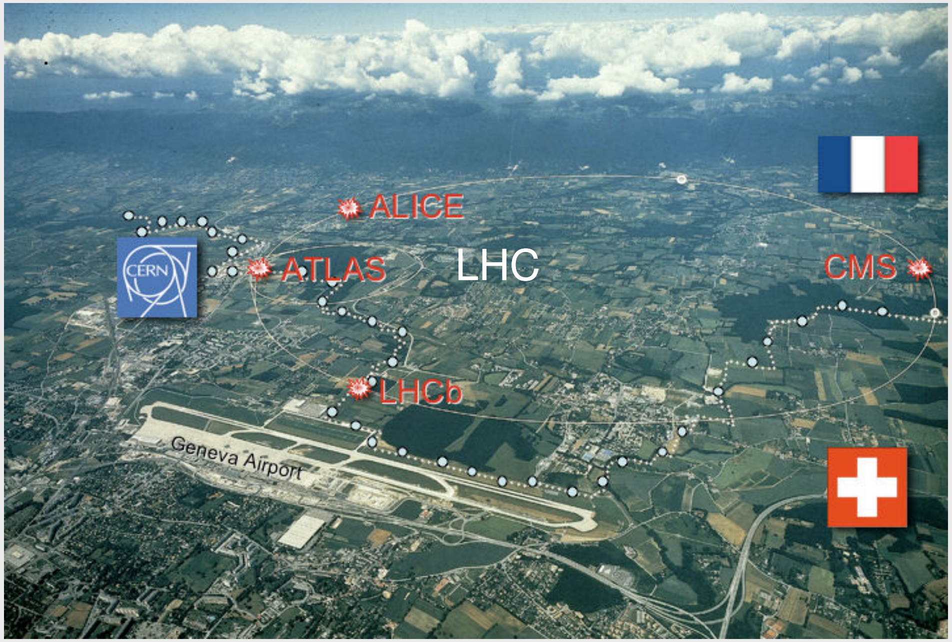
The (imminent) future of Cern



CHIPP 2009

Appenberg
August 24, 2009

Sergio Bertolucci
CERN

2009-2013: deciding years

Experimental data will take the floor to drive the field to the next steps:

- LHC and Tevatron results
- θ_{13} (T2K, DChooz, etc..)
- ν masses (Cuore, Gerda, Nemo…)
- Dark Matter searches
- Rare decays
- Astroparticle expts
- …..

Preparing the next steps

- **More globalization**
- More (coordinated) R&D on accelerators and detectors
- More synergies between Particle and Astroparticle Physics
- More space for diversity

Our agony and ecstasy: the LHC

- **Status**
- Schedule
- Commissioning plans
- Early Physics
- ……

Status of the LHC and commissioning plans

by Helmut Burkhardt / CERN for the LHC team

- **Short introduction - main challenges**
- **LHC status,** 1st experience with beams and status following the incident
- **Commissioning steps and expected beam parameters**

Acknowledgements : LHC team, mentioning in particular
Lyn Evans, the former LHC and current sLHC project leader, and Steve Myers director for accelerators
K-H.Mess and R. Schmidt for advice, in particular on the issue of magnet interconnects and quench protection, O. Brüning & M. Giovannozzi on optics and commis, M. Ferro-Luzzi on physics program, R. Bailey on commis.

Major LHC challenges

High design Centre-of-mass energy of 14 TeV in given (ex LEP) tunnel

•Magnetic field of 8.33 T with superconducting magnets

•Helium cooling at 1.9 K

•Large amount of energy stored in magnets

•"Two accelerators" in one tunnel with opposite magnetic dipole field and ambitious beam parameters pushed for very high of luminosity of 10^{34} cm^{-2} s^{-1}

•Many bunches with large amount of energy stored in beams

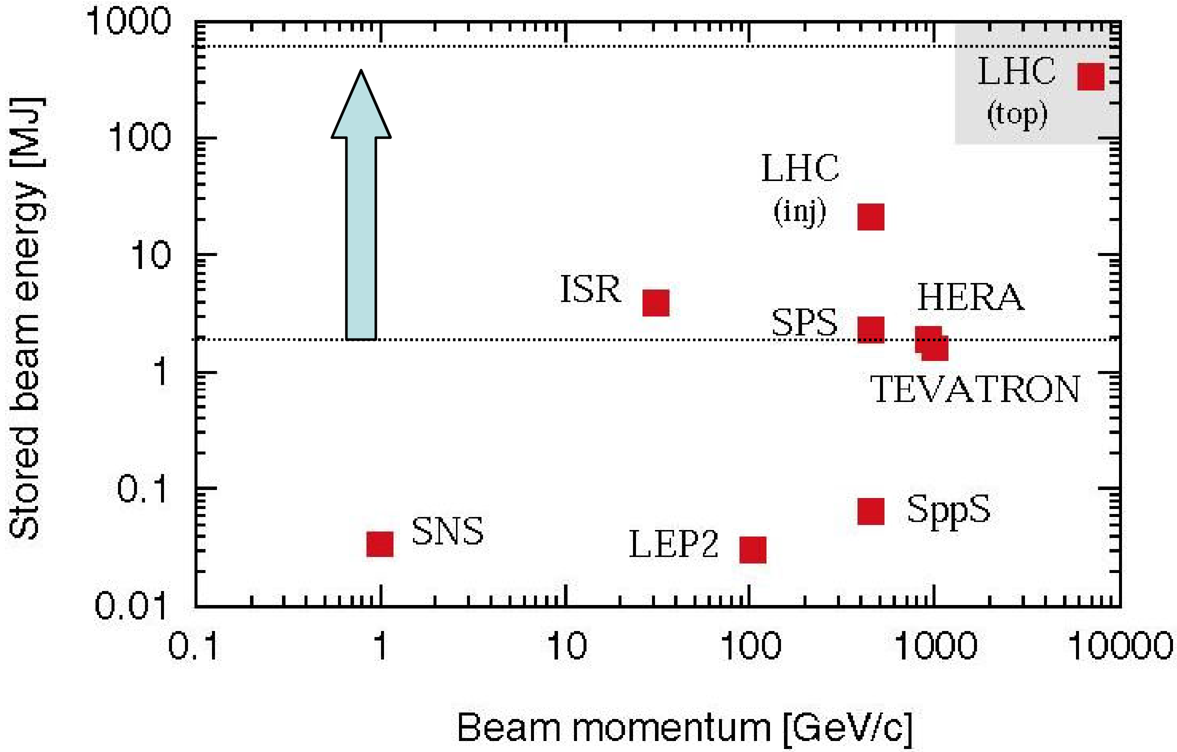
Complexity and Reliability

•Unprecedented complexity with 10000 magnets powered in 1700 electrical circuits, complex active and passive protection systems, ….

- **Emittance conservation** $\sum_N$ = ® © ∑ , related to phase space density conservation, Liouville constant "intrinsic" normalized emittance $\sum_N$, real space emittance ∑ decreases with energy
- **in absence of major energy exchange in synchrotron radiation / rf damping**
- **clean, perfectly matched injection, ramp, squeeze, minimize any blow up from: rf,**
- **kicking beam, frequent orbit changes, vibration, feedback, noise,..**
- **dynamic effects - persistent current decay and snapback**
- **non-linear fields (resonances, diffusion, dynamic aperture, non-linear dynamics)**

The total stored energy of the LHC beams

Nominal LHC design: 3.2 × 10^{14} protons accelerated to 7 TeV
circulating at 11 kHz in a SC ring



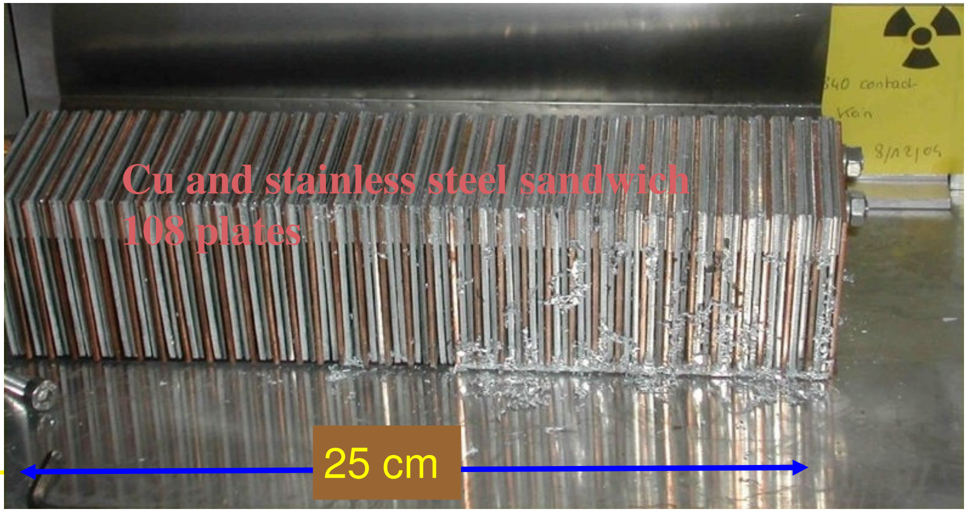
LHC: > 100 × higher stored energy and small beam size: ~ 3 orders of magnitude in energy density and damage potential. Active protection (beam loss monitors, interlocks) and collimation for machine and experiments essential.
Only the specially designed beam dump can safely absorb this energy.

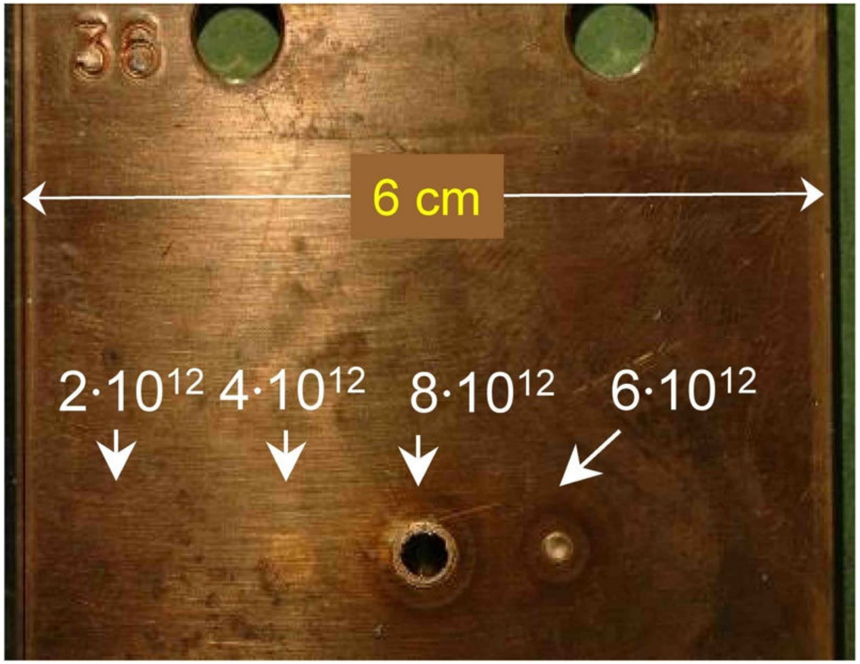
Damage potential : confirmed in controlled SPS experiment

controlled experiment with beam extracted from SPS at 450 GeV in a single turn, with perpendicular impact on Cu + stainless steel target

450 GeV protons →

r.m.s. beam sizes $\sigma_{x/y} \approx 1$ mm





SPS results confirmed :

8×10^{12} clear damage 2×10^{12} below damage limit

for details see V. Kain et al., PAC 2005 RPPE018

For comparison, the LHC nominal at 7 TeV :
$2808 \times 1.15\times10^{11} = 3.2\times10^{14}$ p/beam

at $< \sigma_{x/y} > \approx 0.2$ mm

over 3 orders of magnitude above damage level for perpendicular impact

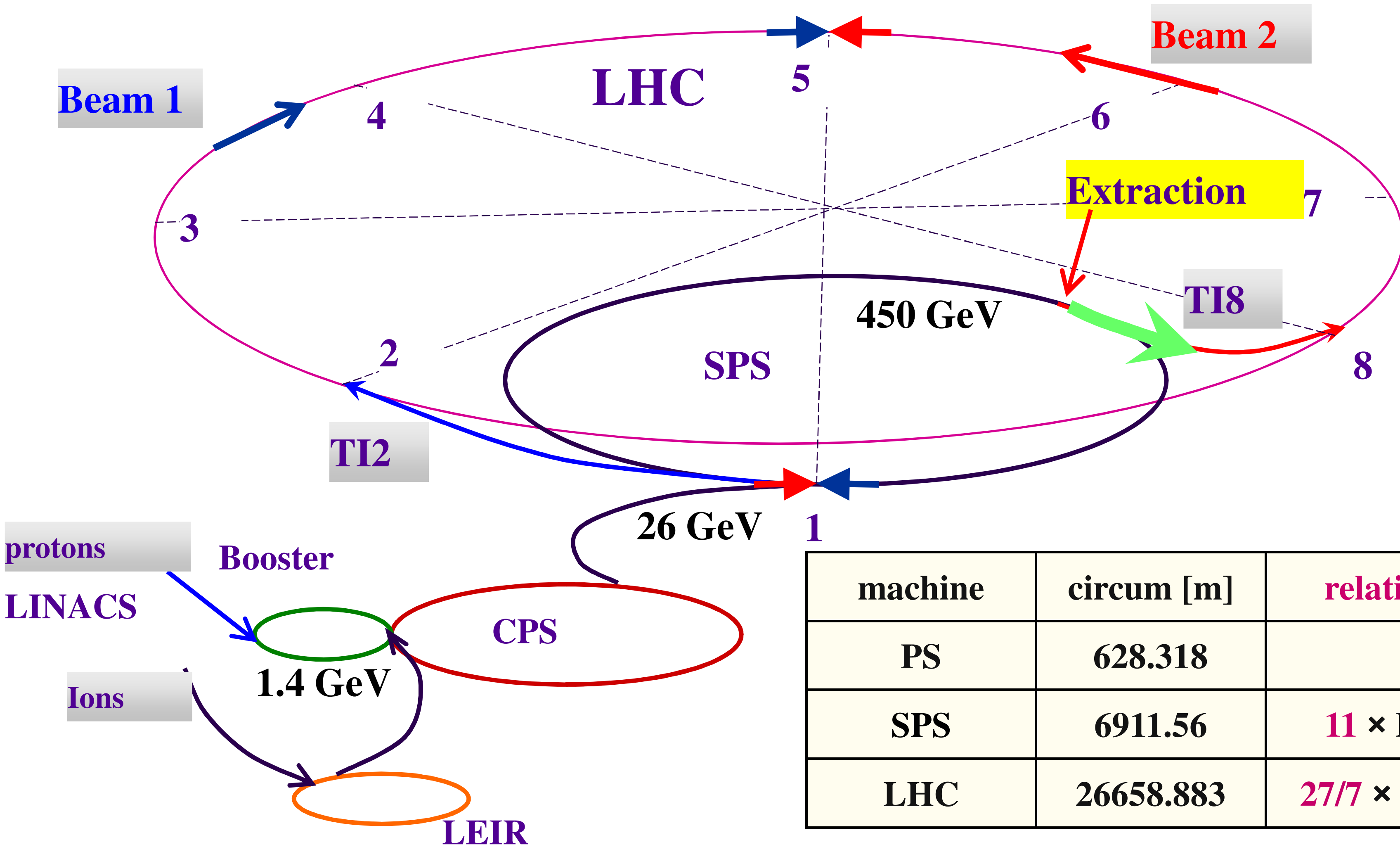
Beam parameters, LHC compared to LEP

	LHC	LEP2
Momentum at collision, TeV/c	7	0.1
Nominal design Luminosity, $cm^{-2}s^{-1}$	1.0E+34	1.0E+32
Dipole field at top energy, T	8.33	0.11
Number of bunches, each beam	2808	4
Particles / bunch	1.15E+11	4.20E+11
Typical beam size in ring, µm	200 – 300	1800/140 (H/V)
Beam size at IP, µm	16	200/3 (H/V)

- **Energy stored in the magnet system: 10 GJoule** Airbus A380, 560 t
- **Energy stored in one (of 8) dipole circuits: 1.1 GJ (sector)** at 700 km/h
- **Energy stored in one beam: 362 MJ** 20 t plane
- **Energy to heat and melt one kg of copper: 0.7 MJ**

the LEP2 total stored beam energy was about 0.03 MJ

The CERN accelerator complex : injectors and transfer



machine	circum [m]	relative
PS	628.318	
SPS	6911.56	11 × PS
LHC	26658.883	27/7 × SPS

simple rational fractions for synchronization
b[...] on a single frequency
[...]ator at injection

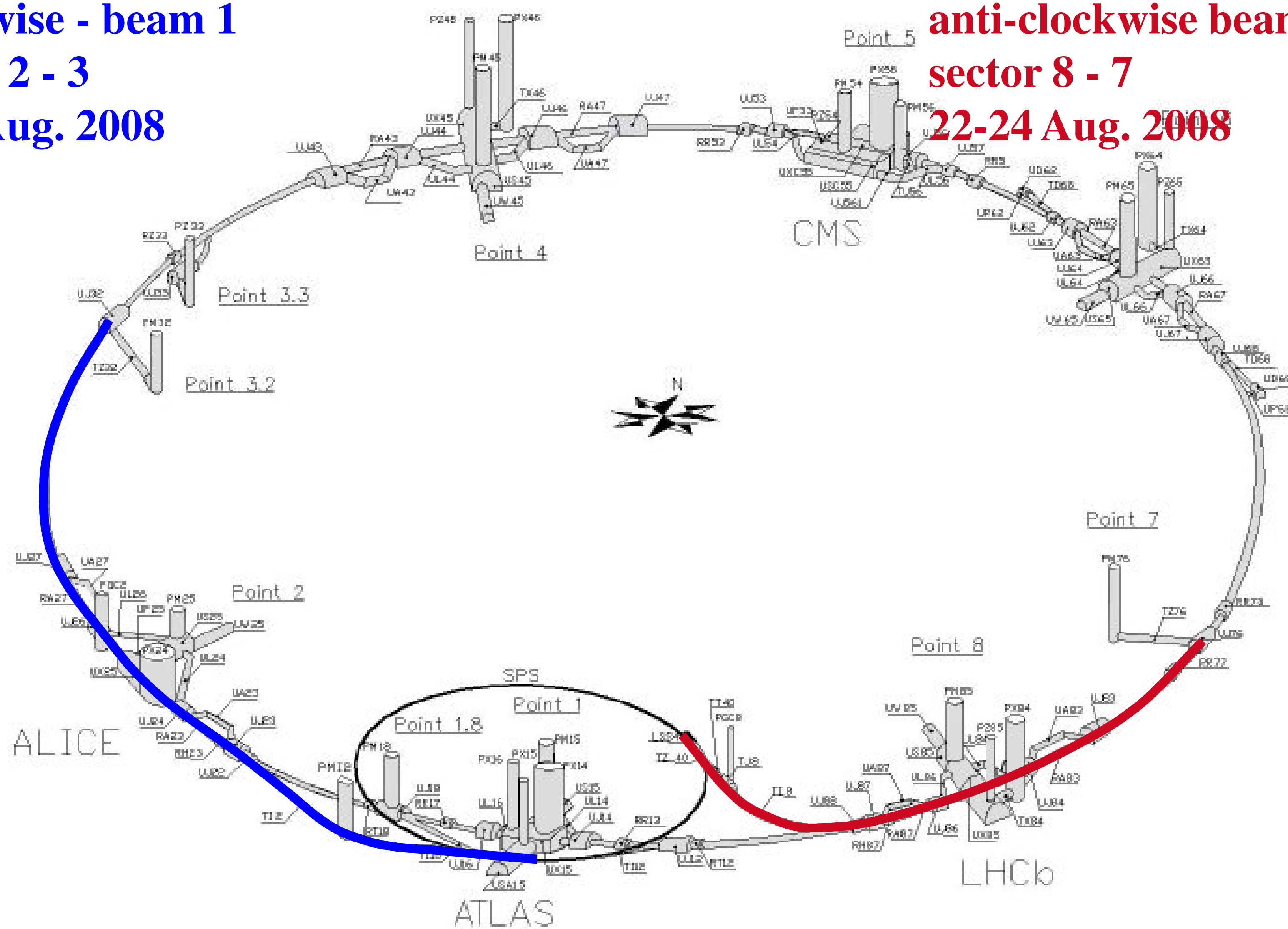
Beam size of protons decreases with energy : area $\sigma^2 \propto 1 / E$

