# THE STATUS OF THE LHC AND FUTURE PROJECTS AT CERN

Emmanuel Tsesmelis
*Directorate Office, CERN &*
*Visiting Lecturer, JAI*

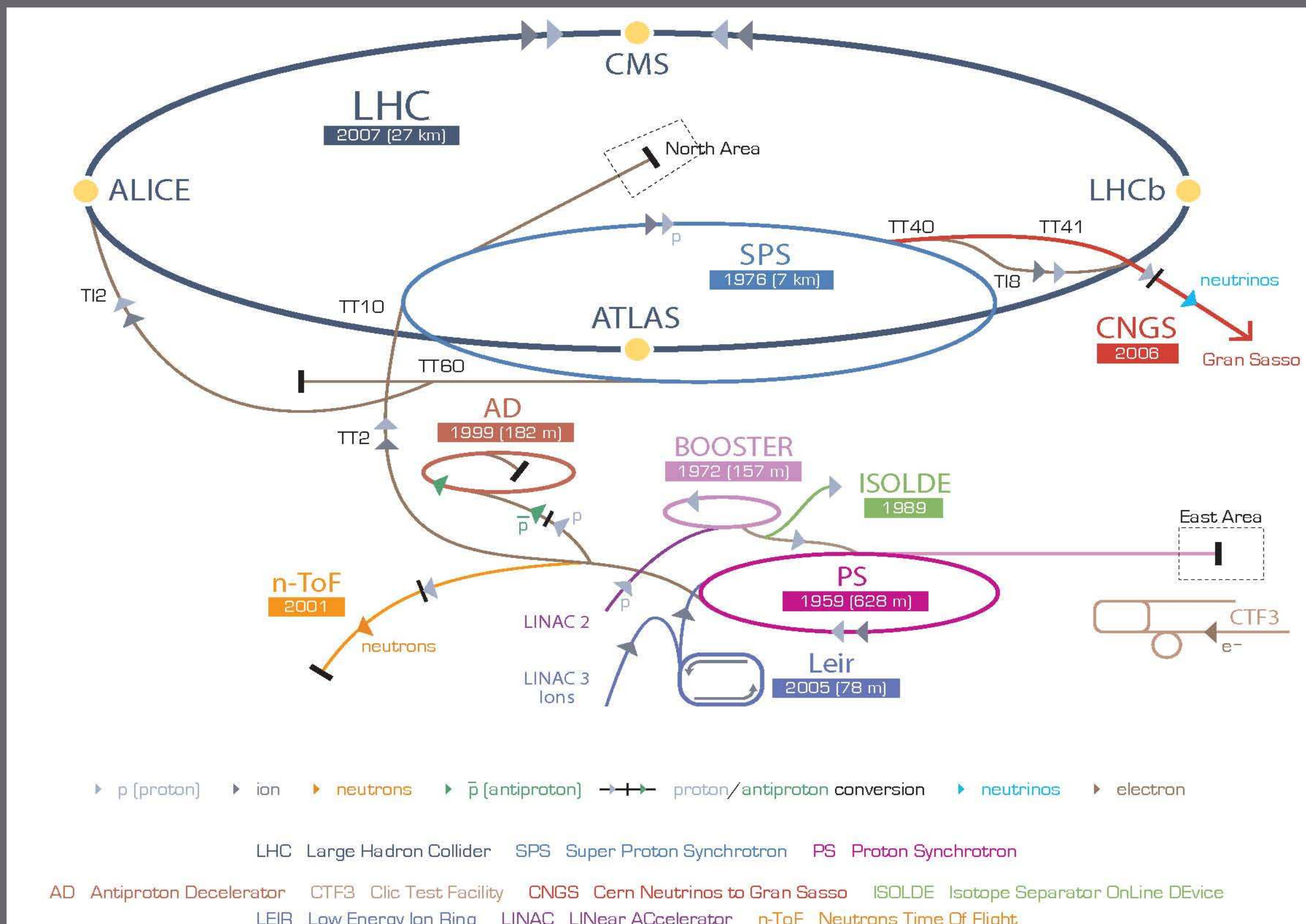
The University of Oxford
13 March 2009

# Table of Contents

- Status of the LHC
  - The LHC Accelerator
  - Commissioning with Beam
  - Sector 3-4 Incident
  - Commissioning the Physics Programme
  - Physics Run 2009-2010
- Future Projects at CERN
  - ATLAS/CMS Interaction Regions
  - LHC Pre-Accelerators

