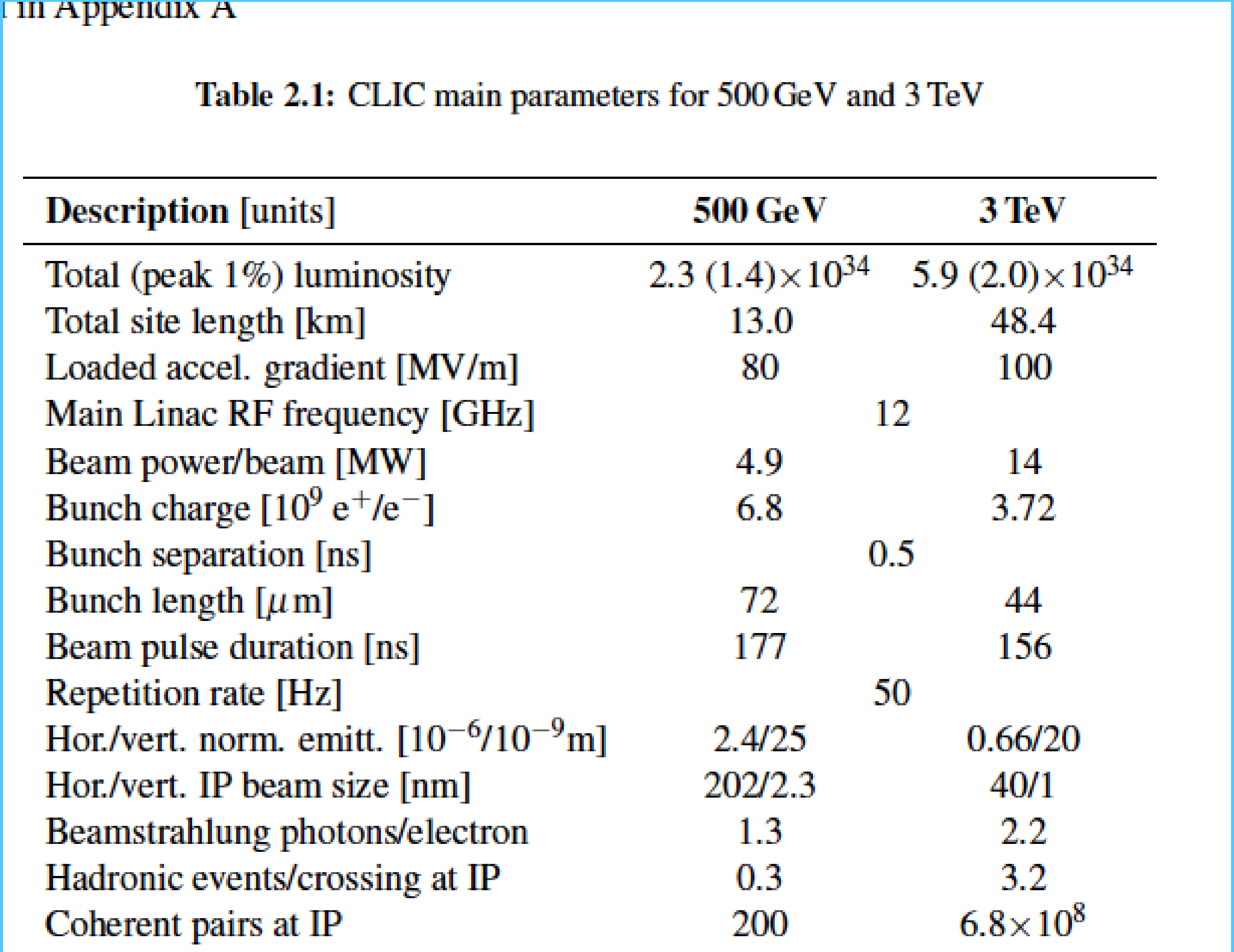
#2



d) To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.*

→Proton –Proton Colliders ***=> e+/e- colliders***

LHC / HL-LHC, HE-LHC ***TLEP, CLIC***



in Appendix A

Table 2.1: CLIC main parameters for 500 GeV and 3 TeV

Description [units]	**500 GeV**	**3 TeV**
Total (peak 1%) luminosity	2.3 (1.4)$\times 10^{34}$	5.9 (2.0)$\times 10^{34}$
Total site length [km]	13.0	48.4
Loaded accel. gradient [MV/m]	80	100
Main Linac RF frequency [GHz]	12	