Beam size largest at injection, using the full aperture

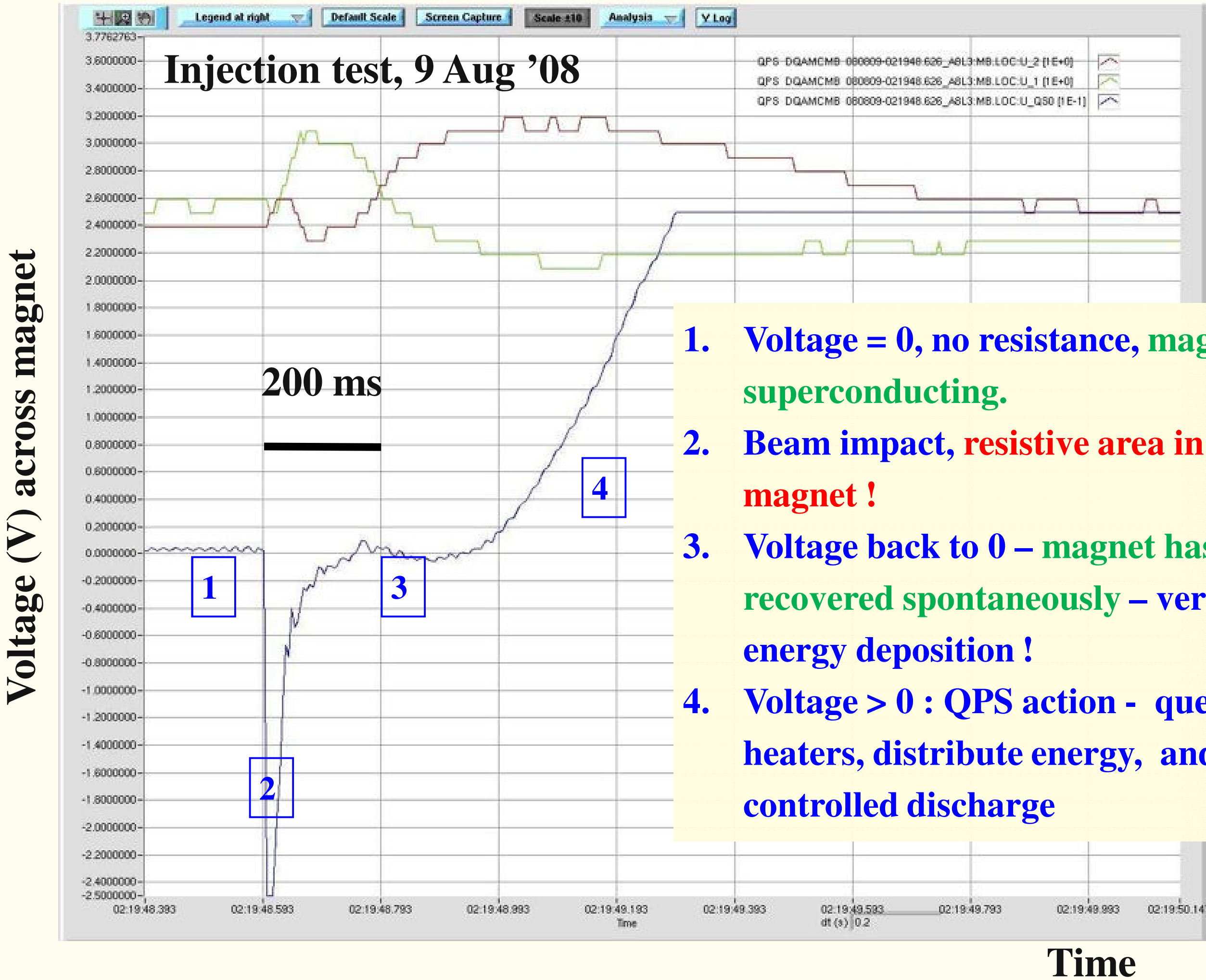
LHC Commissioning : injection tests in August'08

1st Injection
clockwise - beam 1
sector 2 - 3
8-10 Aug. 2008

2nd Injection
anti-clockwise beam 2
sector 8 - 7
22-24 Aug. 2008



Experience with beam : first beam induced quench



1. Voltage = 0, no resistance, magnet is superconducting.
2. Beam impact, resistive area in the magnet !
3. Voltage back to 0 – magnet has recovered spontaneously – very little energy deposition !
4. Voltage > 0 : QPS action - quench heaters, distribute energy, and controlled discharge

Local mini-quench
"quenchino"

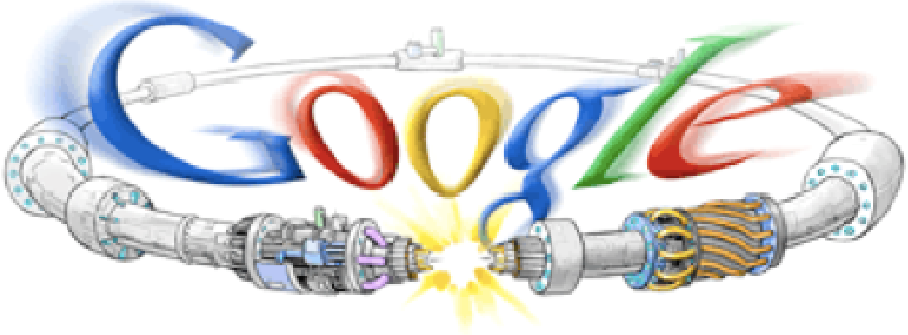
verification of quench limit in magnets ~2×10^9 protons @ 450 GeV and calibration of BeamLossMon system

10 September 2008

10:30 beam 1 3 turns

15:00 beam 2 3 turns

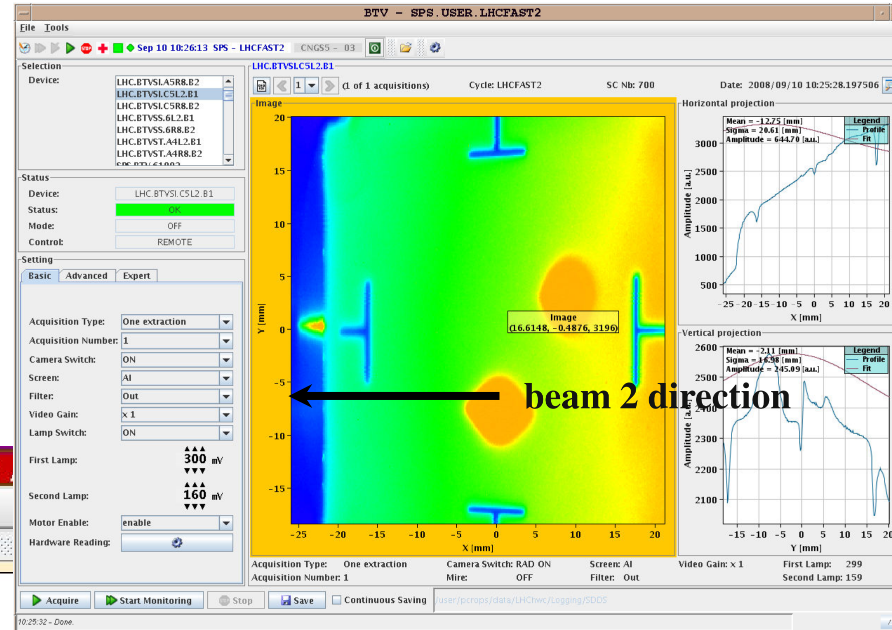
22:00 beam 2 several 100 turns

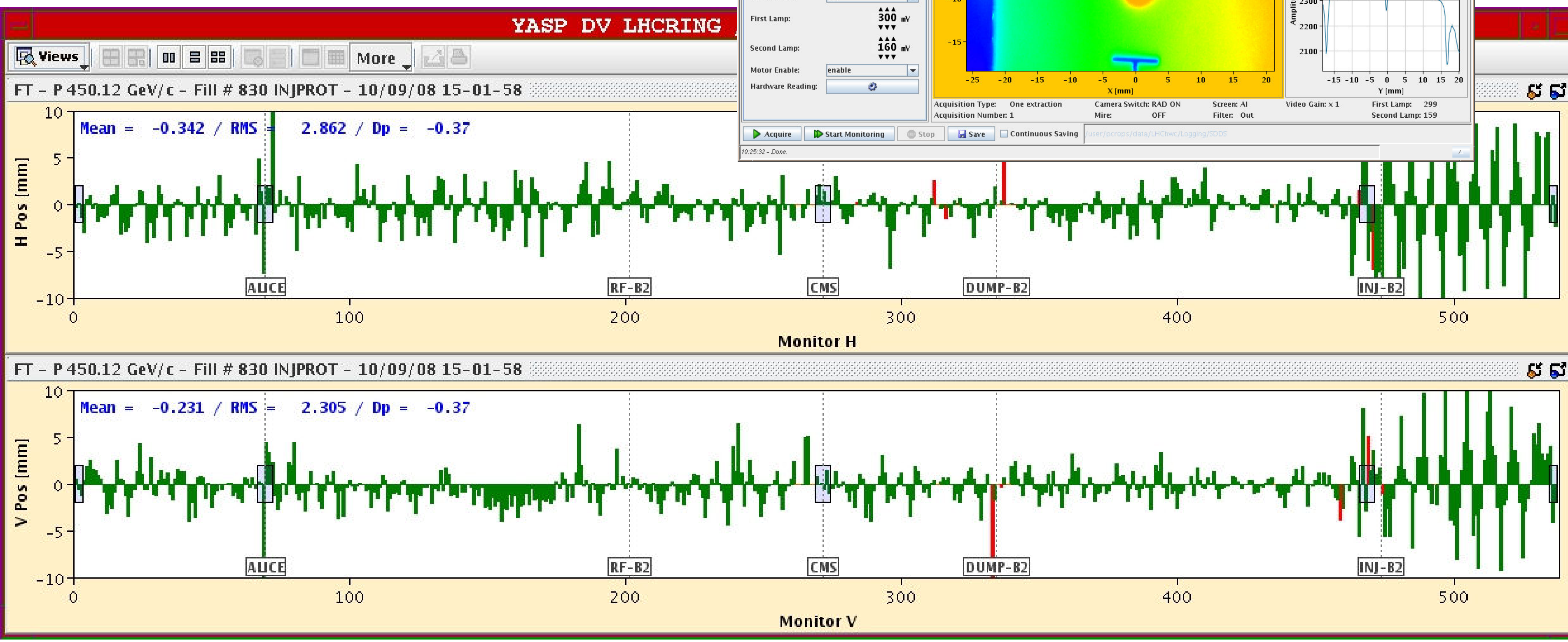


First turn. 10 September 2008

- First & Second Turn on screen
- First Turn on BPM system

Jörg Wenninger
Courtesy of Roger Bailey & O. Brüning



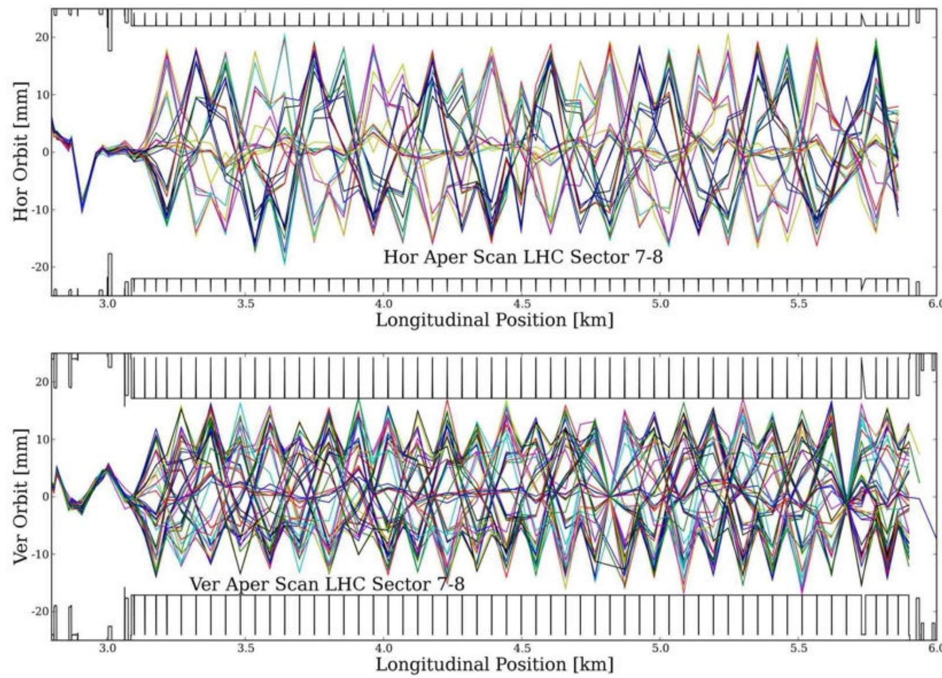


longitudinal position around the ring, s [m], here by monitor number

Examples of detailed aperture and optics measurements

H and V successfully scanned in the range ± 12 - 18 mm

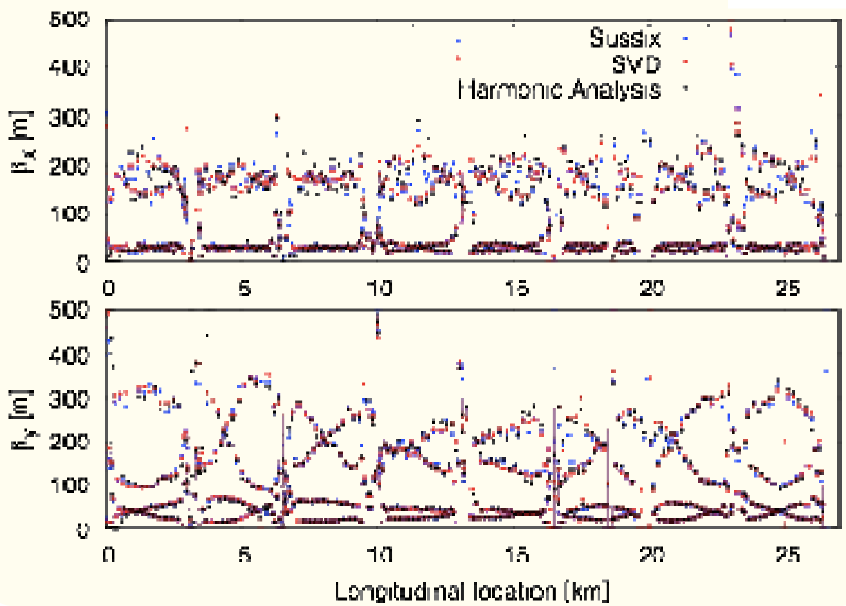
LHC Perf. Note 1 Sep.2008



β-measurements and analysis

LHC Perf. Note 8 Jan 2009

ABP and OP group

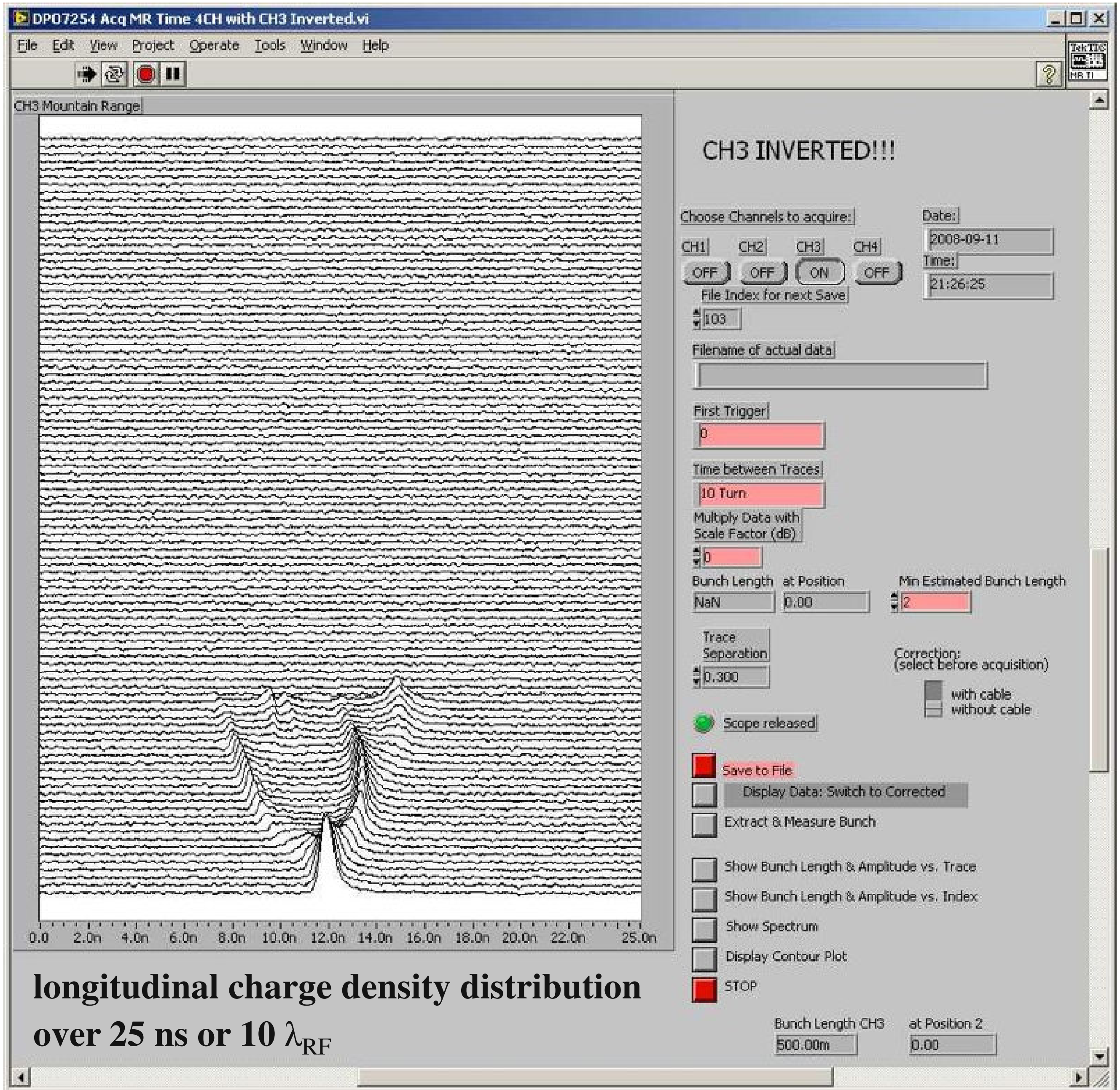


A lot was learned from the cold-checkout, injection tests and the few days with beams in the LHC in 2008. Instrumentation and software and analysis worked very well and allowed many measurements, detailed analysis and adjustments.