# THE LHC ACCELERATOR

# CERN Accelerator Complex

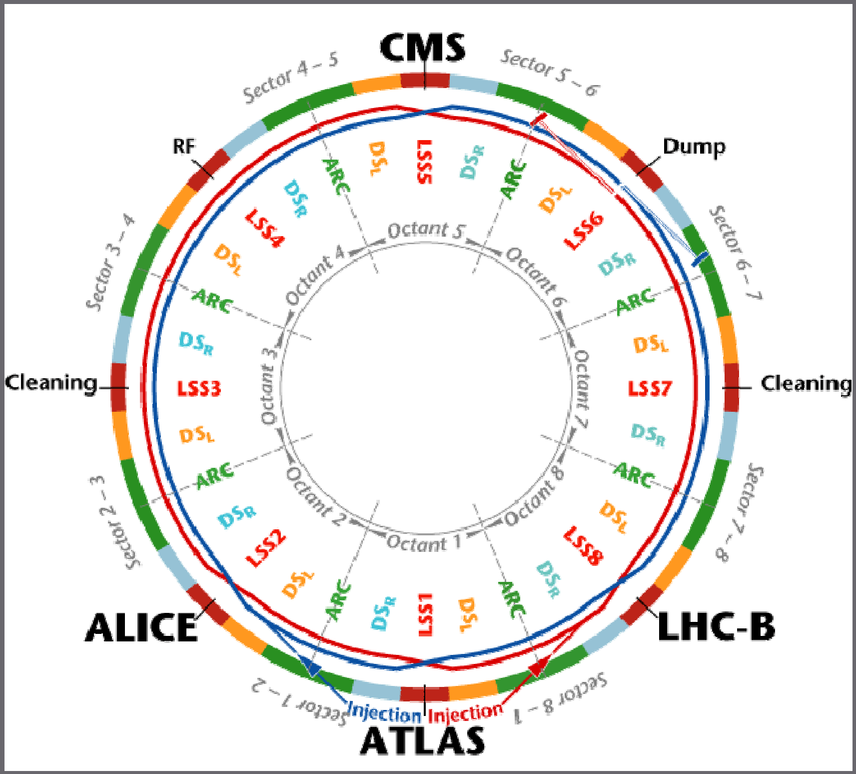


# LHC Accelerator & Experiments


Underground circular tunnel 27 km circum-ference; 100 m underground

4 caverns for experiments (•)

# LHC LAY-OUT




- The LHC is a two-ring superconducting proton-proton collider made of eight 3.3 km long arcs separated by 528 m Long Straight Sections.
- While the 8 eight arcs are nearly identical, the 4 straight sections are very different.

| | | |
|---|---|---|
| **Momentum at collision** | **7 TeV/c** | |
| Momentum at injection | 450 GeV/c | |
| Dipole field at 7 TeV | 8.33 Tesla | |
| Circumference | 26658 | m |
| **Stored energy magnets** | **9.4** | **GJ** |

| | | |
|---|---|---|
| **Luminosity** | **$10^{34}$ $cm^{-2}s^{-1}$** | |
| Number of bunches | 2808 | |
| Particles per bunch | $1.1 \cdot 10^{11}$ | |
| DC beam current | 0.56 | A |
| **Stored energy per beam** | **360** | **MJ** |

| | | |
|---|---|---|
| **Normalised emittance** | **3.75** | **µm** |
| Beam size at IP / 7 TeV | 15.9 | µm |
| Beam size in arcs (rms) | 300 | µm |

Arcs: Counter-rotating proton beams in two-in-one magnets

| | | |
|---|---|---|
| **Magnet coil inner diameter** | **56** | **mm** |
| Distance between beams | 194 | mm |