Beam power/beam [MW]	4.9	14
Bunch charge [10^9 e^+/e^-]	6.8	3.72
Bunch separation [ns]	0.5	
Bunch length [μm]	72	44
Beam pulse duration [ns]	177	156
Repetition rate [Hz]	50	
Hor./vert. norm. emitt. [$10^{-6}/10^{-9}$m]	2.4/25	0.66/20
Hor./vert. IP beam size [nm]	202/2.3	40/1
Beamstrahlung photons/electron	1.3	2.2
Hadronic events/crossing at IP	0.3	3.2
Coherent pairs at IP	200	6.8×10^8

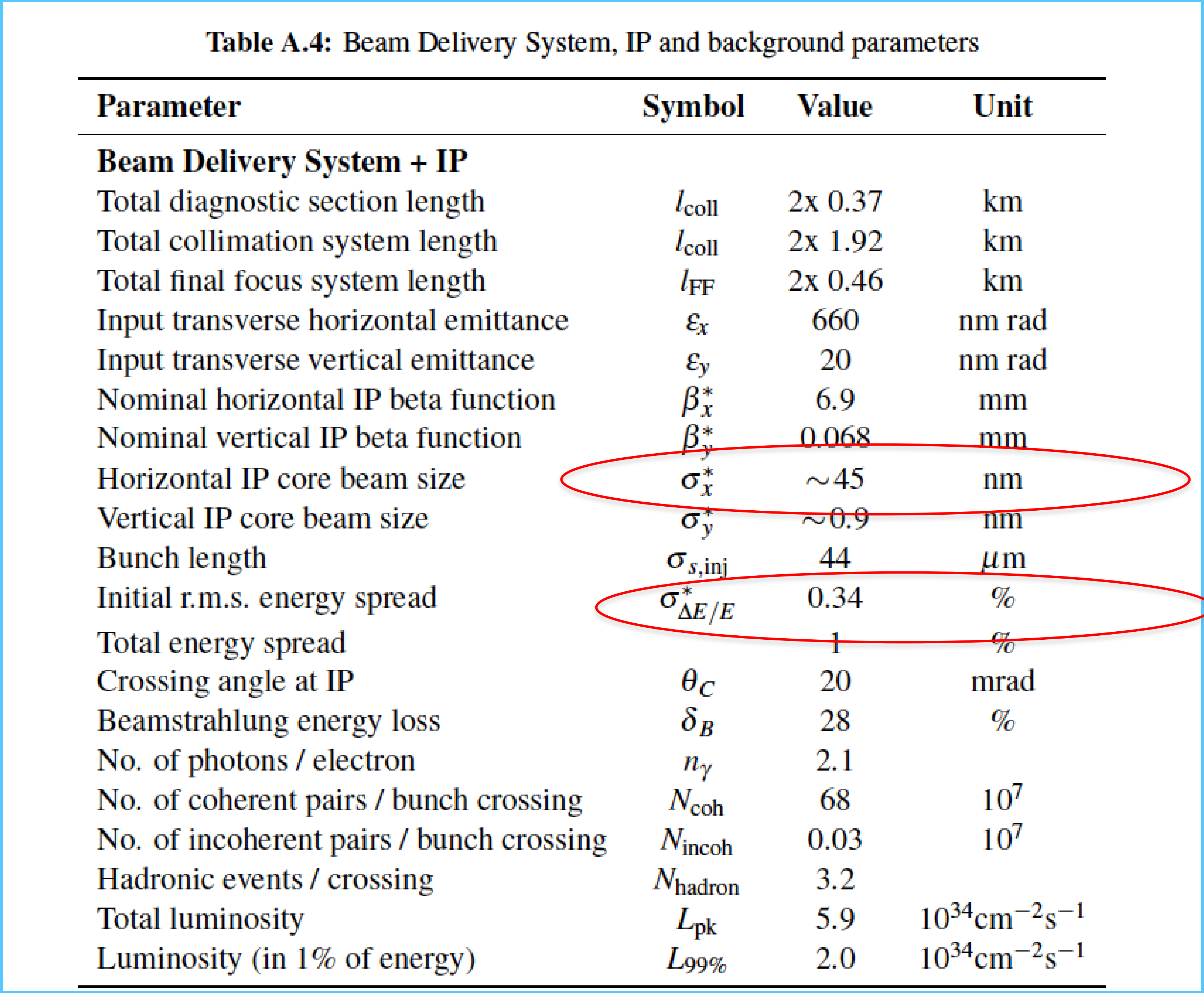
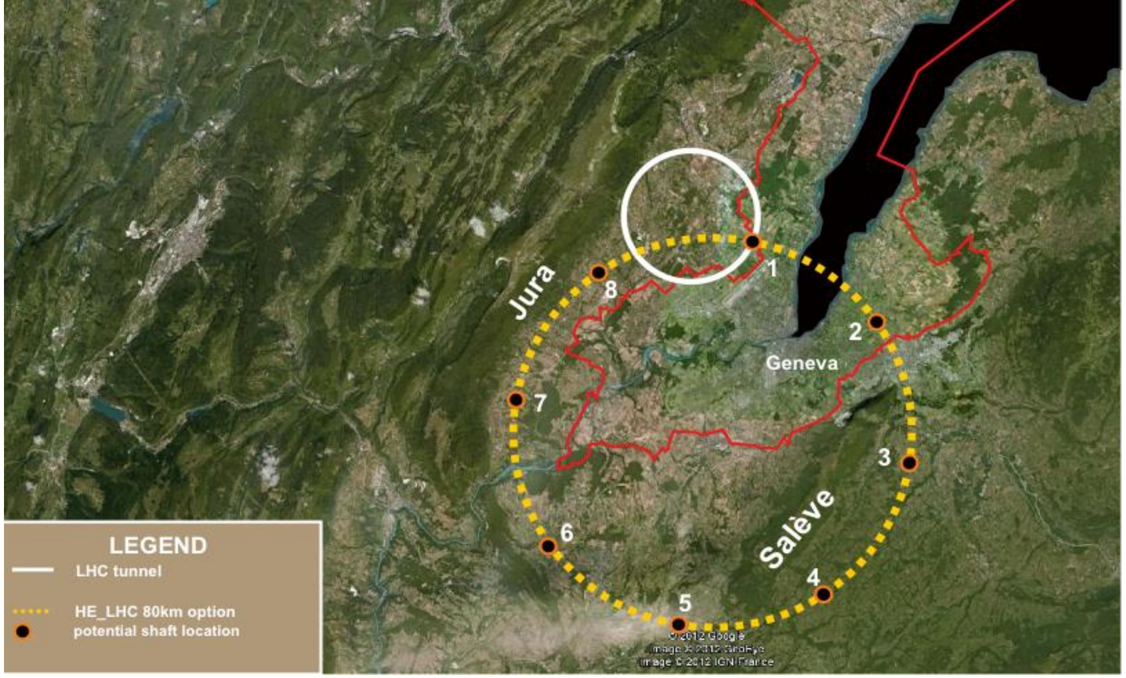