This also allowed to diagnose and later correct noisy channels and cabling error etc.

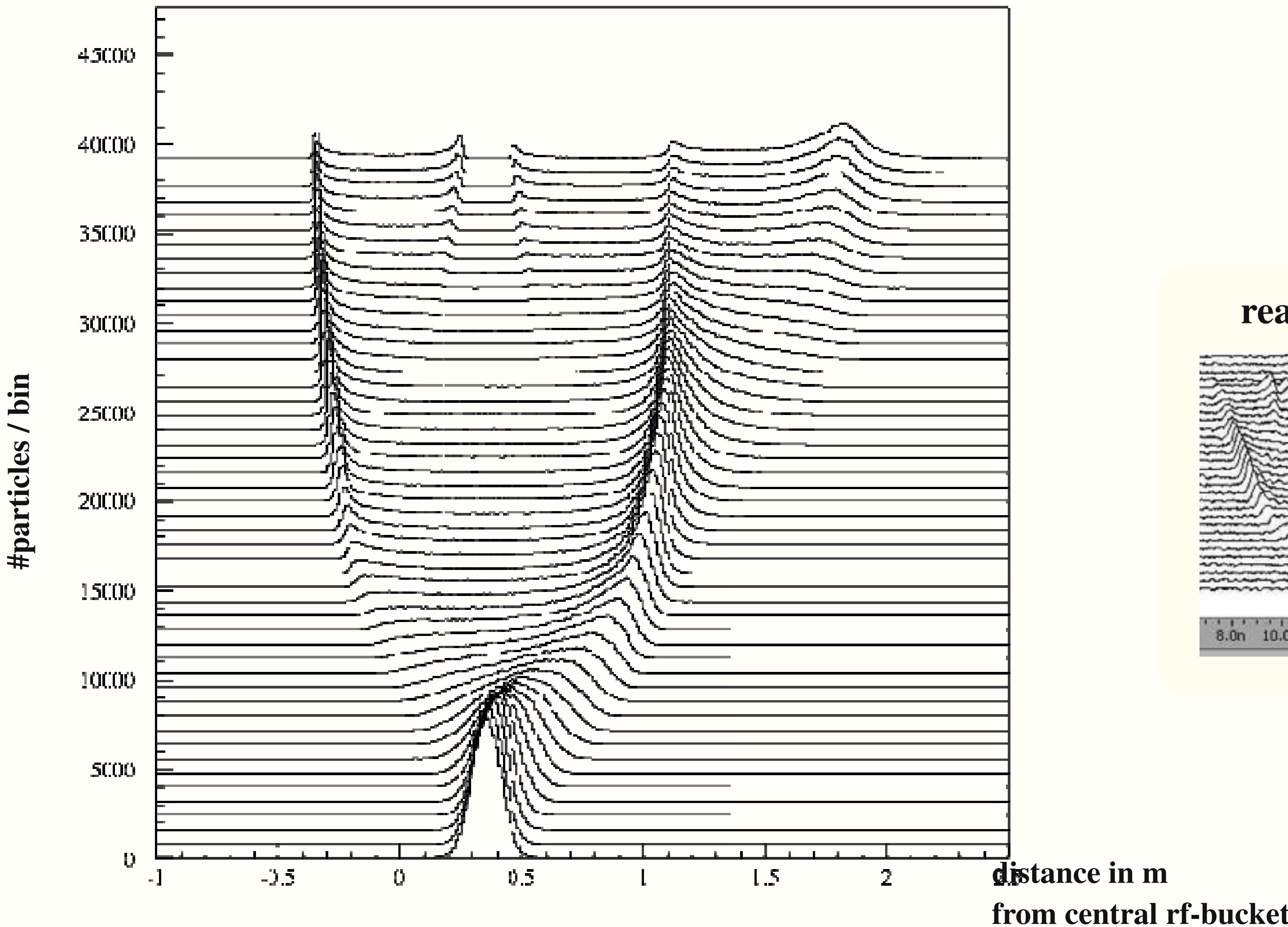
Textbook example : from first attempt to RF capture

one trace every 10 turns

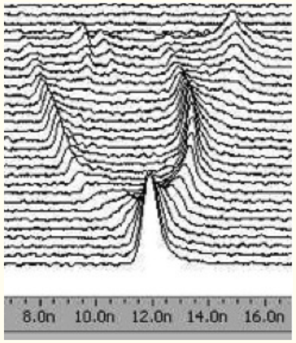


longitudinal charge density distribution over 25 ns or 10 λ_{RF}

Simulation of injection with 170º injection phase offset



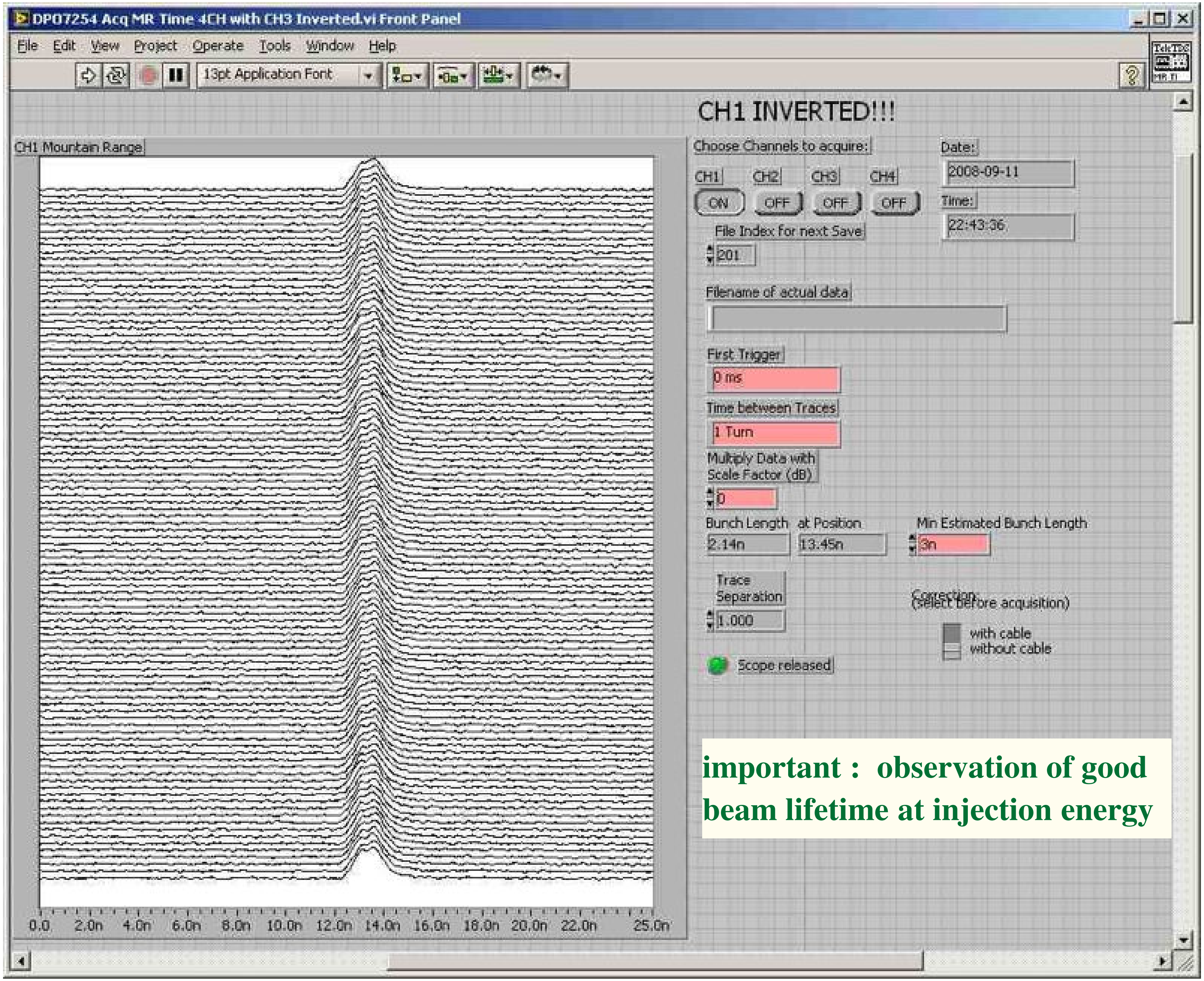
real LHC



projection of previous plot : longitudinal charge density distribution

BeamTrack simulation, 100 000 particles

LHC beam 2 with well adjusted RF capture



important : observation of good beam lifetime at injection energy

Critical Issues

Past

- •QRL cryo-line (He supply)
- •DFB power connections, warm to cold transition
- •Triplet quadrupoles - differential pressure

More recent

•**PIM** plug in module with bellow, systematically checked / repaired after warm up using “ping-pong” ball with RF-emitter : polycarbonate shell, Ø 34 mm, 15 g, 2h battery powered, 40 MHz emitter, signals recorded by LHC BPM

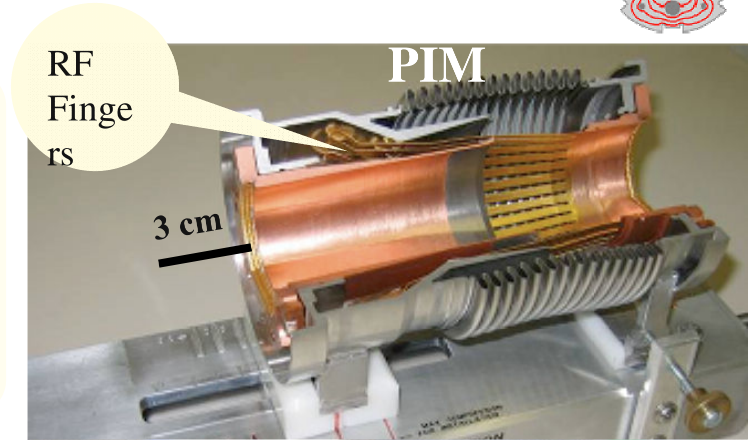
•**Vacuum leaks, condensation - humidity sector 3/4**

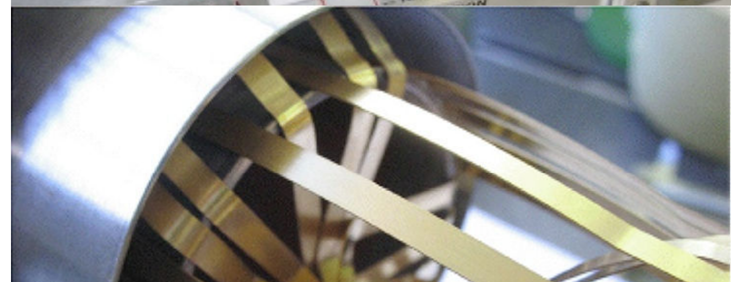
•**Magnet powering** check / correct : min/max, cabling - polarity

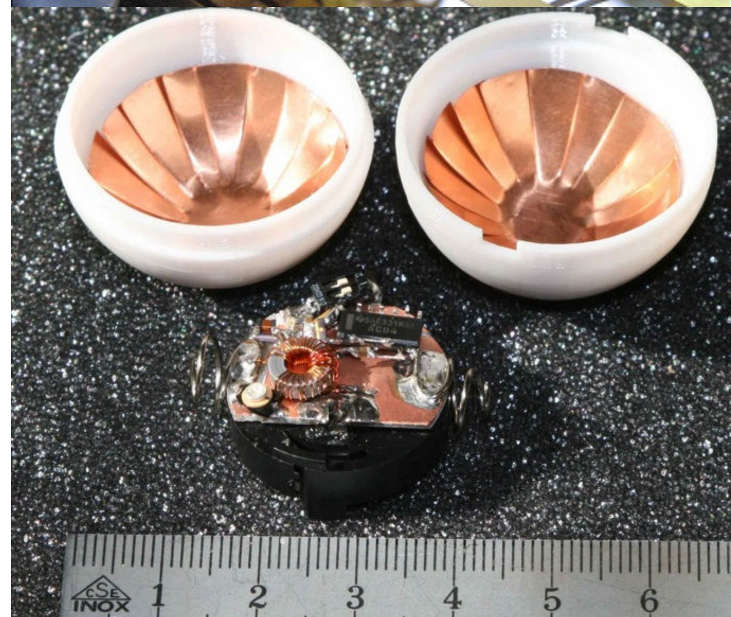
•**Single event upset,** radiation to electronics, shielding etc

•**Magnet re-training** magnets quenching below what was reached in SM18

•**Magnet interconnects, splices** ⇨



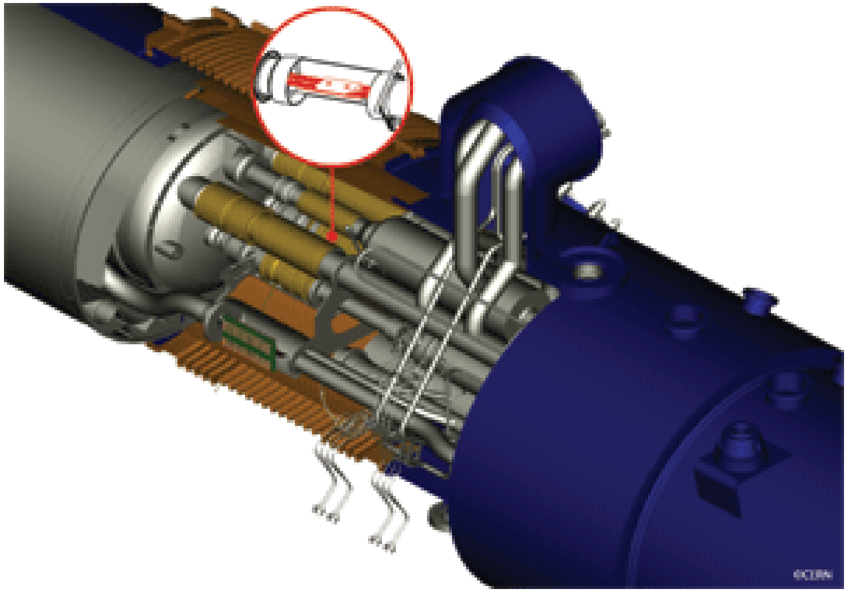




After 3 days of excellent progress with beams

Commissioning with beam interrupted by a series of hardware failures - not related to beams

- **two large transformers ; 13 - 18 September 2008 '08**
- **19 Sept. '08** at 11:18:36, **incident during hardware commissioning of sector 3/4 towards 5.5 TeV/ 9.3 kA, at 8.7 kA or ~ 5.2 TeV,** of the 600 MJ stored energy about 2/3 dissipated into the cold-mass 1 MJ melts 2.4 kg Cu



bad splice 220 nΩ at electrical connection between dipole and quad Q23, ~ 6 t He or 1/2 of arc lost; pressure built up in adjacent each 107 m long, vacuum sub-sectors causing significant collateral damage.

details : LHC-PROJECT-REPORT-1168 March '09

some typical numbers and back of envelope estimates :