High beam energy in LEP tunnel
superconducting NbTi magnets at 1.9 K

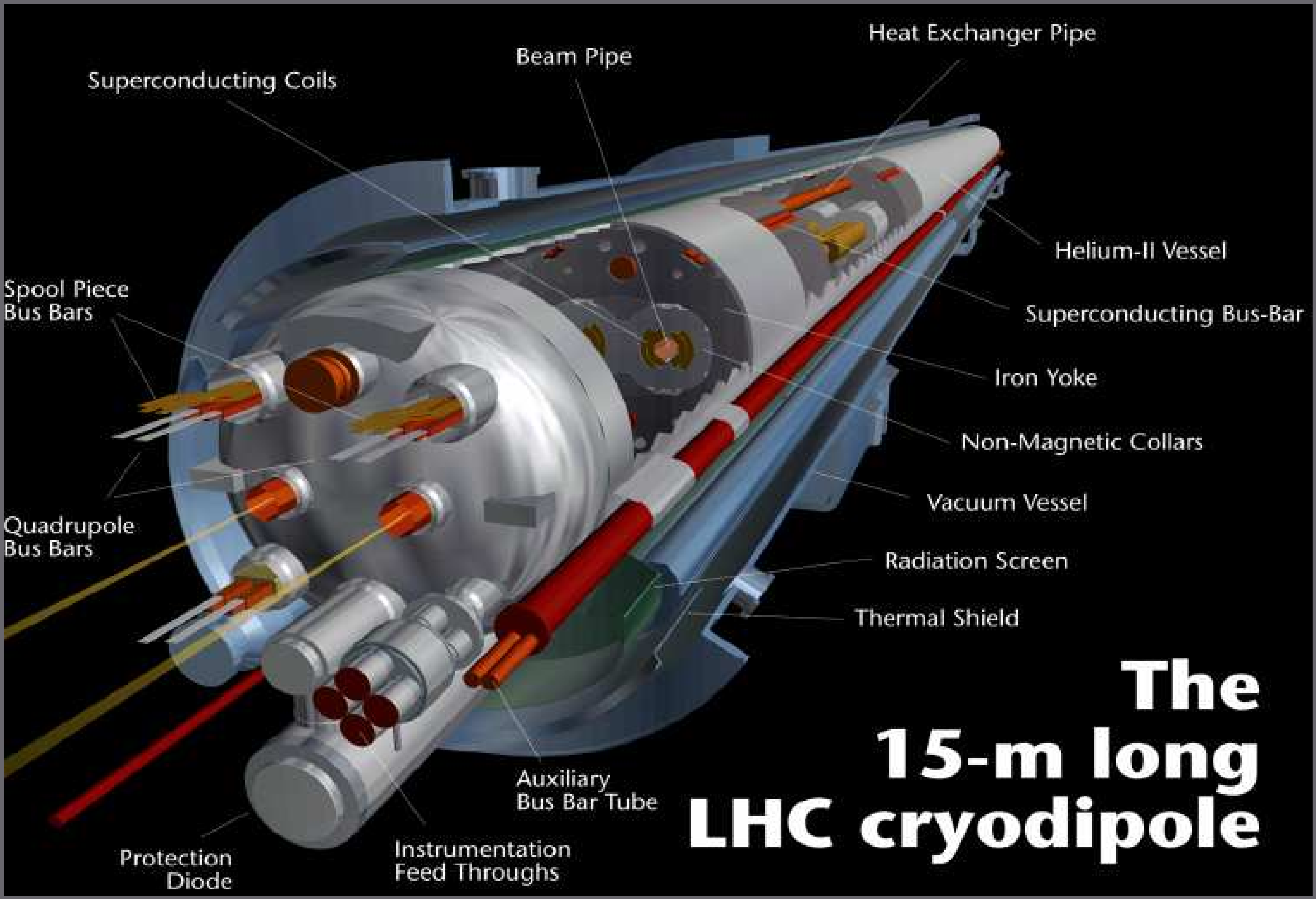
High luminosity at 7 TeV
very high energy stored in the beam