Table A.4: Beam Delivery System, IP and background parameters

Parameter	Symbol	Value	Unit
Beam Delivery System + IP			
Total diagnostic section length	l_{coll}	2x 0.37	km
Total collimation system length	l_{coll}	2x 1.92	km
Total final focus system length	l_{FF}	2x 0.46	km
Input transverse horizontal emittance	ε_x	660	nm rad
Input transverse vertical emittance	ε_y	20	nm rad
Nominal horizontal IP beta function	β_x^*	6.9	mm
Nominal vertical IP beta function	β_y^*	0.068	mm
Horizontal IP core beam size	σ_x^*	$\sim$45	nm
Vertical IP core beam size	σ_y^*	$\sim$0.9	nm
Bunch length	$\sigma_{s,\text{inj}}$	44	μm
Initial r.m.s. energy spread	$\sigma^*_{\Delta E/E}$	0.34	%
Total energy spread		1	%
Crossing angle at IP	θ_C	20	mrad
Beamstrahlung energy loss	δ_B	28	%
No. of photons / electron	n_γ	2.1	
No. of coherent pairs / bunch crossing	N_{coh}	68	10^7
No. of incoherent pairs / bunch crossing	N_{incoh}	0.03	10^7
Hadronic events / crossing	N_{hadron}	3.2	
Total luminosity	L_{pk}	5.9	$10^{34}\text{cm}^{-2}\text{s}^{-1}$
Luminosity (in 1% of energy)	$L_{99\%}$	2.0	$10^{34}\text{cm}^{-2}\text{s}^{-1}$