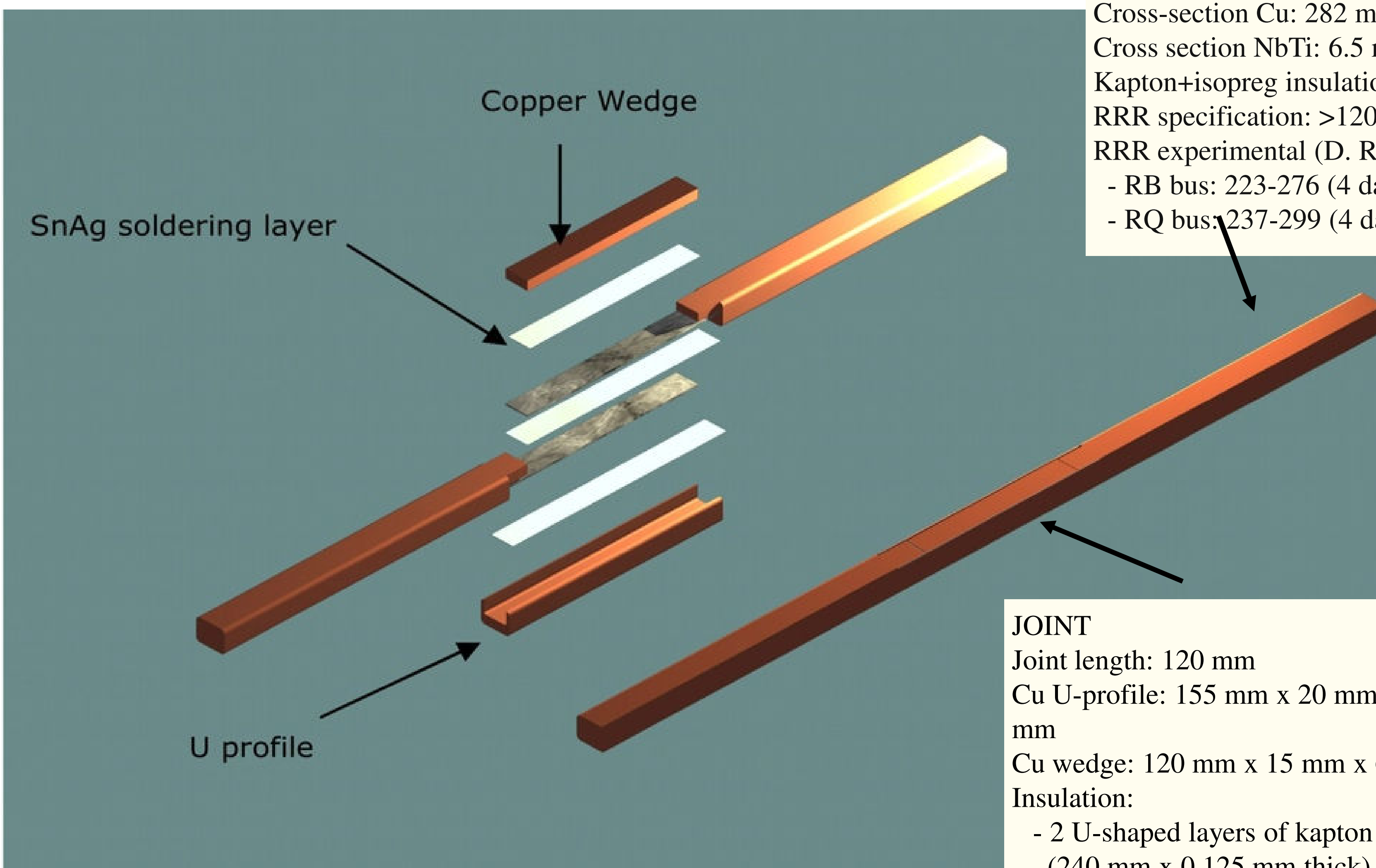
good splice ~ 0.3 nΩ, I = 12 kA, U = R I = 3.6 μV (now) possible to check

$P = R I^2 = 0.043$ W quench would need locally > 10 W - depending on position - less critical in magnet

new QPS triggers at 0.3 mV for > 10 ms

LHC dipole L = 100 mH stored energy in single dipole $I^2 L/2 = 7.2$ MJ × 154 = 1.1 GJ / sector

Busbar Splice



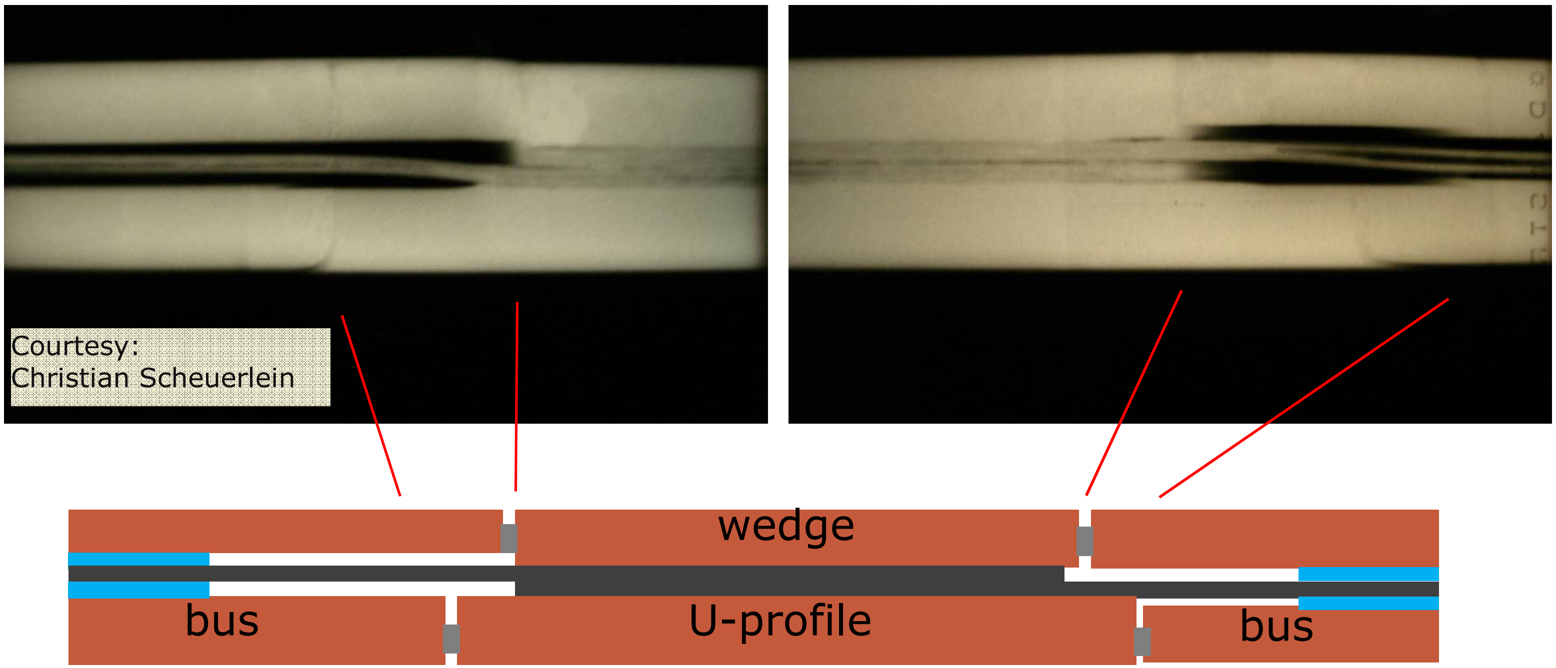
BUS
Cross-section Cu: 282 mm^2
Cross section NbTi: 6.5 mm^2
Kapton+isopreg insulation
RRR specification: >120
RRR experimental (D. Richter)
- RB bus: 223-276 (4 data)
- RQ bus: 237-299 (4 data)

JOINT
Joint length: 120 mm
Cu U-profile: 155 mm x 20 mm x 16 mm
Cu wedge: 120 mm x 15 mm x 6 mm
Insulation:
- 2 U-shaped layers of kapton (240 mm x 0.125 mm thick)
- 2 U-shaped layers of G10 (190 mm x 1 mm)

Busbar Splice

normal conducting, soldered electrical connection between SC cables

1684 units × 6 ≈ 10 000 splices at magnet interconnects; 1/3 dipole, 2/3 quads



A. Siemko et al. LMC 5/08/09

possible problems in soldering :

overheating - SnAg loss

too cold - SnAg unmelted, poor connection

Now possible to diagnose : X-ray, ultrasound, resistance measurement.

Most reliable : resistance measured at room temperature

good : 10 μΩ dipole (RB) , 17 μΩ quadrupole (RQ).

Measured in 5 sectors which were warmed up. Fixed all above ~ 40 μΩ. Other sectors measured at 80 K

Current status - August 2009

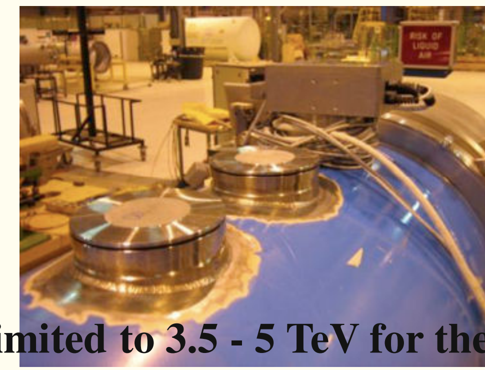
damage repair

•39 dipoles and 14 quadrupoles removed - and re-installed. Last magnet back in tunnel on 30/04/2009, electrical connections finished 2nd June

avoid reoccurrence

•Improved diagnostics, measurements of magnet interconnects - splice resistance

•> 50 % of machine (sectors, 1-2, 3-4, 5-6, 6-7, all standalone magnets) with fast pressure release valves



•Improved anchoring on vacuum barriers around the ring

•Enhanced Quench Protection System

- aperture symmetric quenches and joints in magnets
- 2 × faster discharge

•Remaining risks minimized by keeping maximum beam energy limited to 3.5 - 5 TeV for the first run

Major amount of work - much of the hardware work is finished

Time also used to further improve crucial systems like BLM, complete collimator installation ..

Restart LHC with beam by mid-November 2009

Strategy for the first LHC physics run

Main strategy in commissioning :
establish circulating beams and good lifetime at the injection energy. ✔ Sept. 2008

Chamonix 2/2009 baseline
1 month commissioning
10 month proton physics
1 month lead ions

August '09 : Detailed discussion of the knowledge from the 5 sectors measured at warm and the 3 sectors measured at 80 K
All put together and discussed in special LMC meeting on 5 Aug. 2009.
Decision by management - 6 Aug. 2009.

Go in three steps
- **collisions at injection energy 2 × 0.45 TeV = 0.9 TeV**
- **physics run at 2 × 3.5 TeV = 7 TeV**
- **physics run at increased energy, max. 2 × 5 TeV = 10 TeV**

Towards the end of 2010 before the winter shutdown : 1st run with heavy ions, lead - lead.

Next steps in commissioning with beam

- complete the BPM checks (70%H, 30% V done)
- adjust and capture beam 1
- beam 1 & beam 2 timing
- experiments magnets : turn on solenoids and toroids
- possible to allow for first collisions at 2 × 450 GeV
- turn on IP2 / 8 spectrometers - verify perfect bump closure
- start to use collimators, increase intensity
- check out the beginning of the ramp, ~ 450 GeV to 1 TeV
- QPS commissioning
- beam dump commissioning
- full ramp commissioning to initial physics energy of 3.5 TeV
- first collisions at physics energy of 2 × 3.5 TeV
- increase intensity and partial squeeze

Maximum beam intensity LHC year 1

design LHC intensity : 3.23×10^{14} protons / beam

1st years, limited by magnet quench / collimation

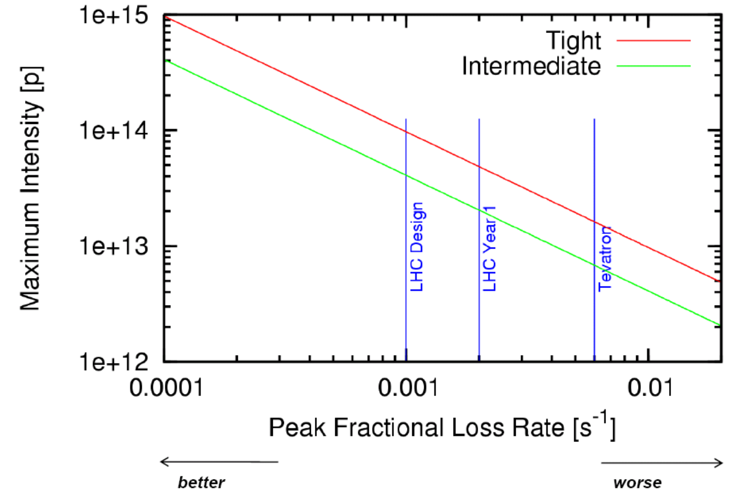
maximum beam loss rate ~ 10^{-3} /s fraction or ~4×10^{11} p/s

Examples for 0.001/s Loss Rate

- It is really the loss rate that matters above a few ms. So what counts is the ratio of loss amount over loss duration (short loss spikes are very dangerous). We get the peak loss rate 0.001/s from:
  - **1% of beam lost in 10 s.**
  - **0.1% of beam lost in 1 s.**
  - **0.01% of beam lost in 100 ms.**
  - **0.001% of beam lost in 10 ms.**
- Stick with the official loss rate 0.001/s from now on, adding some evolution.
- Assume 0.002/s is achieved in the first year of LHC operation at 5 TeV, as shown in following slides.

Ralph Assmann 21

Result: Intensity Limit vs Loss Rate 5 TeV



Ralph Assmann 18

 # bunches : nominal is 2808 bunches, 25 ns spacing

LHC year 1 : Important to go in small steps - minimize beam losses. Max. total intensity at 5 TeV roughly ~ 1/10 nominal.

start of physics run : $I < 2\times10^{13}$ p with intermediate coll. settings

later : $I < 5\times10^{13}$ p with tight coll. settings.

3.5 TeV intensities could be a bit higher - details remain to be worked out

Scaling of beam parameters with energy

Baseline beam parameters for E_b = 5 TeV have been worked out, discussed and agreed, LPC 7/5/09
Details for 3.5 TeV still need to be defined.

		scale factor 3.5 to 5 TeV
intensity	more critical at high E	take 1 ; conservative
emittance	E^{-1}	1.43
β*	$\sim E^{-1}$ triplet aperture	1.43
Luminosity	$\sim E^{-2}$	2
beam-beam tune shift	constant	1

Luminosity estimates : roughly 2× less at 3.5 TeV compared to 5 TeV
this should be conservative and does not take into account that lower energies are less critical for protection, shorter ramp time and faster turnaround.

Beam-beam tune shift parameter ξ
for head-on collisions depends only
on intensity (not energy, β*)