25 ns bunch-spacing

Beam power concentrated in small area

Limited investment
small aperture for beams

# LHC Main Bending Cryodipole

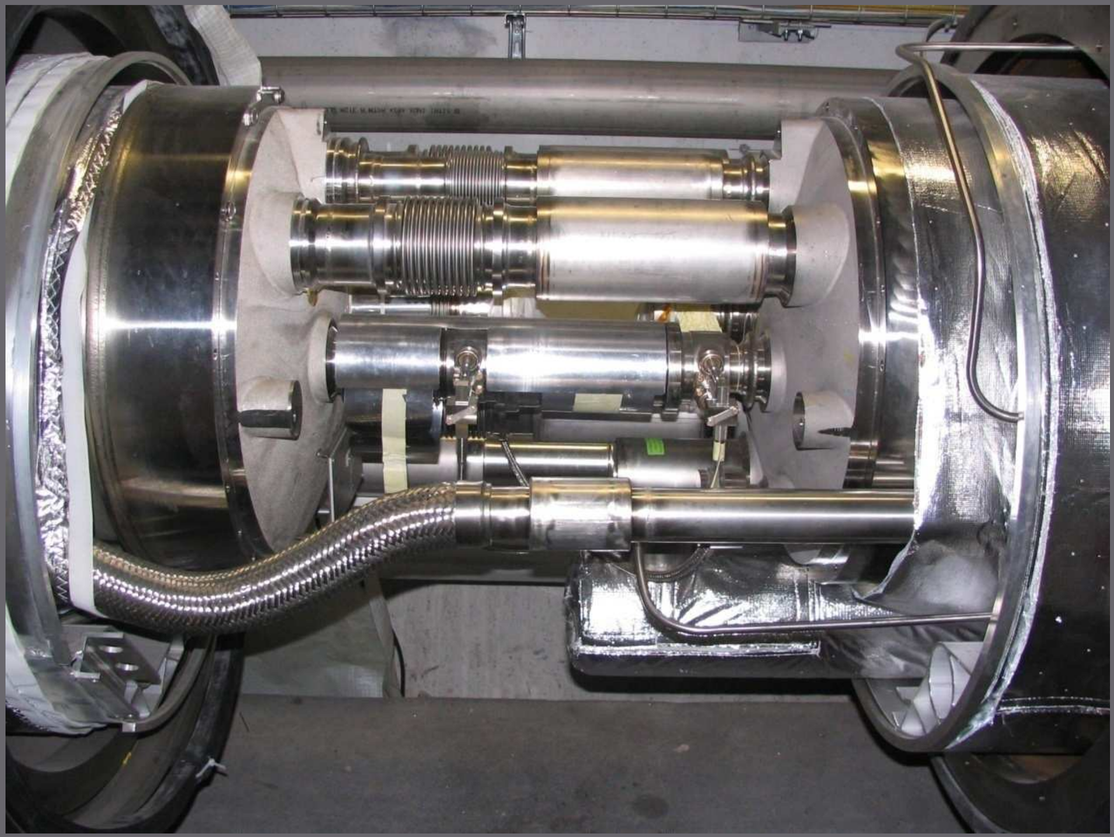



8.33 T nominal field

11850 A nominal current

# The LHC Arcs

# Magnet Interconnections



DIPOLE-DIPOLE INTERCONNECT BEFORE FINAL CLOSURE

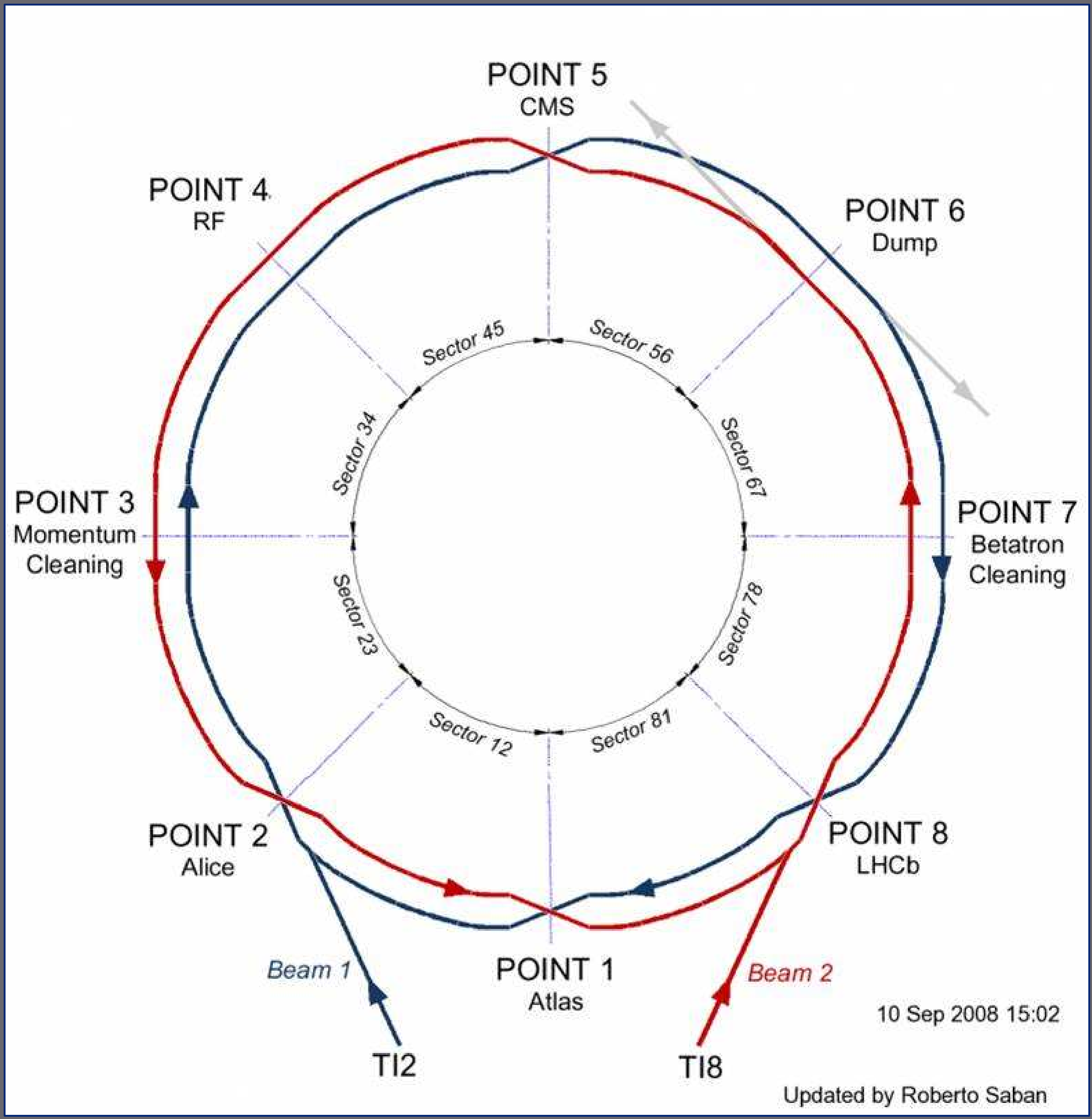
Consist of several operations:

- TIG welding of cryogenic channels (~50 000 welds)
- Induction soldering of main superconducting cables (~ 10 000 joints)
- Ultrasonic welding of auxiliary superconducting cables (~ 20 000 welds)
- Mechanical assembly of various elements
- Installation multi-layer insulation (~ 200 000 $m^2$)

**All interconnections completed in November 2007**

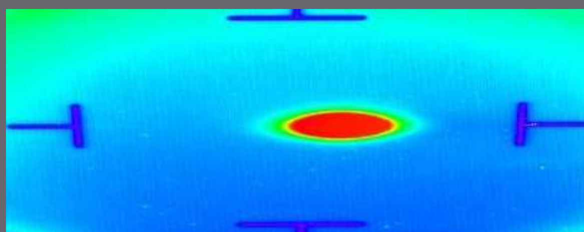
# COMMISSIONING WITH BEAM

# LHC Injection

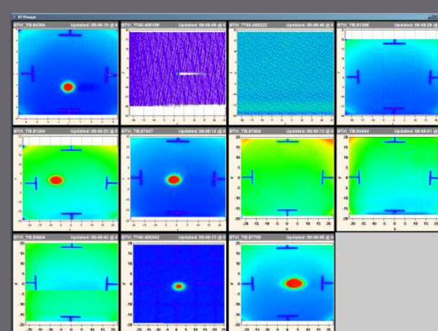


# Preparing the LHC Synchronisation Tests

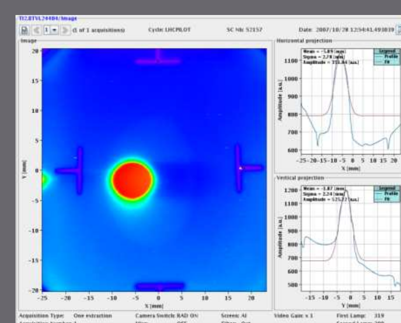
TT40 – Sept/Oct 2003



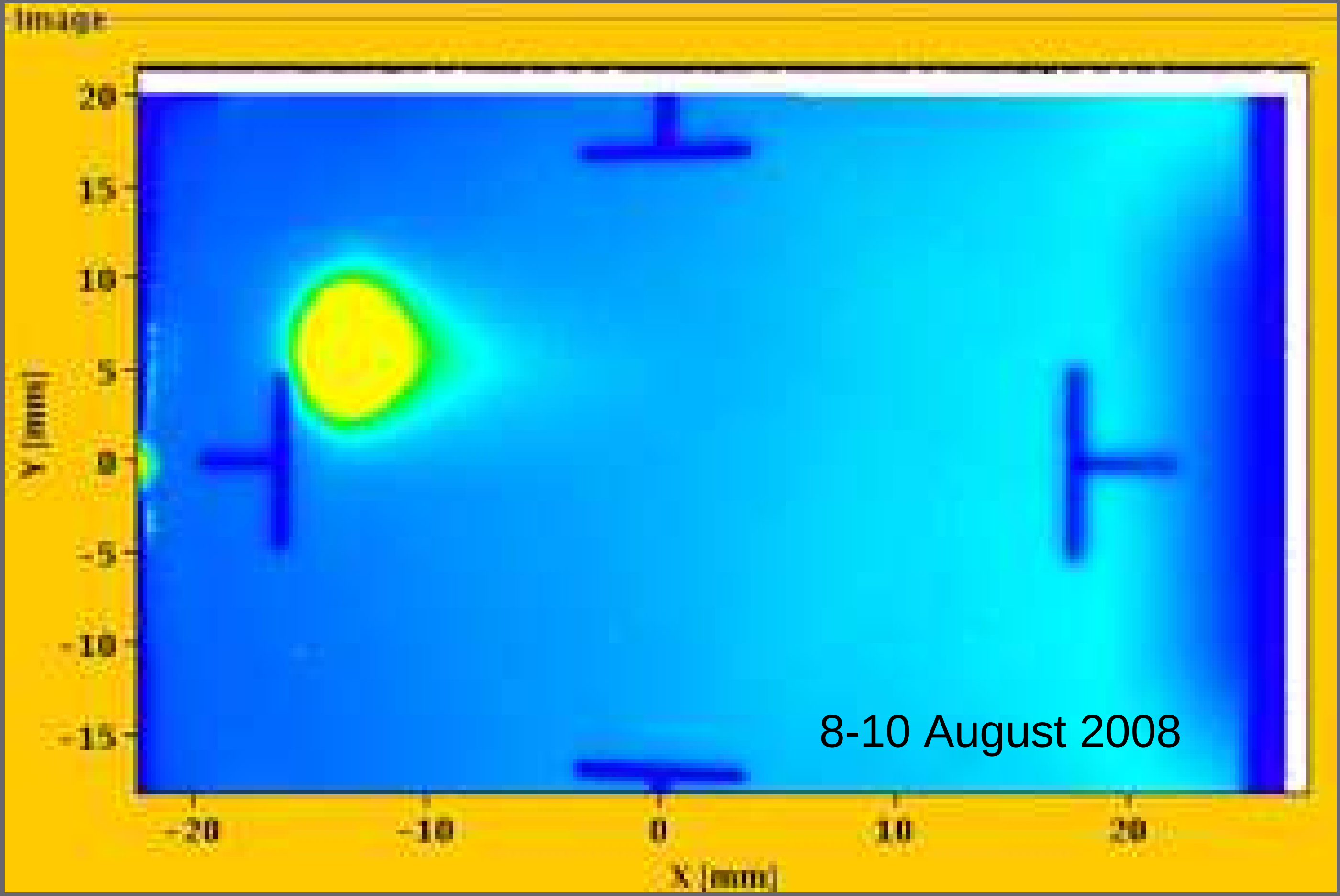
TI8 – Sept 2004



TI2 - 2007



# Synchronisation of LHC Clockwise Beam



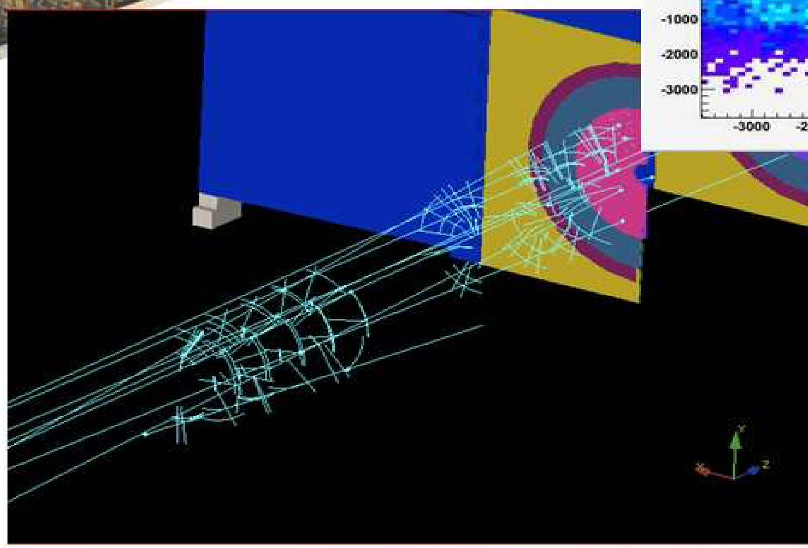

The yellow spot shows a bunch of a few particles arriving at Point 3 of the LHC ring