e+ / e- Ring Colliders



Design Parameters TLEP

E = 175 GeV / beam
L = 100 km

$$\Delta U_0(keV) \approx \frac{89 * E^4(GeV)}{\rho}$$

$$\Delta U_0 \approx 8.62\ GeV$$

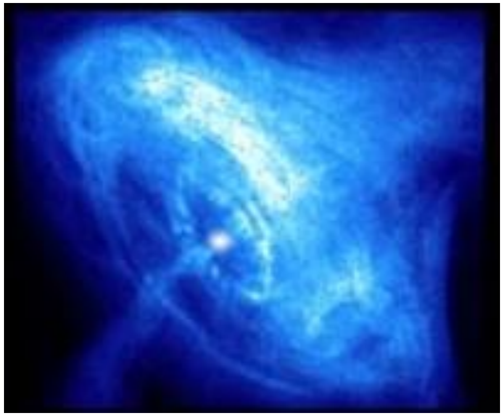
$$\Delta P_{sy} \approx \frac{\Delta U_0}{T_0} * N_p = \frac{10.4*10^6 eV*1.6*10^{-19}Cb}{263*10^{-6}s}*9*10^{12}$$

$$\Delta P_{sy} \approx 47\ MW$$

Circular e+ / e- colliders are severely limited by synchrotron radiation losses and have to be replaced for higher energies by linear accelerators

Looking for highest acceleration technologies

to keep the linear structure as compact as possible



crab nebula,
burst of charged particles $E = 10^{20}$ *eV*

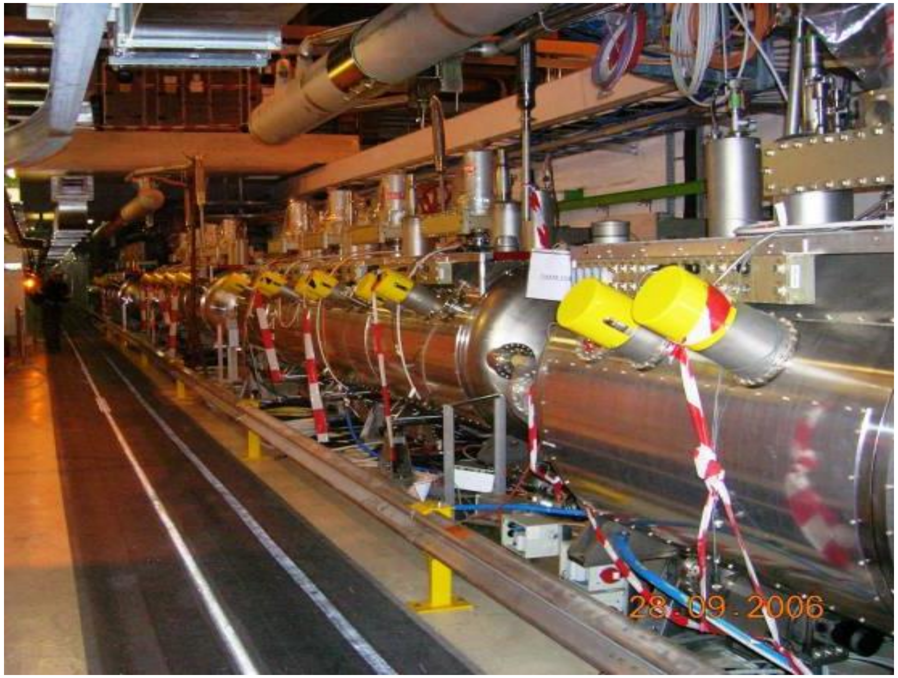
Super conducting cavities $\Delta E = 30$ *MV/m*