$$\xi = \frac{r_p N}{4\pi \epsilon_N}$$

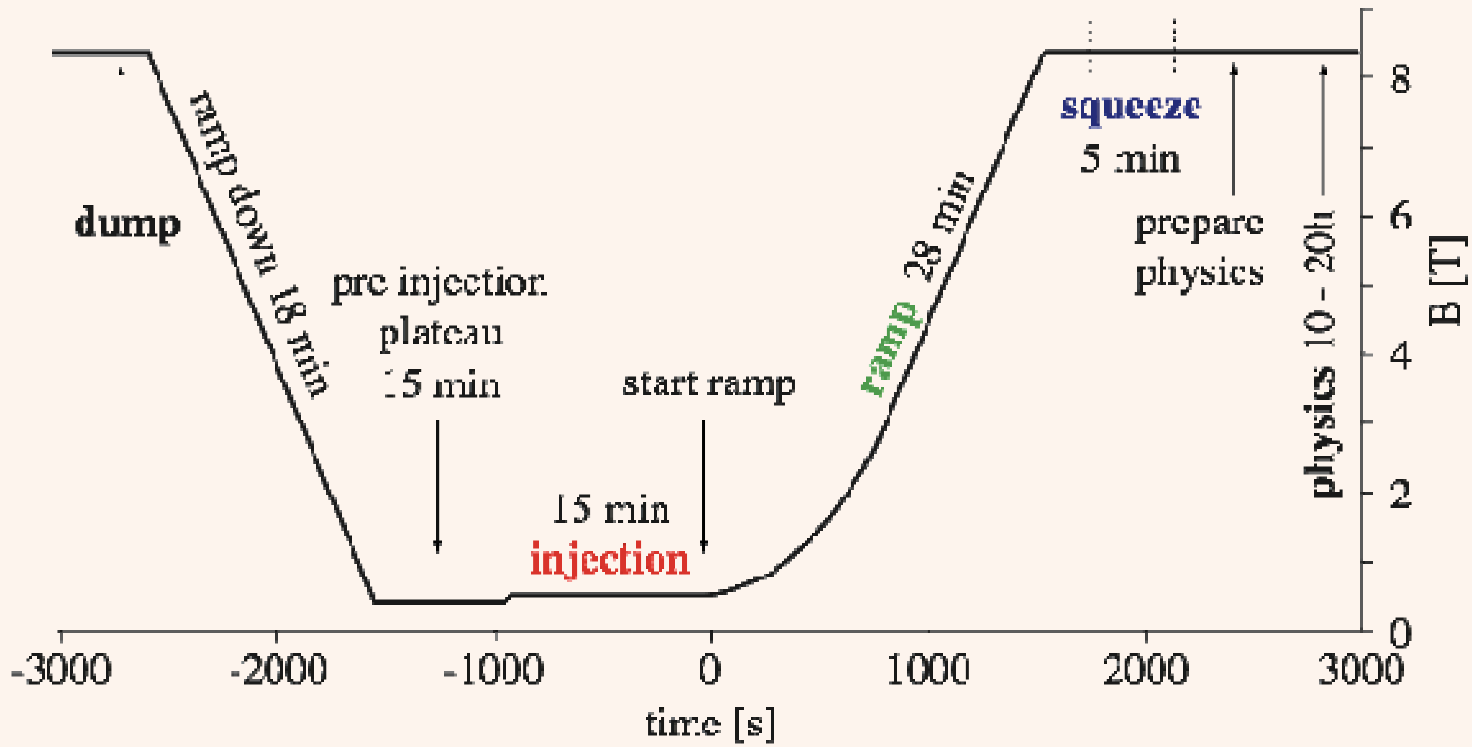
nominal LHC : round beams and const ε_N

$$\sigma_{x,y} = \sqrt{\beta_{x,y}\,\epsilon_N/\gamma}$$

N	ξ
5×10^9	0.000163
4×10^{10}	0.00130
1.15×10^{11}	0.00374

at the design emittance

LHC operation

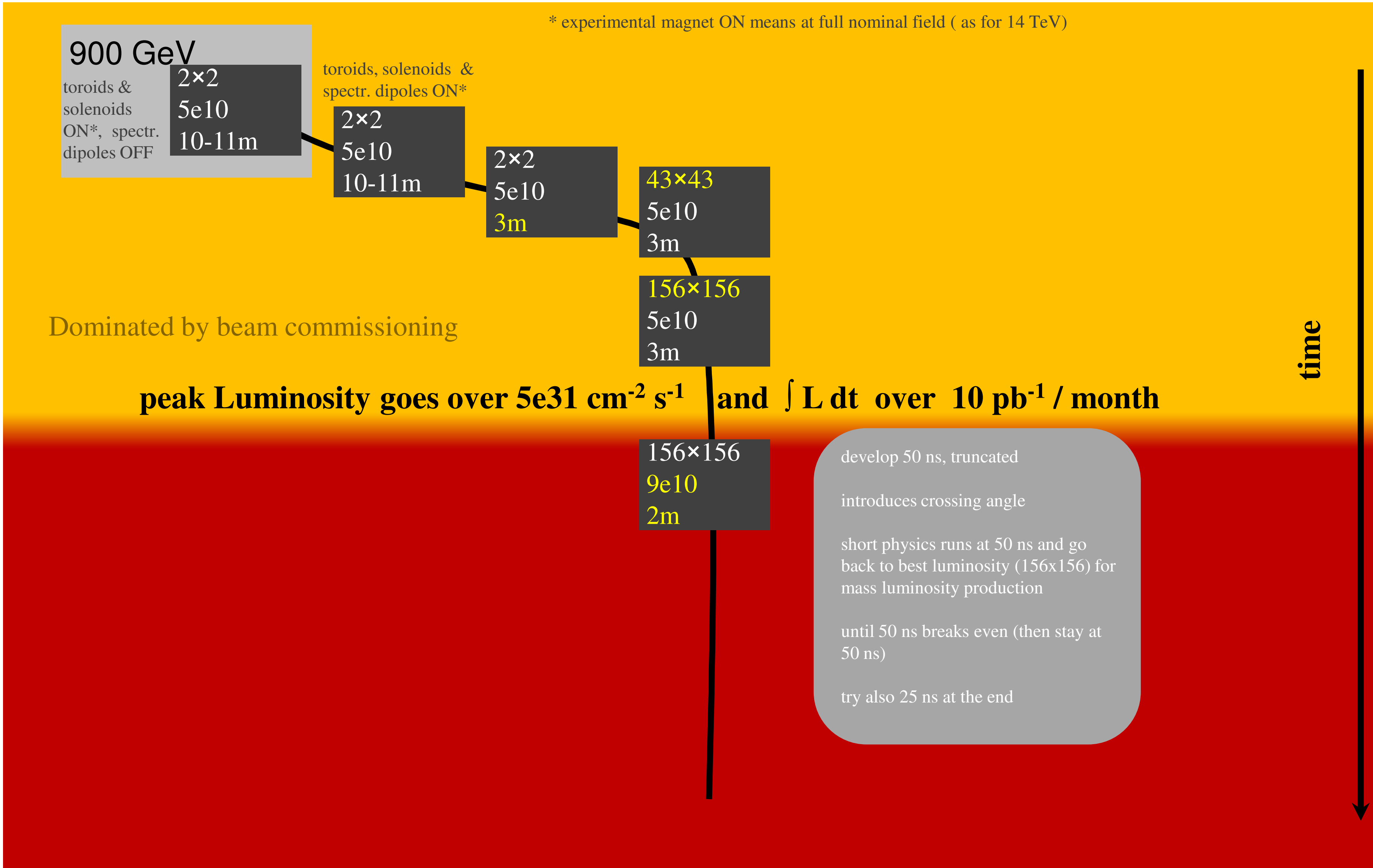


Many machine modes

Here concentrating on STABLE BEAMS. How to get the most for physics

Optimize conditions - based on direct feedback from experiment

Physics run modes for the 1st year



Based on Massimiliano Ferro-Luzzi, LPC 7-May 2009. Scaled to 2 × 3.5 TeV

Parameter space

		No crossing angle						Crossing angle				
Energy	TeV	0.45	0.45	3.50	3.50	3.50	3.50	3.50	3.50	4.00	5.00	7.00
Bunch intensity	1.E+10	1	4	4	4	4	9	9	9	9	9	11.5
Bunches		4	43	43	43	156	156	702	1404	2808	156	2808
Emittance	μm	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
β*	m	11	11	11	2	2	2	3	3	3	2	1
Luminosity	$cm^{-2} s^{-1}$	4.2E+26	7.2E+28	5.6E+29	3.1E+30	1.1E+31	5.6E+31	1.7E+32	3.3E+32	7.7E+32	8.0E+31	1.0E+34
Protons		4.0E+10	1.7E+12	1.7E+12	1.7E+12	6.2E+12	1.4E+13	6.3E+13	1.3E+14	2.5E+14	1.4E+13	3.2E+14
% nominal		0.0	0.5	0.5	0.5	1.9	4.3	19.6	39.1	78.3	4.3	100.0
Stored energy	MJ	0.0	0.1	1.0	1.0	3.5	7.9	35.4	70.8	161.7	11.2	361.7
Monthly (0.2)	pb-1	0.00	0.04	0.29	1.59	5.76	29.16	85.84	171.67	399.85	41.65	5231.88
Physics month				1	2	3	4	?	?	?	?	
Pile-up, σ_{in} = 75 mb				0.09	0.5	0.5	2.4					

(10^6 seconds @ <L> of 10^{33} $cm^{-2} s^{-1}$ → 1 fb^{-1})

courtesy : Roger Bailey, 7 Aug. 2009

Experimental conditions, LBS

LBS : LHC Background Study Group.
Chaired by H. Burkhardt, deputy D. Macina, scientific secretary A. Macpherson

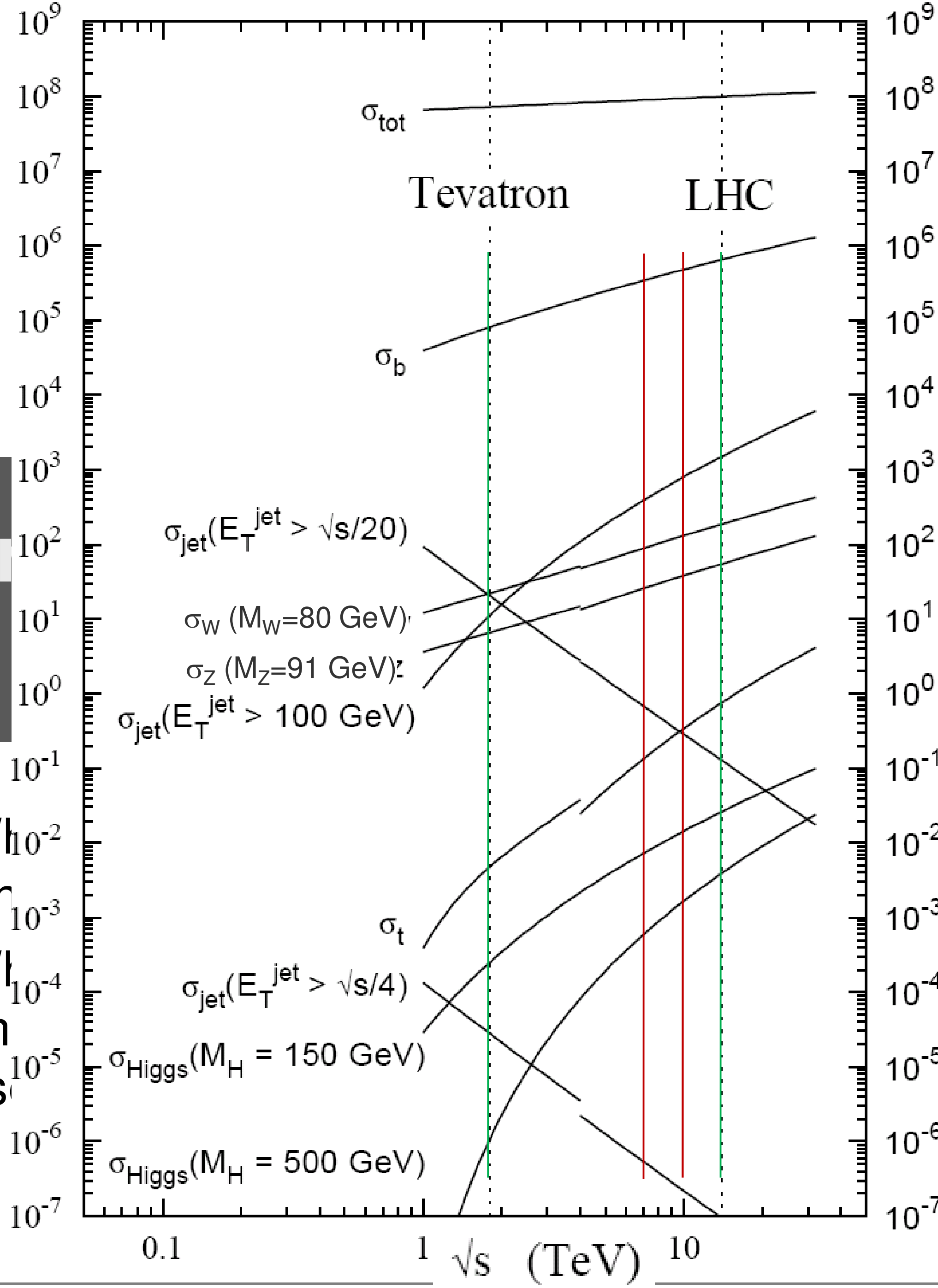
In addition to background simulation, studies and optimization covering more generally experimental conditions including luminosity optimization and calibration and signal exchange between experiments and machine.

Core members include the physics coordinator & LPC chairman Massimiliano Ferro-Luzzi and contact persons from the experiments

ALICE Antonello Di Mauro, Andreas Morsch + Werner Riegler
ATLAS Witold Kozanecki, Christophe Clement, Mika Huhtinen + Siegfried Wenig
CMS Richard Hall-Wilton, Tiziano Camporesi, + Nicola Bacchetta
LHCb Gloria Corti, Richard Jacobsson + Magnus Lieng
TOTEM Mario Deile; **LHCf** Daniela Macina

Currently meeting once per month on Thu. afternoon at the CCC
Open to all interested and help most welcome.
Next meeting is on 27 August, see indico

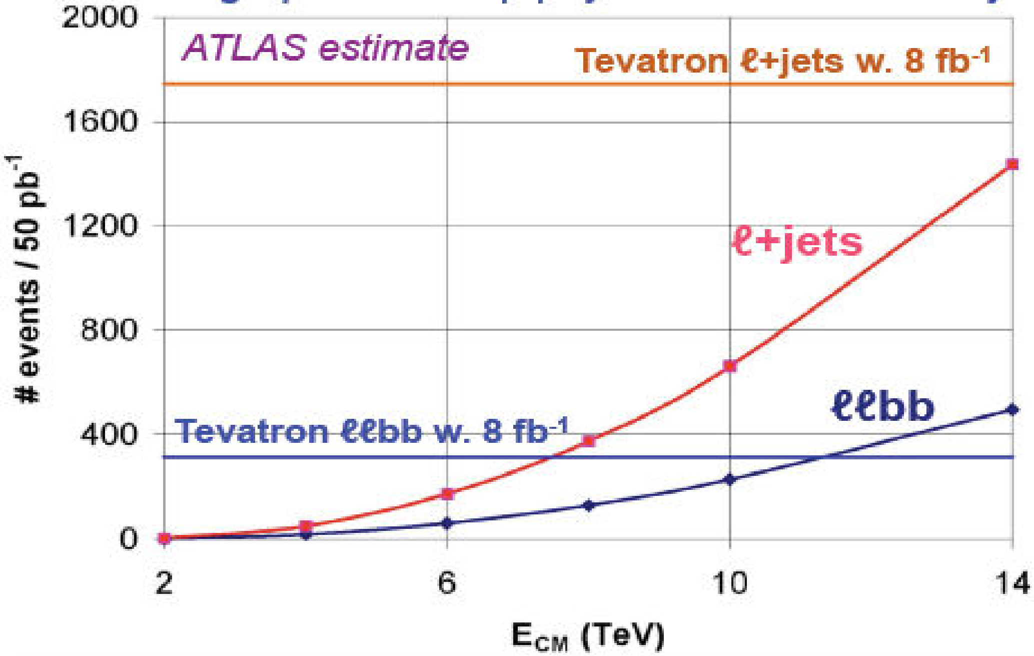
Integr… section



- Wh… n,
  wh…
- Wh… en
  en… ics run
  us… eV)

Top quark

- Background to new physics searches – must measure cross-section & properties in data
- Expected Tevatron statistics provide a benchmark:
  - Cross-section statistical precision will then be comparable to other uncertainties
  - High-precision top physics will be underway



~50 pb^{-1}@14 TeV would match full Tevatron sample

- lose ~factor 2 in cross-section dropping to 10 TeV
- lose ~another factor 2 dropping to 8 TeV

Below 8 TeV samples will be rather small, with a few tens of pb^{-1}

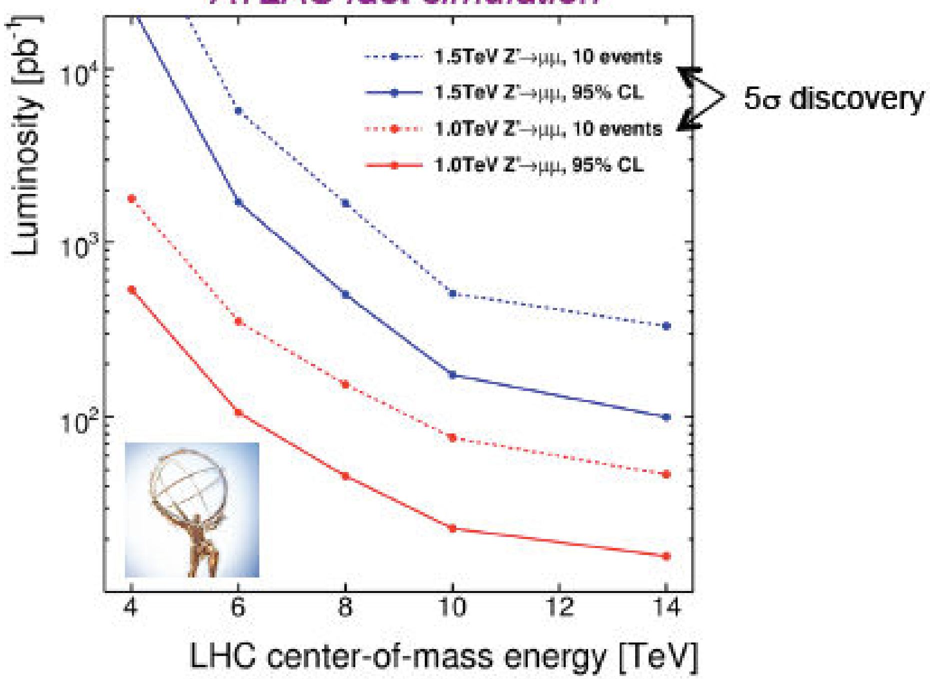
Catch up with Tevatron with **$s^{1/2}$ = 8-10 TeV** and ~**200-100 pb^{-1} g.d.**

Z'

Z': Heavy partner of the Z (SSM)

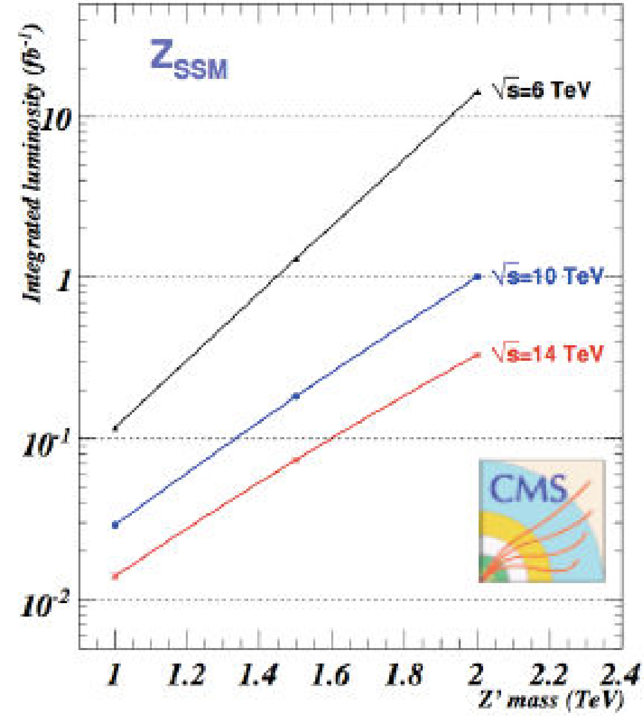
- Very clean experimental signal: $Z' \to \ell\ell$
- Tevatron 95% CL limit at $m_{Z'}$ =1 TeV

ATLAS fast simulation



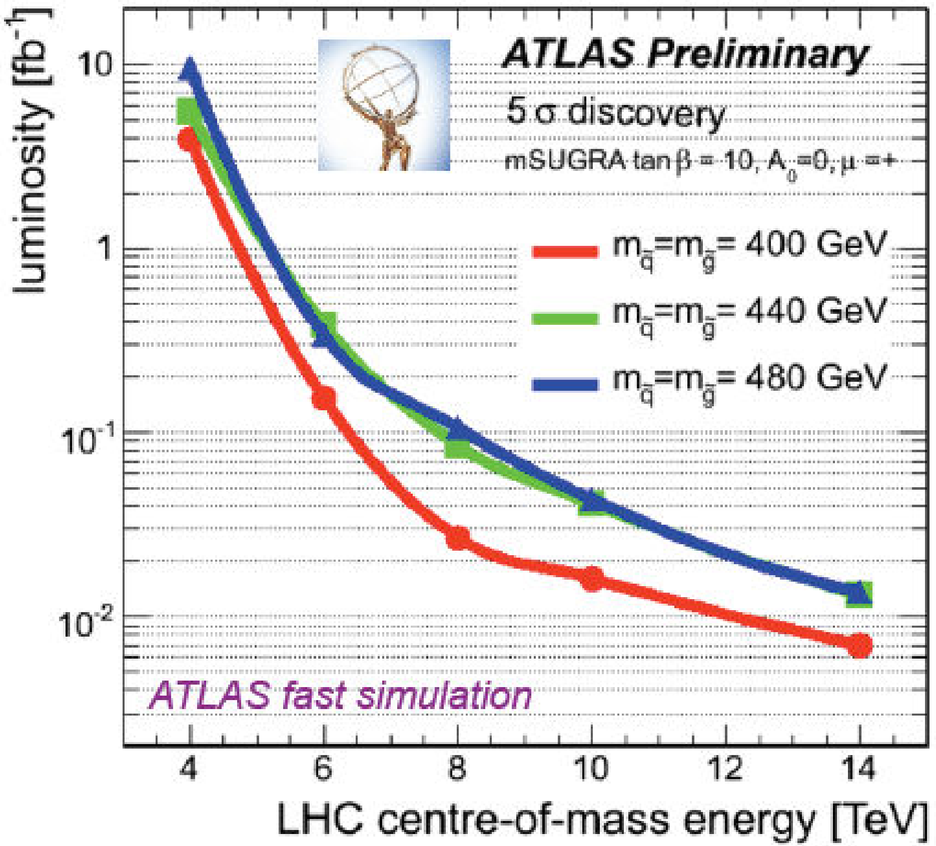
Needed luminosity for 95%CL exclusion at $m_{Z'}$ = 1 TeV :