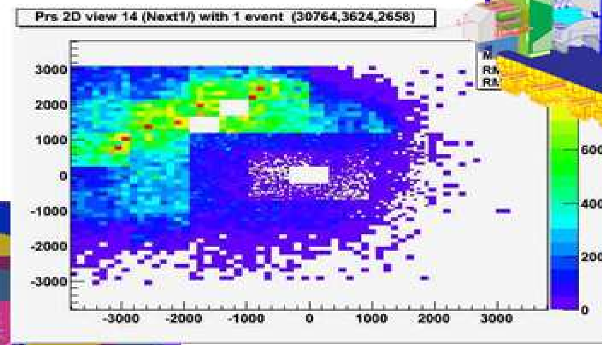
# Injected Beam to LHCb

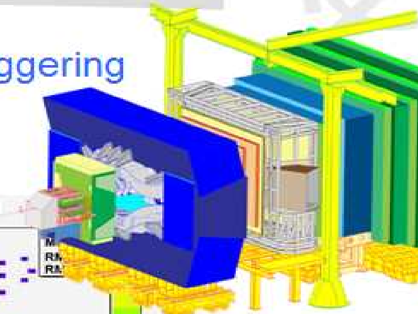
22-24 August 2008

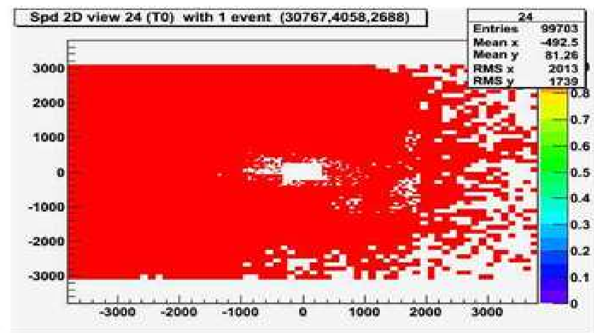
## LHCb events with beam on TED!

- Scintillator-Pad and Preshower detector ON and used for triggering
- VELO 5 out of 21 modules ON in both VELO halves
  - Successfully time-aligned the VELO!