Normal conducting cavities, drive beam concept: $\Delta E = 100$ *MV/m*

In a linear structure we cannot use the accelerating gradient several times (i.e. turn by turn)
=> the complete acceleration process has to be obtained in one go

The LHC RF system

LHC ... as a low gradient example 16 MV / 27000m



28.09.2006

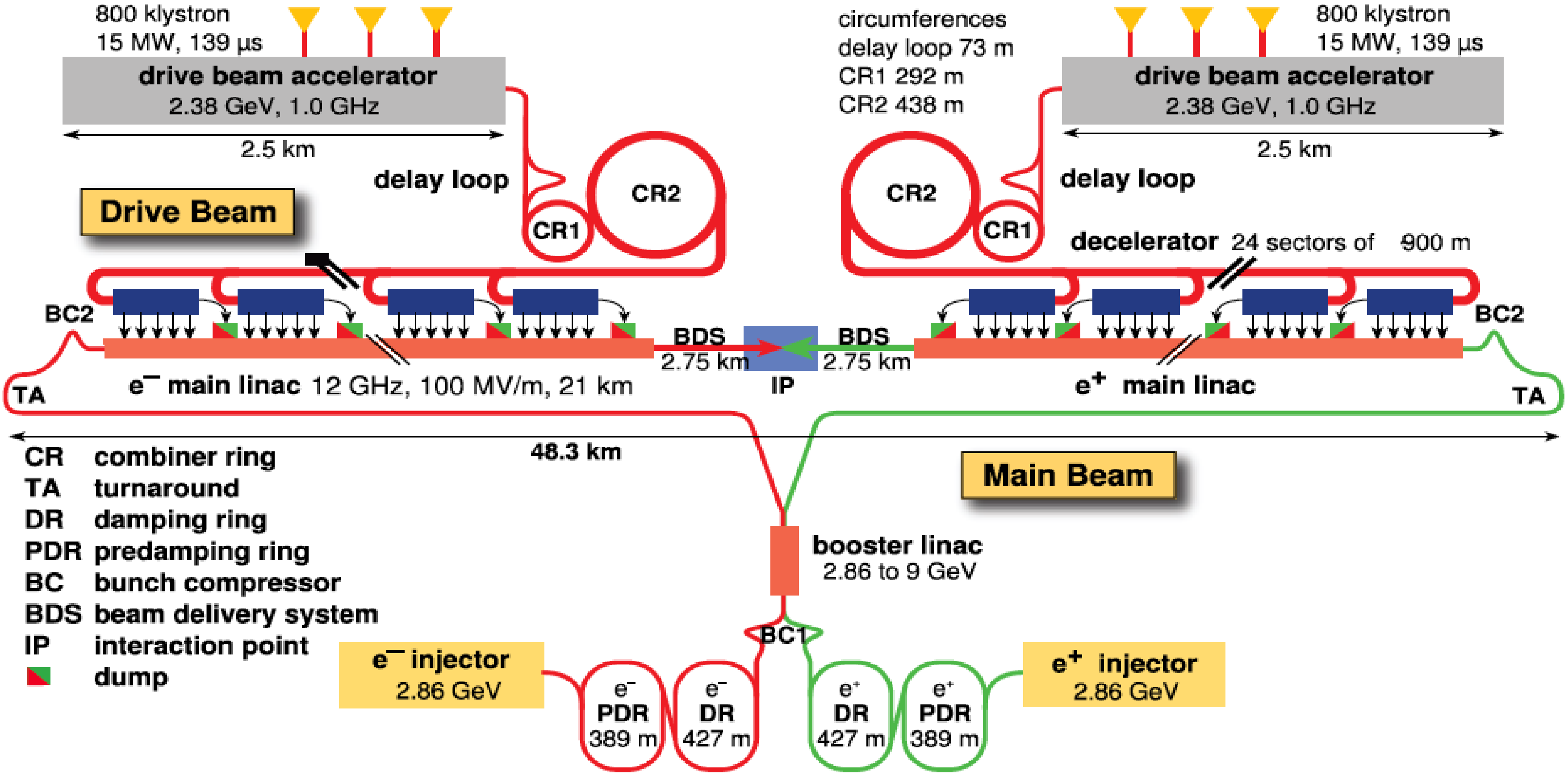
4xFour-cavity cryo module 400 MHz, 16 MV/beam
Nb on Cu cavities @4.5 K (=LEP2)
Beam pipe diam.=300mm