$s^{1/2}$:	14	→	10	→	6 TeV
Lumi:	13	→	30	→	110 pb^{-1}



SUSY, an example

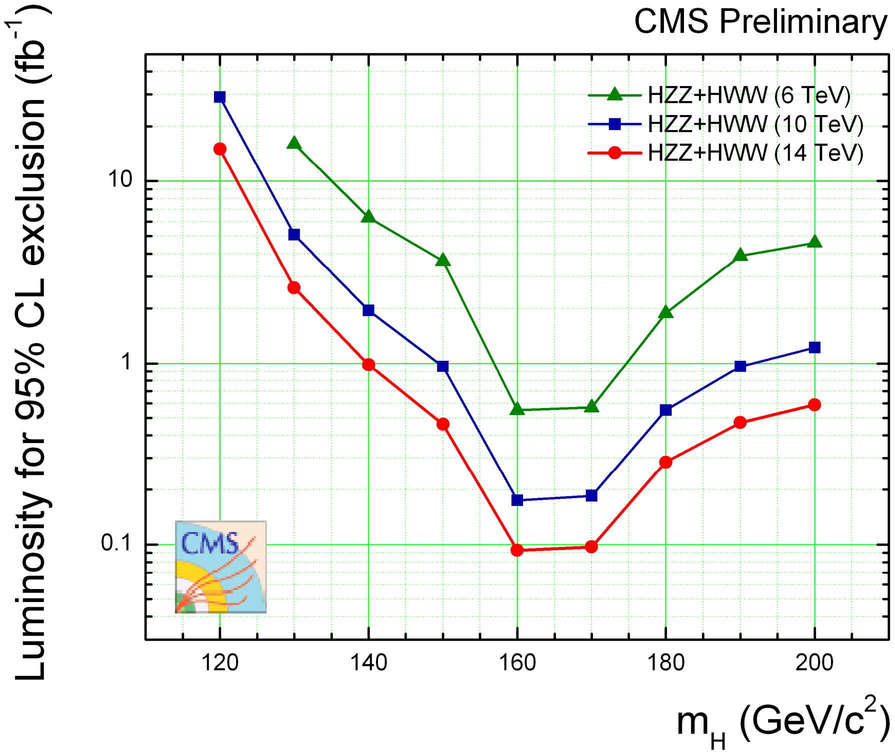
- ℓ+jets+missing-E_T channel
  - Not most sensitive, but will be usable before inclusive jets +missing-E_T analysis
- Tevatron limit currently is 380 GeV in this model ($m_{\tilde{q}} = m_{\tilde{g}}$)
  - plot shows 3 masses above this
- We will be sensitive to a region overlapping with ultimate Tevatron reach
- Below E_{cm}≈8 TeV, the sensitivity collapses



5σ discovery beyond current Tevatron limits is possible with
$s^{1/2}$ = 8-10 TeV and ~**30-15 pb^{-1} g.d.**

Higgs 95% CL at LHC GPD , H→ weak bosons, indicative

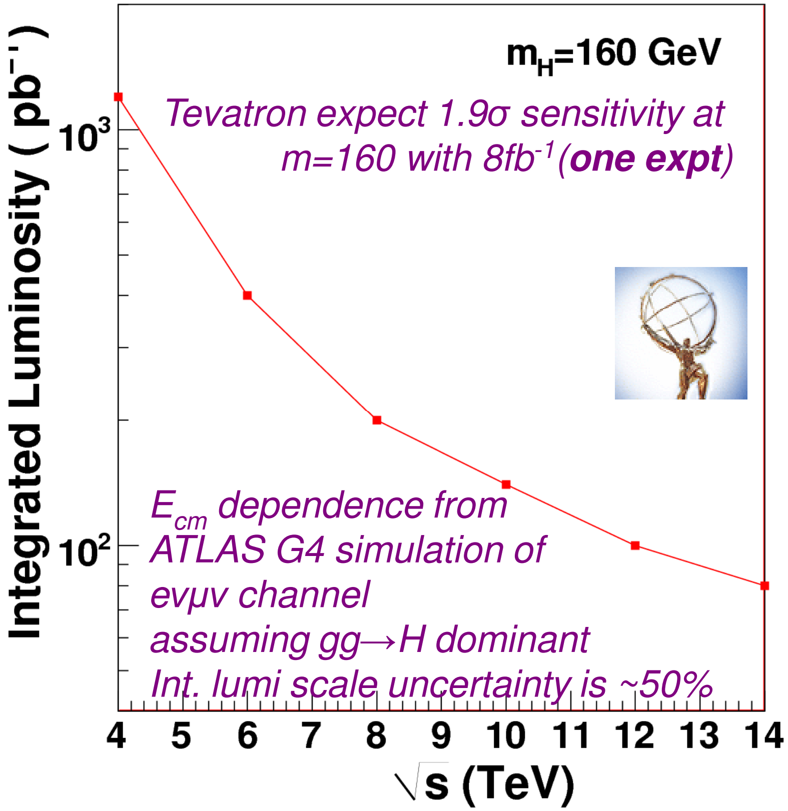
Combined H→WW + H→ZZ: lumi for 95% CL



- Energy $s^{1/2}$ 14 → 10 → 6 TeV
- Lumi needed 0.1 → 0.2 → 0.6 fb^{-1}

Compare sensitivity to Tevatron with 8 fb^{-1}

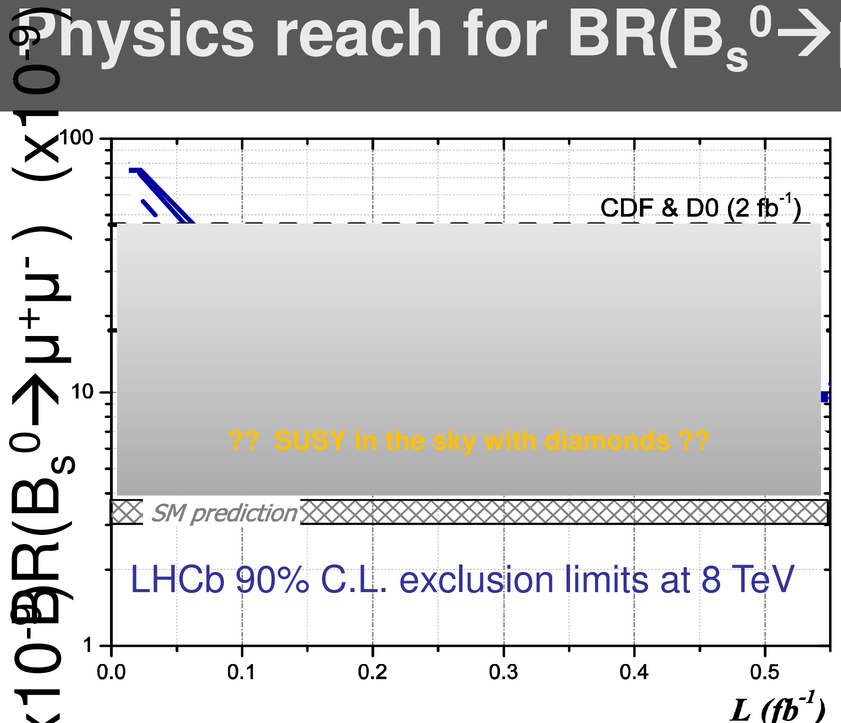
(only H→WW→ $\ell\nu\ell\nu$)



- Massive loss of sensitivity below 6 TeV

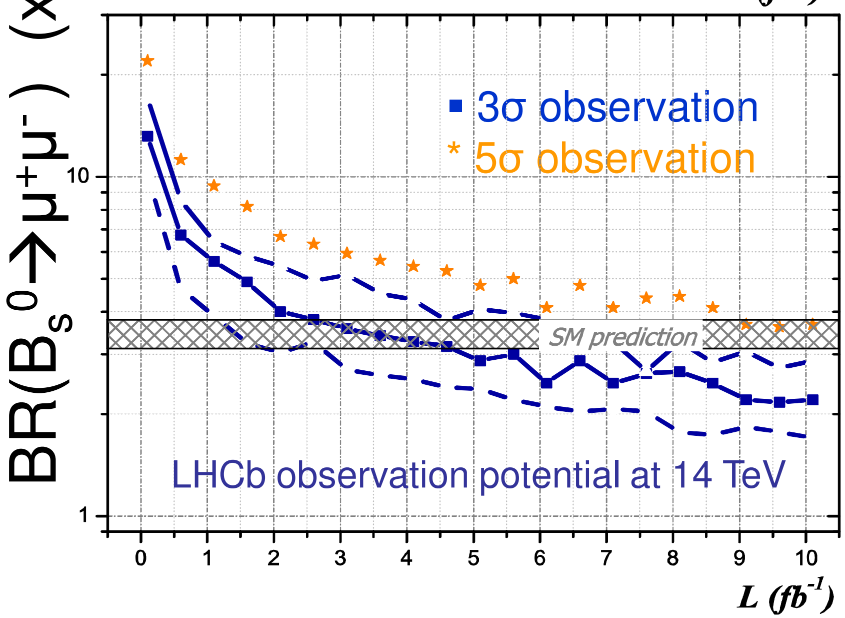
To challenge Tevatron with **$s^{1/2}$ = 8-10 TeV**, we need ~**300-200 pb^{-1} g.d.**

Physics reach for BR($B_s^0 \to \mu^+\mu^-$)



- as function of integrated luminosity (and comparison with Tevatron)

At $s^{1/2}$ = 8 TeV, need ~**0.3-0.5 fb^{-1} g.d.** to improve on expected Tevatron limit



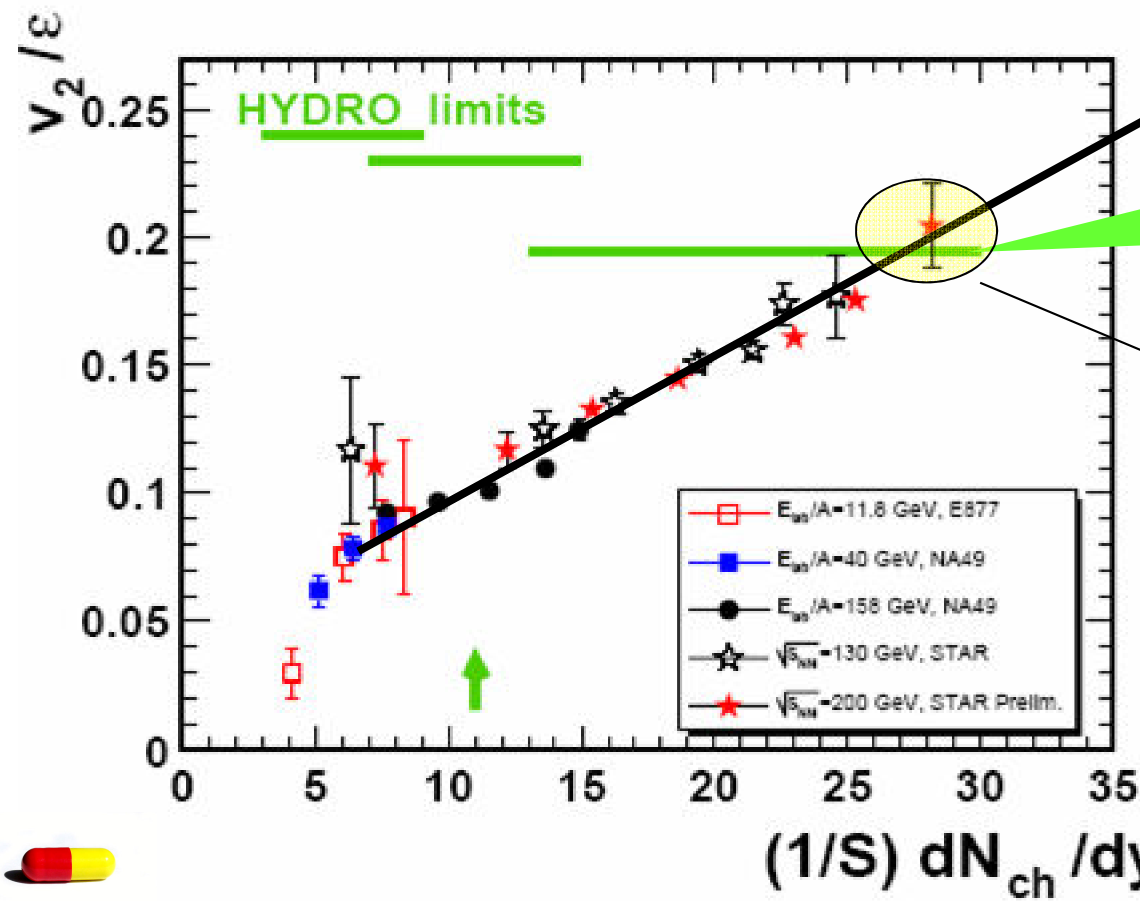
Collect ~3 fb^{-1} for 3σ observation of SM value

Heavy Ions: Flow at LHC

- one of the first and most anticipated answers from LHC
  - 2nd RHIC paper: Aug 24, 22k MB events, **flow surprise** (v_2)
    - Hydrodynamics: modest rise (Depending on EoS, viscosity, speed of sound)

LHC ?

increase of flow



BNL Press release, April 18, 2005:

Data = ideal Hydro

"Perfect" Liquid

New state of matter more remarkable than predicted – raising many new questions

LHC will either

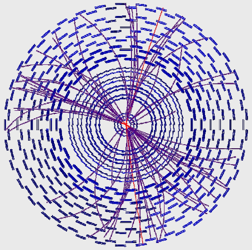
confirm the RHIC interpretation

(and measure parameters of the QGP EoS)

OR

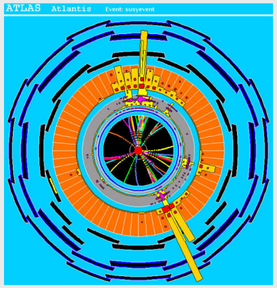
……………………..

LHC Physics in 2009/2010



First beams: very early physics - rediscover SM physics

Detector synchronization, in-situ alignment and calibration



10 pb^{-1}: Standard Model processes

measure jet and lepton rates, observe W, Z bosons

first look at possible extraordinary signatures…

30 pb^{-1}

Measure Standard Model Processes (at 10TeV need ~ 30pb^{-1}):

- ~ 10^4 Z $\rightarrow$ e+e- (golden Z's for detector studies (1%))
- ~ 10^5 W $\rightarrow$ eν
- ~ 10^3 ttbar (measure σ to 10%)

} Background for new physics
Need to understand very well

Initial Higgs searches and searches for physics beyond the SM

> 200 pb^{-1} Entering Higgs discovery era and explore large part of SUSY and new resonances at ~ few TeV

Operational Consolidation : Strategy

1. we have prepared an inventory of
   a) the existing spares and spare components for the LHC
   b) the existing spare components of the LHC infrastructure
   c) Consolidation needed to increase the efficiency of safe operation of the machine in the longer term
2. we have prepared a preliminary estimate of the total materials cost
3. In the MTP, we have planned a budget of 25MCHF/year to carry out this programme
4. The time prioritization of the operational consolidation work will be done by Risk Ranking of the inventory (by September 2009)
5. The manpower needed to carry out this programme has not yet been identified

40

Operational Consolidation

Materials cost only

- Spares (29MCHF)
- Helium storage (7.7MCHF)
- Cooling Tower maintenance and consolidation (LEP/LHC HVAC) (33MCHF)
- Electrical network consolidation (43MCHF)
- Radiation to electronics SEU; continuation of protection (4MCHF)

Vertical Pits/shafts (30MCHF)

- Tunnel modifications for overpressure: safety requirements (5MCHF)
- ARCOM-RAMSES replacement (10MCHF)
- Improvement in controlled access system (5MCHF)
- Clamping of busbar splices, development followed by campaign of replacements? (12MCHF)
- Vacuum consolidation to reduce collateral damage in case of splice rupture (+ protection of experiments)

Not yet known how to do technically)

- Centralised radiation workshop (3.0MCHF)
- Consolidation workshops (3) Transport (12.8), Radio protection (4)...19.8MCHF
- Water cooled cable replacement (if FLOHE would not pay).. (4MCHF)

MTP Approved!

Very preliminary total cost 176MCHF or if shafts needed ~ 200MCHF + vacuum consolidation

Not Only LHC….

“New Opportunities in the Physics Landscape at CERN”

http://indico.cern.ch/conferenceDisplay.py?confId=51128

- took place at CERN on May 10-13,
- a **starting point** to assess new ideas for **unique** experiments, which can be performed at CERN, outside the LHC programme.

Large interest in the community

- attendance (> 500),
- more than 100 abstract received,
- very lively community.

All abstracts, talks and recording of presentations, plus the summaries by the conveners appear on the site.