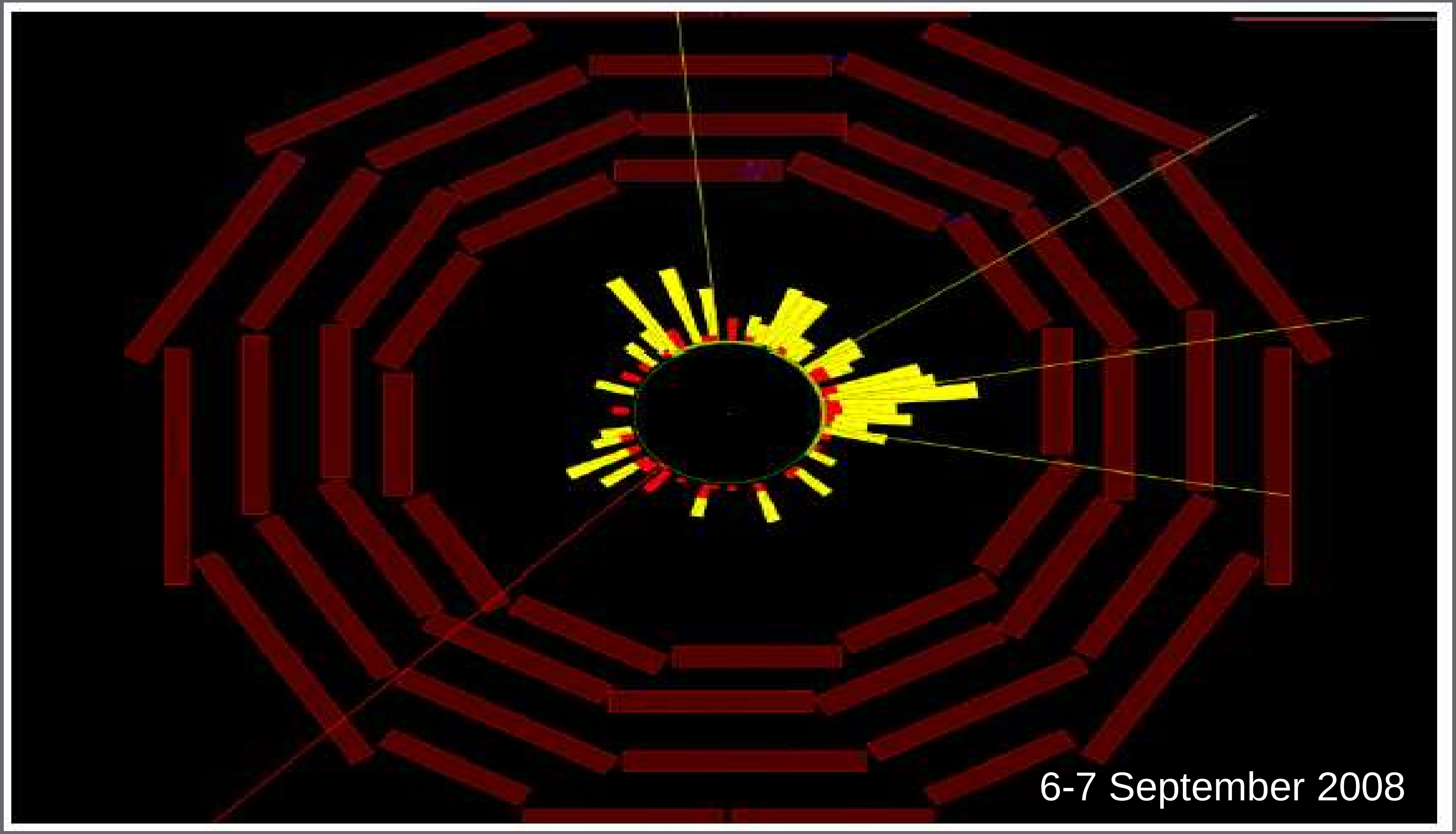








R. Jacobsson

# 3rd Synchronisation Test