Bunch length (4σ)	*ns*	*1.06*
Energy spread (2σ)	10^{-3}	*0.22*
Synchr. rad. loss/turn	*keV*	*7*
Synchr. rad. power	*kW*	*3.6*
RF frequency	*MHz*	*400*
Harmonic number		*35640*
RF voltage/beam	*MV*	*16*
Energy gain/turn	*keV*	*485*
Synchrotron frequency	*Hz*	*23.0*

CLIC ... a future Linear e+/ e- Accelerator

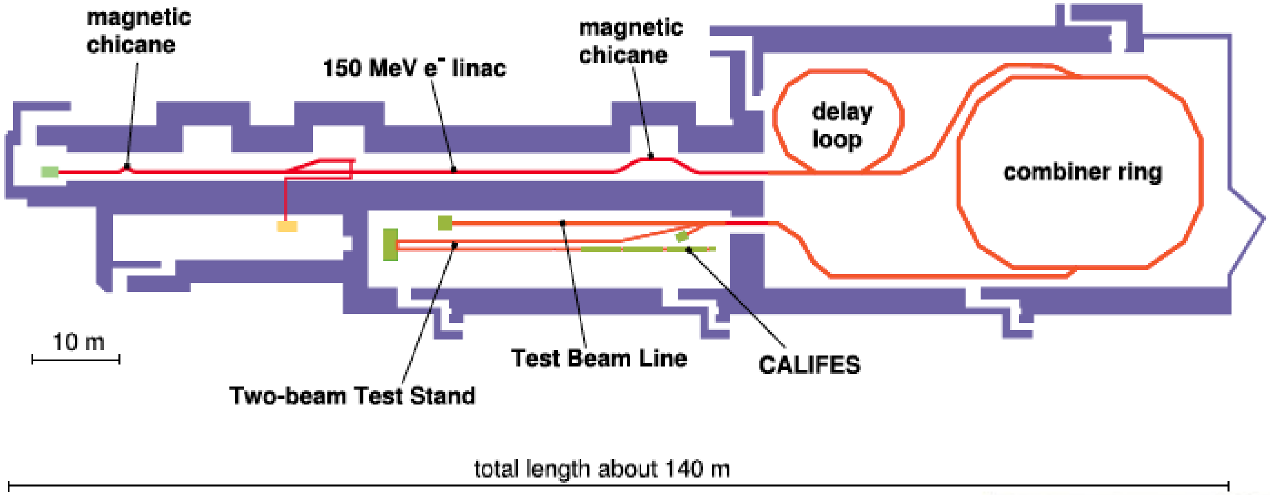
Avoid bending magnets => no synchrotron radiation losses