The sessions

Divided by subject and "accelerator requirements"

- SPS:
  - Deep inelastic scattering, including polarized targets – E.Aschenauer
  - Rare K-decays and CNGS – C. Touramanis
  - Hadrons and Ions – K. Peters
- PS and Non-accelerator Experiments – T. Sloan
- ISOLDE – Y. Blumenfeld
- n-ToF – F. Gunsing
- Test beams and Irradiation facilities – C. Rembser
- Antiproton decelerator (AD) – H. Abramowicz
- Possible future developments – M. Mangano

More work(shops) underway

- A neutrino workshop, co-organized with the SPC Study Group, will be held on October 1-3, 2009, to **focus the discussion** on the **European Strategy** on ν **physics**
- A workshop on LHeC is being held at Divonne on Sep 1-3
- A stronger connection among the CLIC and ILC **accelerator** and **detector** R&D is being realized.
- A technical review of the LHC new injection chain (LINAC4,SPL,PS2) is underway

Two special sessions

14:15->*16:05* New Proton drivers at CERN (Convener: L. Evans)

14:15	LINAC4 (10') (Slides)	Maurizio Vretenar (*CERN*)
14:25	PS2 (20') (Slides)	Michael Benedikt (*CERN*)
14:45	SPL (20') (Slides)	Roland Garoby (*CERN*)
15:05	SPS (10') (Slides)	Elena Shaposhnikova (*CERN*)
15:15	Future possible fixed target program from new injectors (20') (Slides)	Ilias Efthymiopoulos (*CERN*)
15:35	SPL: a driver for EURISOL? (10') (Slides)	Yorick Blumenfeld (*CERN*)
15:45	Beta-beams (10') (agenda)	Elena wildner (*CERN*)
15:55	Requirements on the proton source for future neutrino facilities (10') (Slides)	Alain Blondel (*Departement de Physique Nucleaire et Corpusculaire (DPNC)*)

11:15->*13:15* Other facilities (Convener: L. Evans)

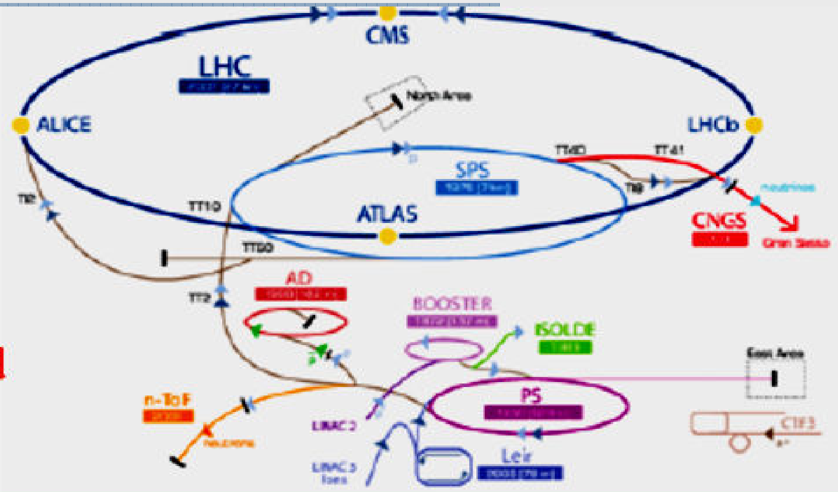
11:15	FERMILAB (20') (Slides)	Giorgio Apollinari (*Fermi National Accelerator Laboratory (FNAL)*)
11:35	BNL (20') (Slides)	Thomas Roser
11:55	KEK/JParc (20') (Slides)	Masakazu Yoshioka
12:15	GSI (20') (Slides)	Dieter Kraemer
12:35	Accelerator Requirements for a Neutrino Factory and Muon Collider (20') (Slides)	Michael Zisman (*Lawrence Berkeley National Laboratory*)
12:55	Dubna (20') (Slides)	Grigory Trubnikov (*Joint Institute for Nuclear Research, Dubna*)

Accelerators at Cern

LHC INJECTOR COMPLEX

Now saturated for the Fixed Target program

Upgrade for SLHC should be optimized as function of FT strategy



Now : LINAC2 $_{50\,MeV}$ → PSB $_{1.4\,GeV}$ → PS $_{26\,GeV}$ → SPS $_{400\,GeV}$ → LHC

Possible Upgrade : LINAC4 $_{160\,MeV}$ → SPL $_{4\,GeV}$ → PS2 $_{50\,GeV}$ → SPS+ $_{400\,(1000?)\,GeV}$ → SLHC

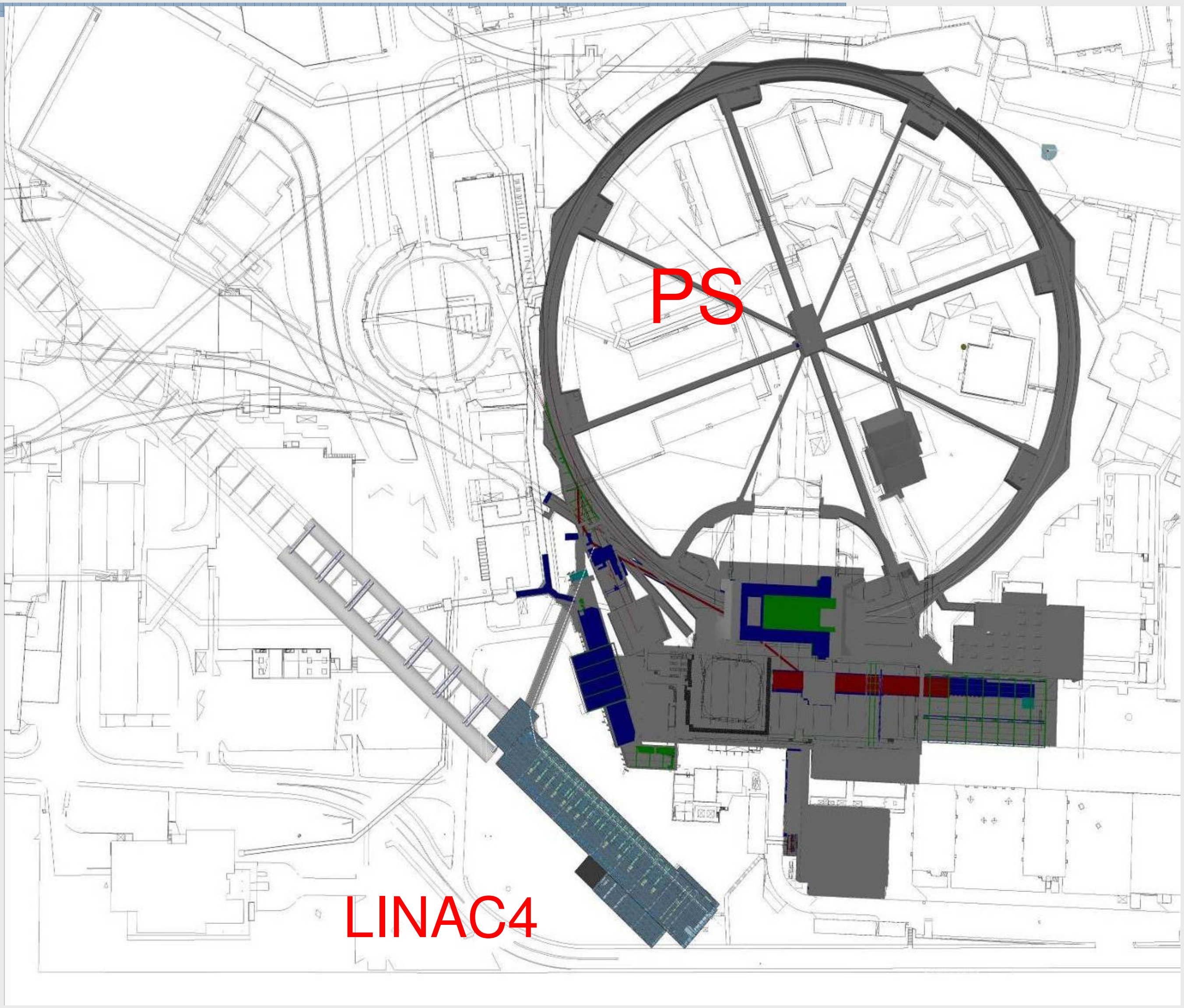
Strong potential impact on FT physics:
rare K/μ decays[87], new light leptons[11], ν superbeams/beta-beams/factory

Also few proposals to have LHC extracted beams for μ_{Bc} measurement [37] and study of high density systems [5] like in FAIR

A unique feature of CERN in the availability of high-E (low-I?) beams in addition to low-E/high-I beams from LHC injectors as in JLAB/JPARC/GSI/Project X

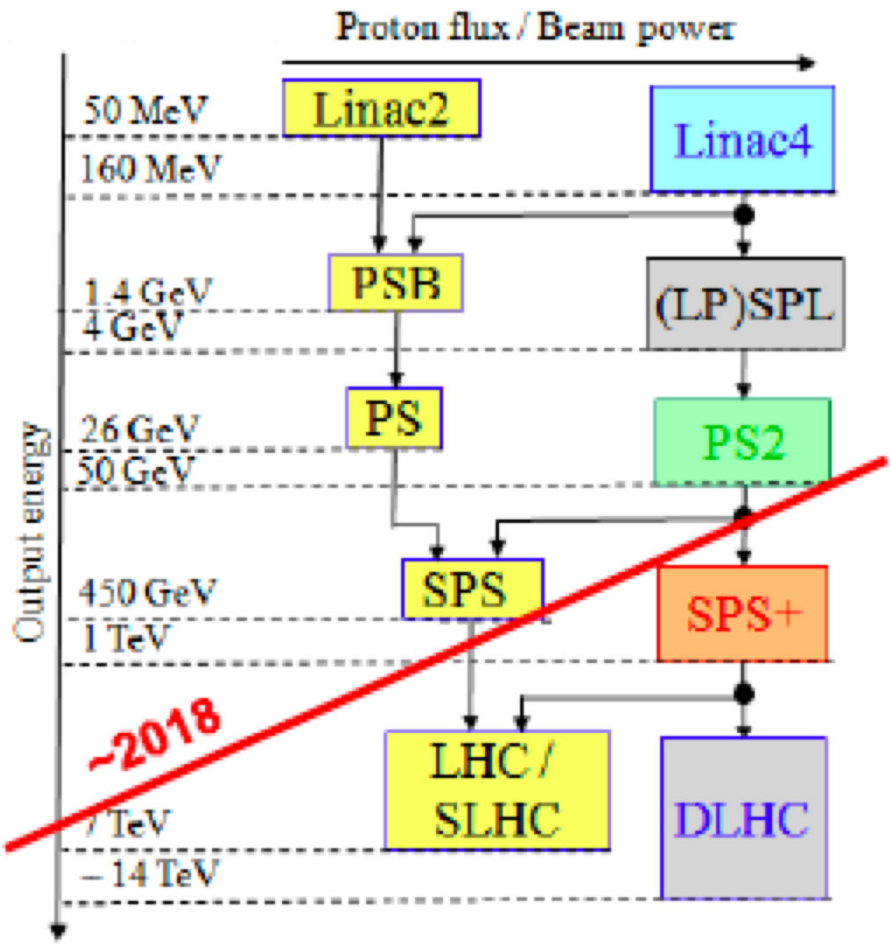
LINAC4 at the CERN side

- Correct size (~100m x 30m).
  - Easy connection to existing Linac2-PSB line.
  - Orientation allowing future extension to the SPL.
  - Natural (earth) shielding.
- Linac4 because the 4th ion linac to be built at CERN



A possible scenario

Landscape sometime in >2018 (2020?)



- LEIR in operation (since 2010)
  - 2011 ion extraction to NA possible
    - max 10^9 Ions/pulse
    - Pb^{82} and possibly light ions (for NA61)
- PS2 replaces PS
  - ~5 ÷ 50 GeV/c beams
  - 1.0×10^{14} ppp
  - 2.4s cycle fast / 3.5 slow extraction
  - end of PS-EA, nTOF, AD
    - ISOLDE gets the beam SPL
- SPS Upgrade
  - Single injection form PS2 → shorter cycles
  - The machine is upgraded and can handle the PS2 delivered intensity!

Study group is working on PS2 experimental area options, report end June 2009.

Cern in the next 5-10 years

from the conclusions of SPSC and INTC chairs

High Energy Frontier
LHC

Hadronic Matter
deconfinement
hadron structure
non-perturbative QCD

Neutrino Oscillations

Low Energy
heavy flavours
rare decays
antiprotons

Non-accelerator
dark matter
double β decay
astroparticles

Multidisciplinary
climate, medecine, …

s,

ISOLDE
isotopes He to Ra
10^{-6}eV – 3MeV/u
shell evolution, shapes,
exotic nucl.,tests of SM

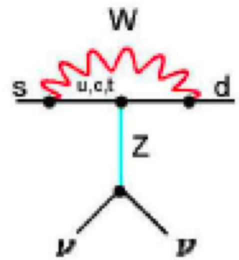
SPS - looking for new physics

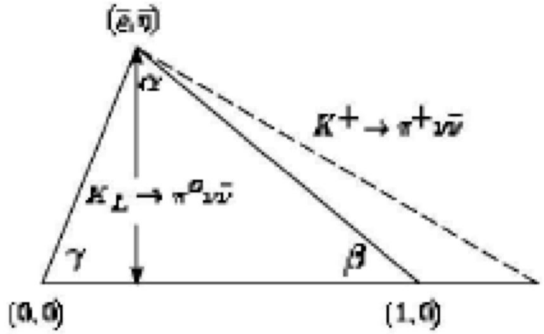
RARE DECAYS:
K PHYSICS

Two ultra-rare K decays
$K^0 \to \pi^0 \nu\nu$, $K^+ \to \pi^+ \nu\nu$
with very precise SM prediction

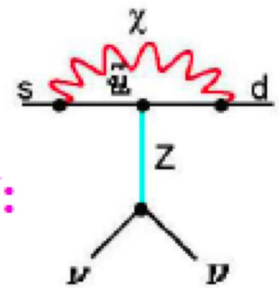
Complementary to B factories for CKM and BSM searches

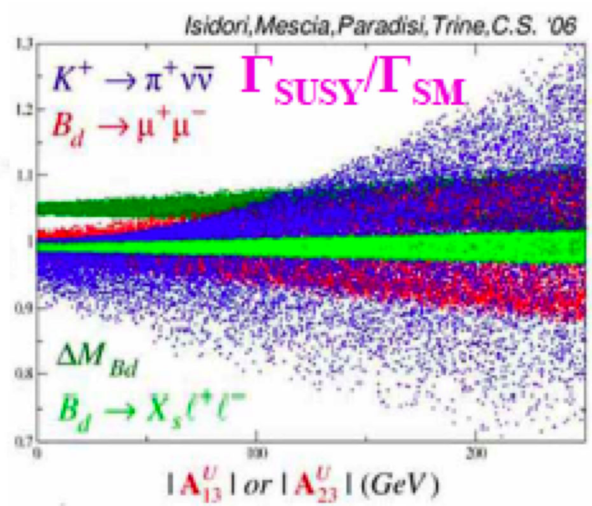
SM:





SUSY:

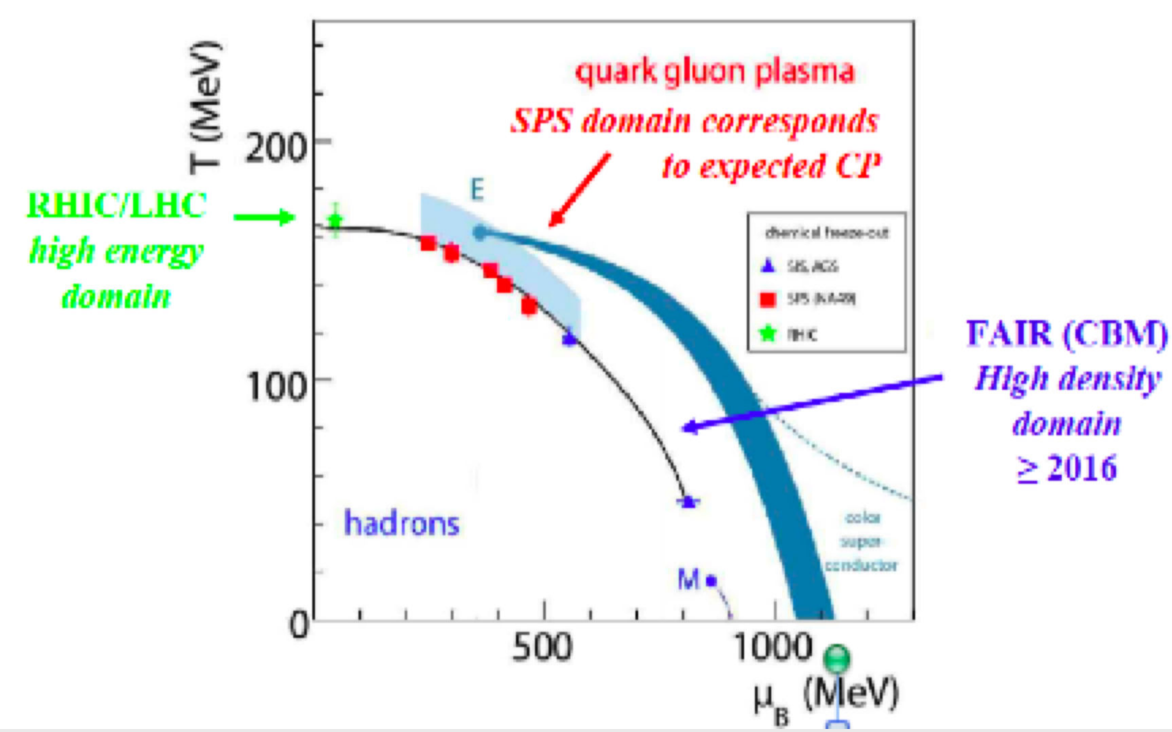




Current Results
- $K^0 \to \pi^0 \nu\nu$: BR(SM) ~ $o(10^{-11})$, current upper limit $o(10^{-7})$
- $K^+ \to \pi^+ \nu\nu$: BR(SM) ~ $o(10^{-10})$, current value $1.7 \pm 1.1 \; 10^{-10}$ based on a few events at BNL

No experiment currently in operation

SPS (light) ion program

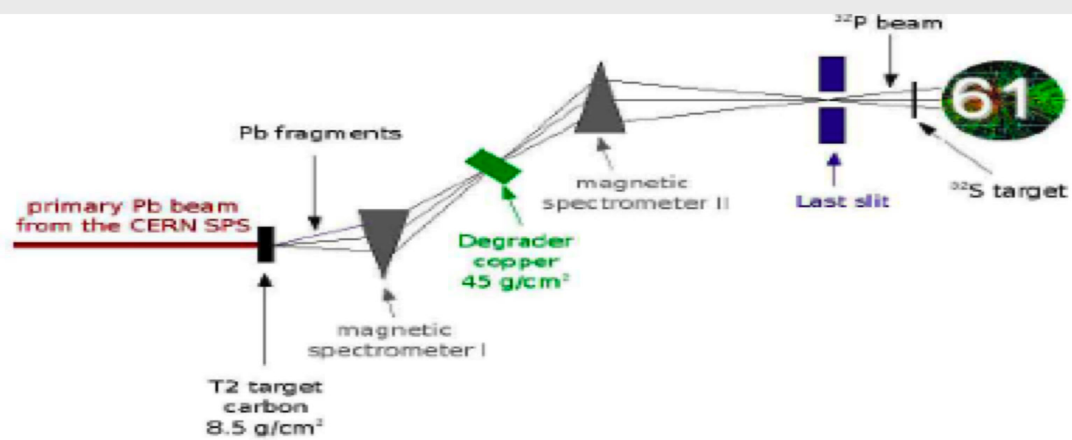


- Hadronic matter
- → deconfinement
- search for critical point, understanding of phase transition

SPS gives an unique possibility for a scan

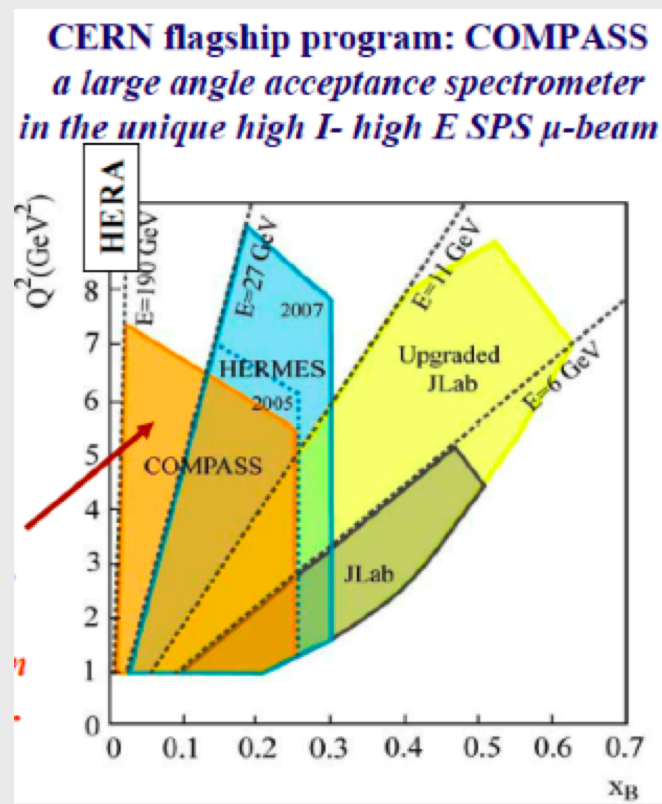
option of light ion in parallel with Pb for LHC being checked