=> energy gain has to be obtained ***in ONE GO***



CLIC-Test Facility: CTF-3

Proof of principle for the CLIC drive beam / main beam concept

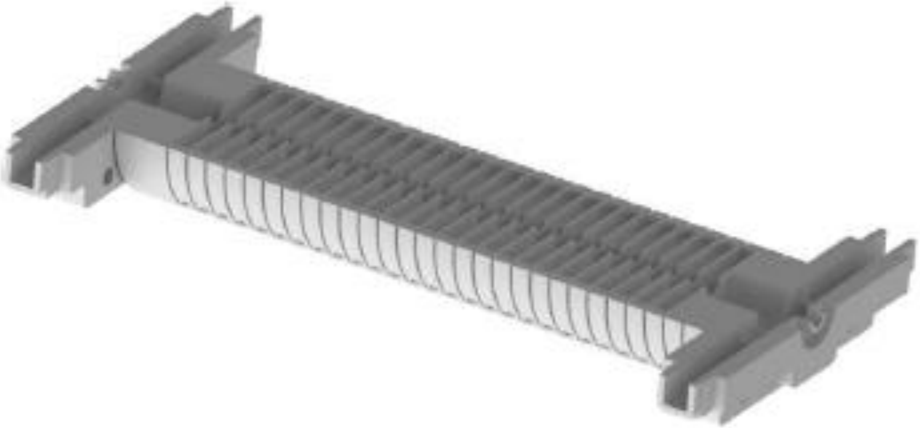


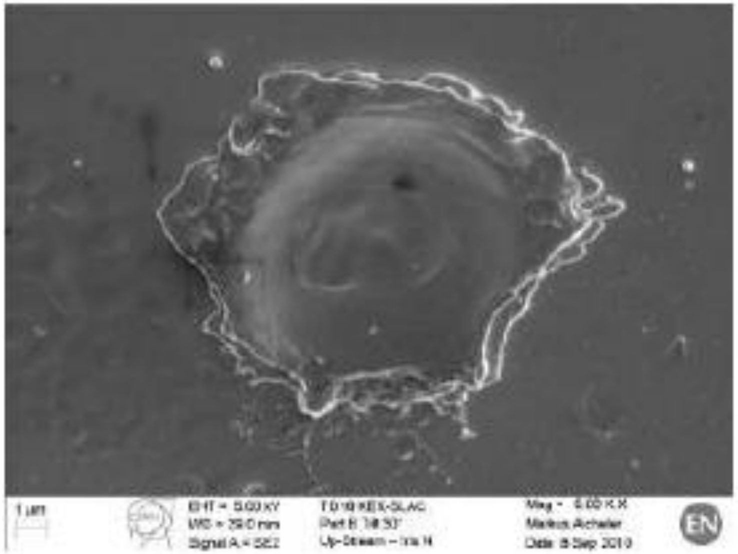
Test facility to study ultra high gradient acceleration
... optimisation
... technical set up
... the limits => BD

RF break downs have to be studied and understood in detail

as they have impact on

=> the accelerator performance (luminosity)
=> beam quality
=> and the accelerating structure itself



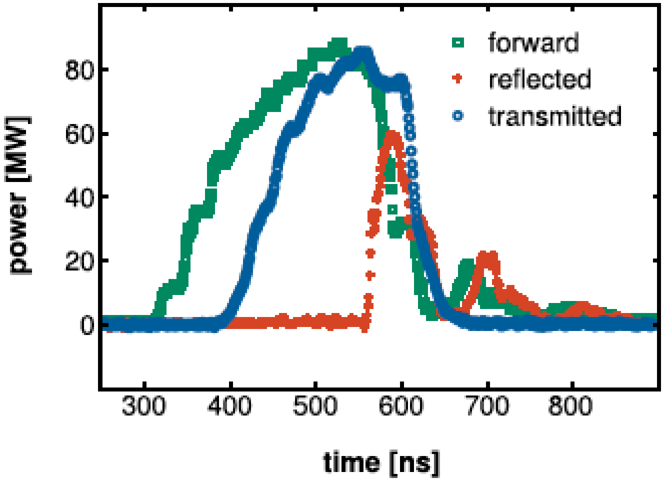


“ how far can we go and how much can we optimise such a future accelerator before we reach technical limits and how can we push these limits ? ”

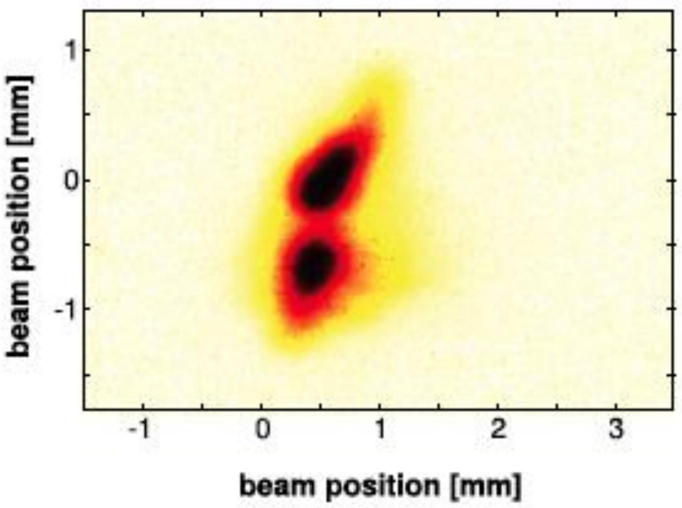
Pushing the technology to highest gradients

means pushing the gradient to the limit set by voltage break downs.

Andrea Palaia studied in his thesis the impact that vacuum discharges, or rf breakdowns, in high-gradient accelerator structures have on the beam and as a consequence on the accelerator performance

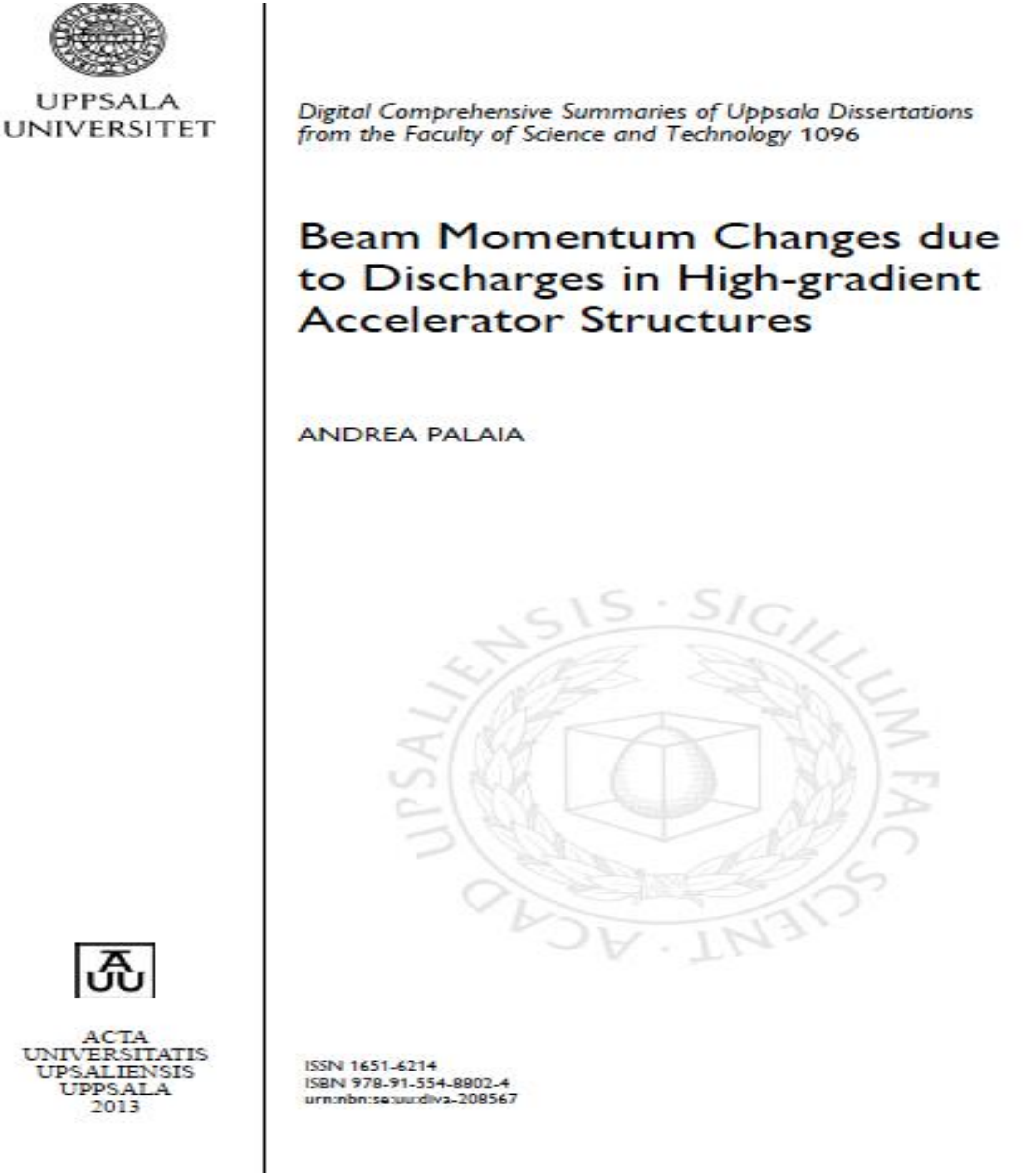


RF Power during a Break Down



Effect on the Beam

Second High Light of the Year



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