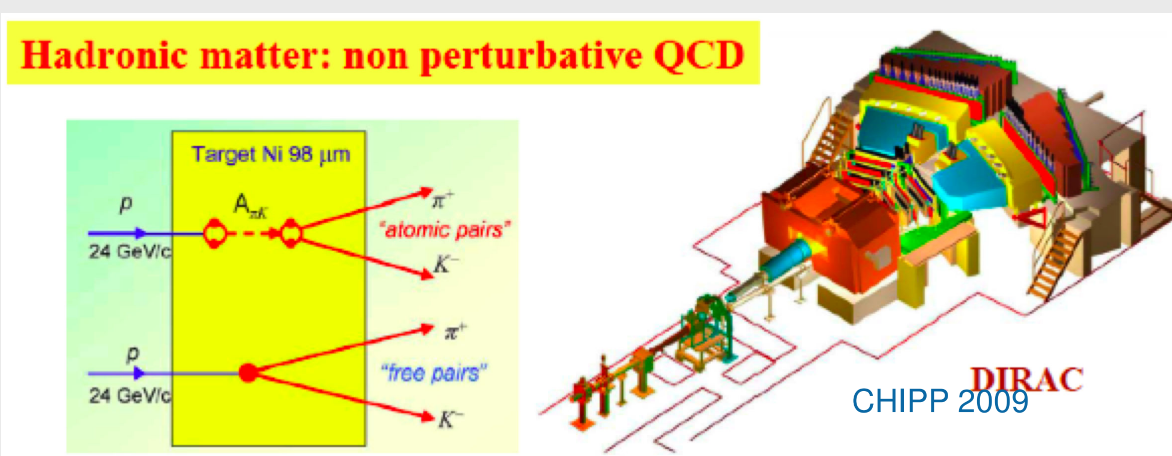
No light ions foreseen for LHC before ≥ 2015 !
→ scan may need secondary ions produced from primary Pb with a degrader [61]



SPS program – muon and hadron beams

- hadron structure physics tries:
  - to understand the phenomenology resulting from QCD
  - provide input for searches for New Physics
- improvements in precision and kinematic coverage for parton distributions is still needed
  - COMPASS short, medium and long term plans:
    - spin structure, GPD, D-Y on pol. nucleon
    - exotic states, central production
  - DIRAC – now PS, 2011→SPS (πK,KK,$\pi\mu$)





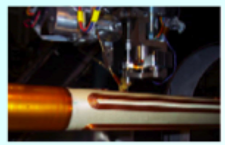
Antiproton decelerator (AD)

At the CERN AD a number of unique, important CPT tests were already conducted and improved ones are on their way :

- **ASACUSA** $\bar{p}He$, $\bar{p}He^{+}$, $\bar{p}H$, $\bar{p}$

- **ATRAP** $\bar{p}$, $\bar{p}H$

- **ALPHA** $\bar{p}H$



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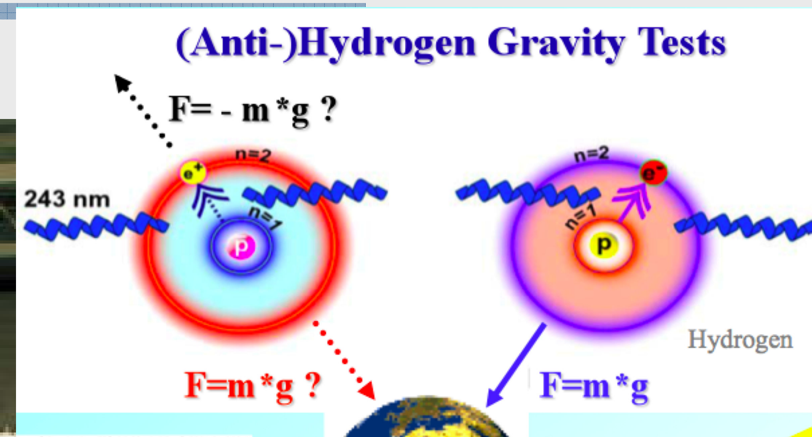
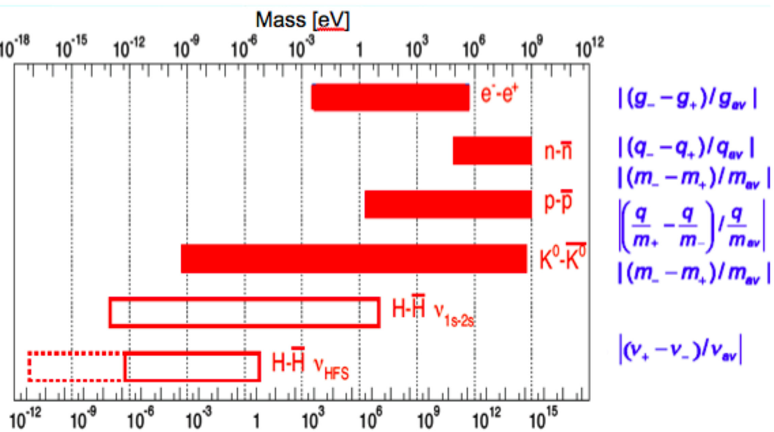


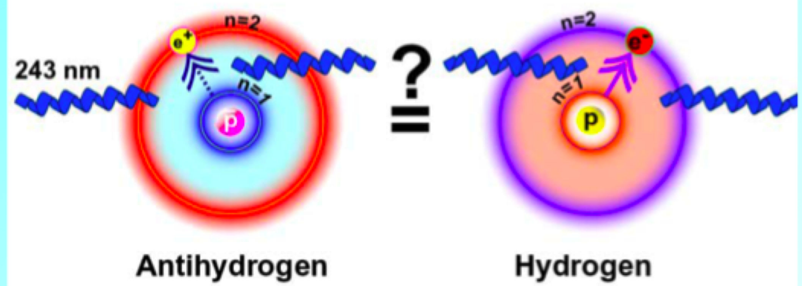
anti-protons experiments

Verifications of CPT symmetry

Using the Kostelecky *et al.* Standard Model Extension scheme



(Anti-)Hydrogen CPT Tests

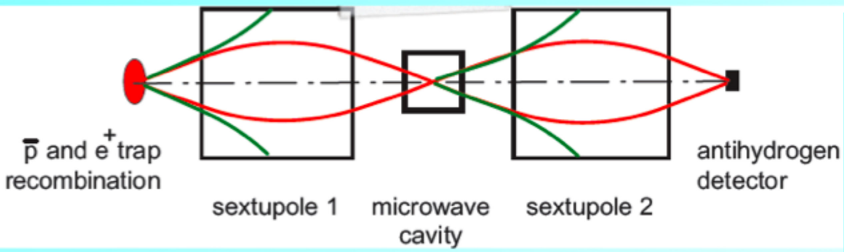


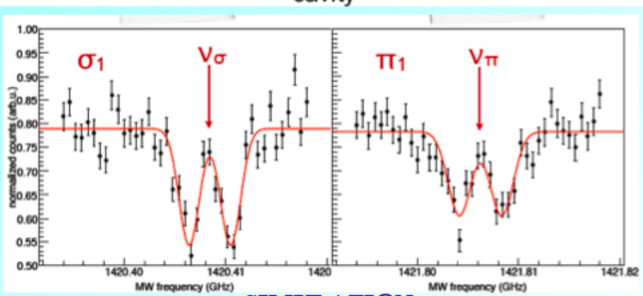
Laser spectroscopy 1s-2s -------- Microwave spectroscopy 1s Hyperfine Structure

$\Delta\nu_{1s2s} = \frac{3}{4} * R_\infty + \varepsilon_{QED} + \varepsilon_{nucl} + \varepsilon_{weak} + \varepsilon_{CPT}$ $\Delta\nu_{HFS} = \text{cons.} * \alpha^2 R_\infty + \varepsilon'_{QED} + \varepsilon'_{nucl} + \varepsilon'_{weak} + \varepsilon'_{CPT}$

"Long distance" Interaction "Contact" interaction

p̄H Ground-state Hyperfine Structure

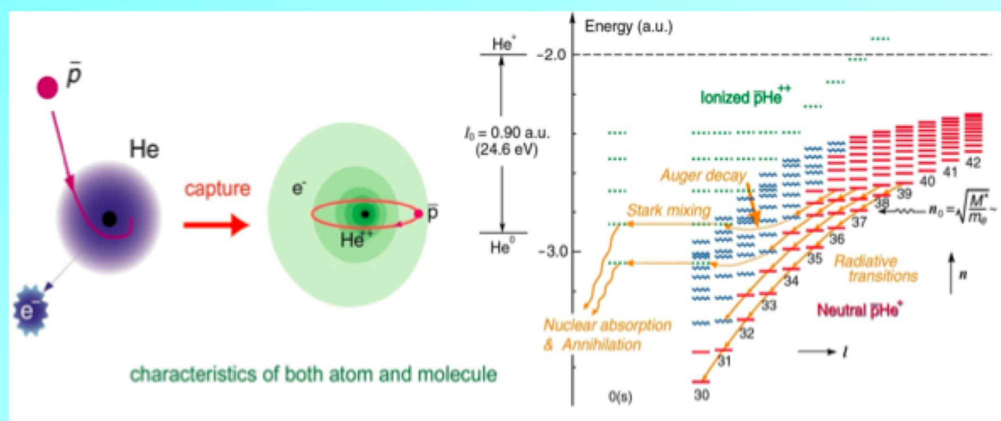




SIMULATION

Need less particles (2 p̄H / s) because of narrow natural linewidth

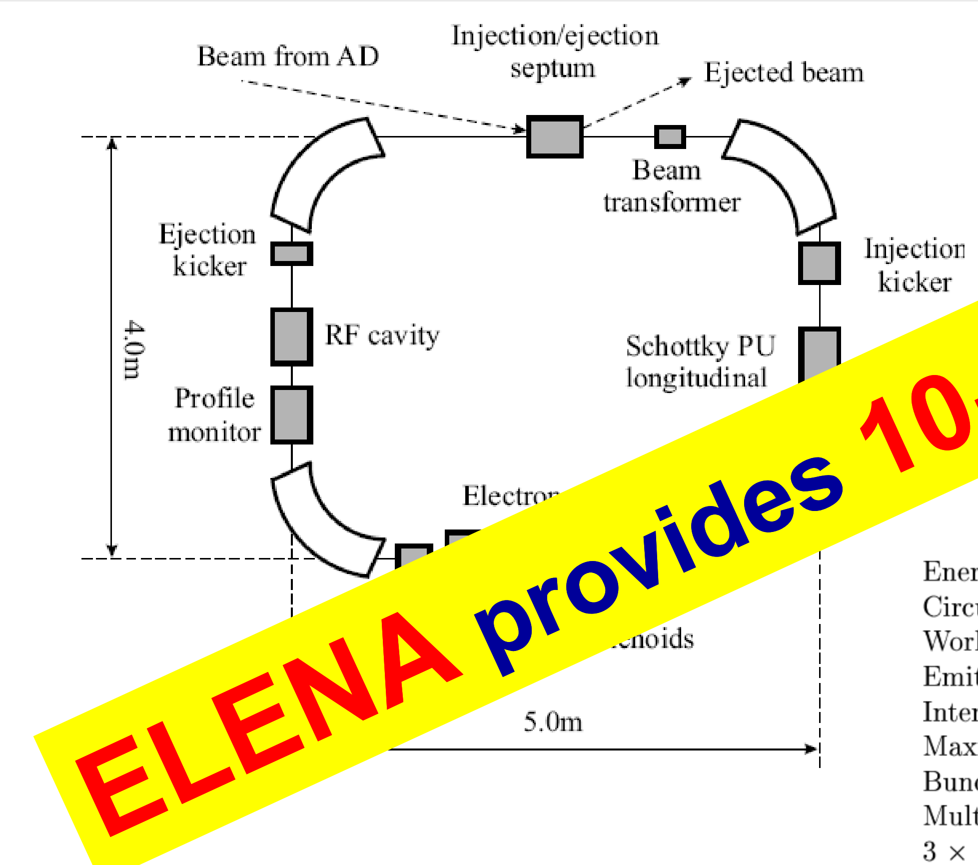
p̄He⁺ Atom – a naturally occurring trap for antiproton



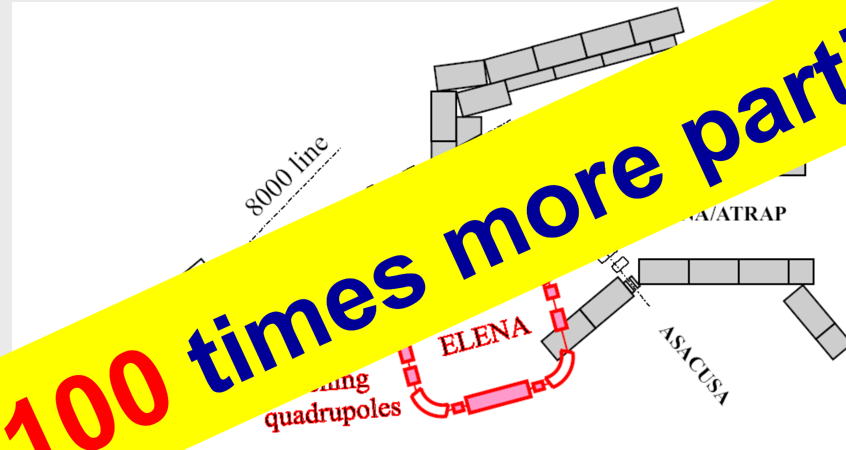
- Serendipitously discovered by Tokyo group at KEK

Consequent Future Developments

ELENA@CERN



Layout of the ELENA ring.



ELENA provides 10-100 times more partic

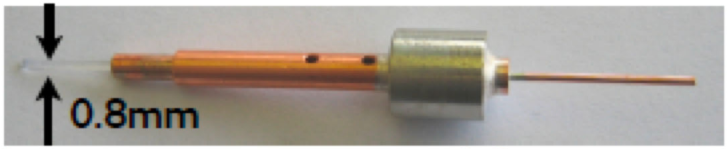
Energy range, MeV	5.3 - 0.1
Circumference, m	16.7
Working point	1.64 / 1.62
Emittances at 100 keV, π mm mrad	5 / 5
Intensity limitations due to space charge	1.7×10^{7}
Maximal incoherent tune shift	0.10
Bunch length at 100 keV, m / ns	1.3 / 300
Multiple scattering blow up rate for 3×10^{-12} Torr (N_2 equiv.), $\pi mm\ mrad/s$	0.5
IBS blow up times, s ($\Delta p/p = 2\ 10^{-3}$)	3.2 /-30.6 / 3.9

needed synchronization with FLAIR @ GSI/FAIR (>2015)

Interdisciplinary research at CERN

- CLOUD combines atmospheric physics & chemistry, solar physics, cosmic ray physics and particle physics
- CERN makes an essential contribution to CLOUD:
  - facilities: particle beam
  - specialist expertise:
    - ultra-clean/UHV surfaces & welds, ceramic-metal brazing, electric field cages, cryogenics, gas systems…
  - "culture":
    - coordination of complex experimental facilities built by large international collaborations (design, construction, assembly, operation & analysis)
    - obsessive attention to technical design details
    - all problems - technical and scientific - are viewed at a fundamental physical level (even chemistry...)

UV fibre feedthrough S.Mathot, A. Braem



Astroparticle Physics
Relations to CERN

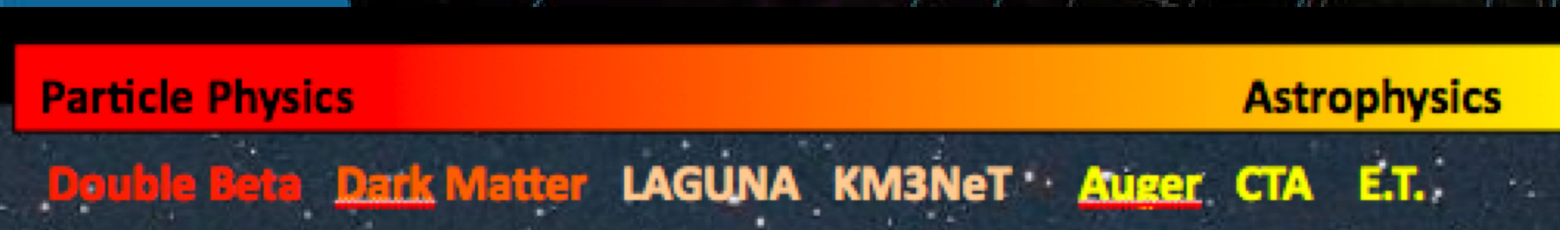
CAST search for solar axions

Christian Spierin

ISOLDE, n-TOF ↔ nuclear astrophysics

NA-61 ↔ air showers

… are examples for CERN experime
on astroparticle physics or closely rela
to astroparticle physics



Detector R&D for DM search and other experiments can largely profit form CERN expertise and resources

A European Centre for Astroparticle Theory could be established either in one of the European countries or at CERN.
Given the synergy between LHC physics and astroparticle physics, CERN would be a natural host, particularly in view of several astroparticle experiments being CERN recognized experiments.

New proposals

- search for neutral lepton (PS,SPS..)
- study of "MiniBoone anomaly" (neutrino beam from PS)
- MODULAR – very massive Liquide argon detector on CNGS beam
- charm baryons magnetic moment (extr. LHC beams)
- charm production (fixed target with LHC protons)
- mono energetic gammas, electrons in LHC
- Proton Driven Plasma Wakefield Acceleration
- measurement of u/d quarks distribution inside proton (for interpretation of LHC results)
- novel axion helioscope - axion detection in the gradient of magnetic field

Making CERN more global

- Council group for CERN enlargement has been setup and has started to organize its actions.
- Cern has intensified bilateral meeting with the other regions (labs, agencies)
- More proactive role of Cern in improving networking among the European Labs

In summary

- By year 2013, **experimental results** will be dictating the agenda of the field.
- Early discoveries will greatly accelerate the case for the construction of the next facilities (Linear Collider, ν-factory, SLHC…)
- No time to idle: a lot of work has to be done in the meantime

In summary

We will need

- Flexibility
- Preparedness
- Visionary global policies

Very exciting years are ahead of us