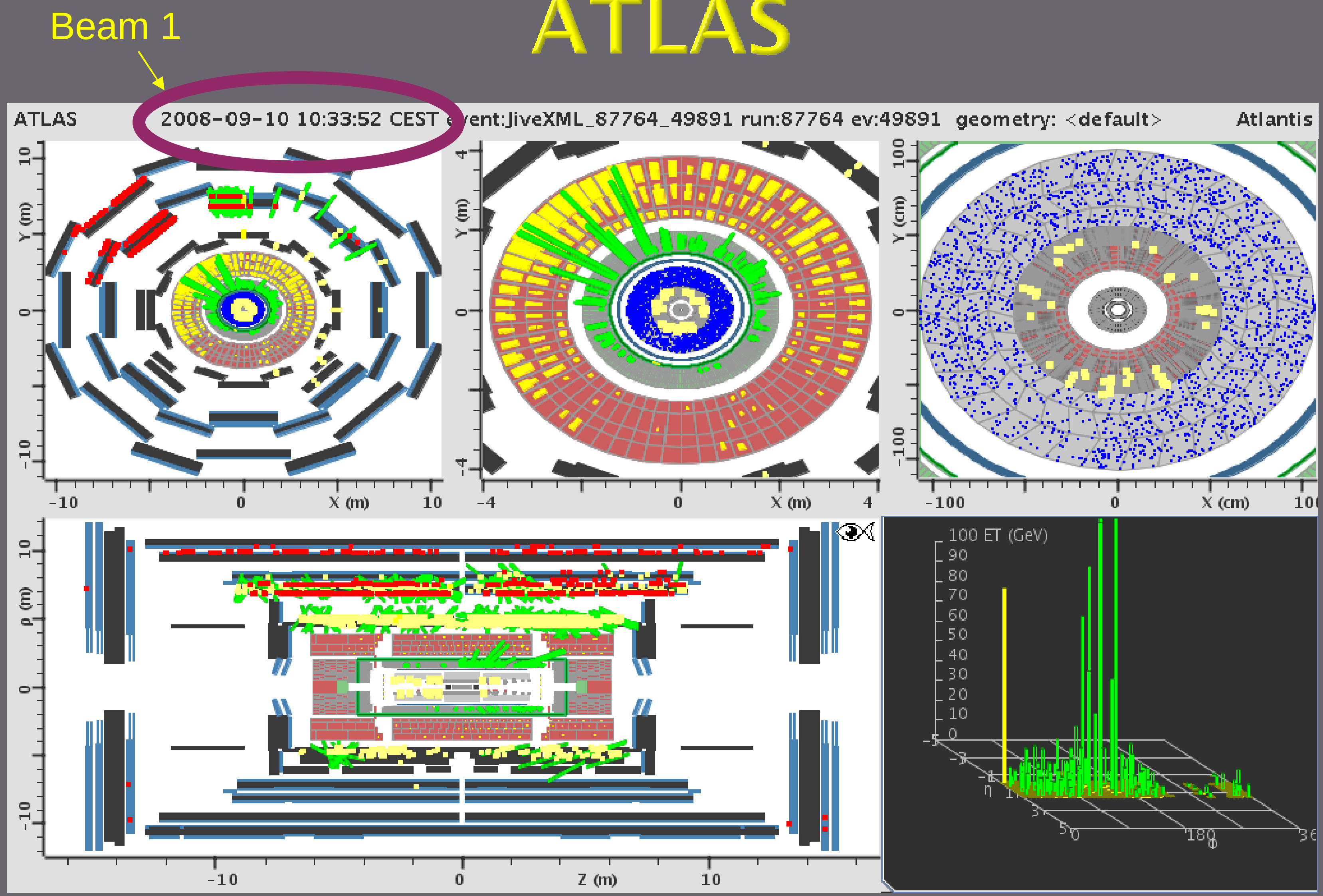



CMS Calorimeter and Muon System Recording Beam Dump on TCT in 5L

# 10 September 2008

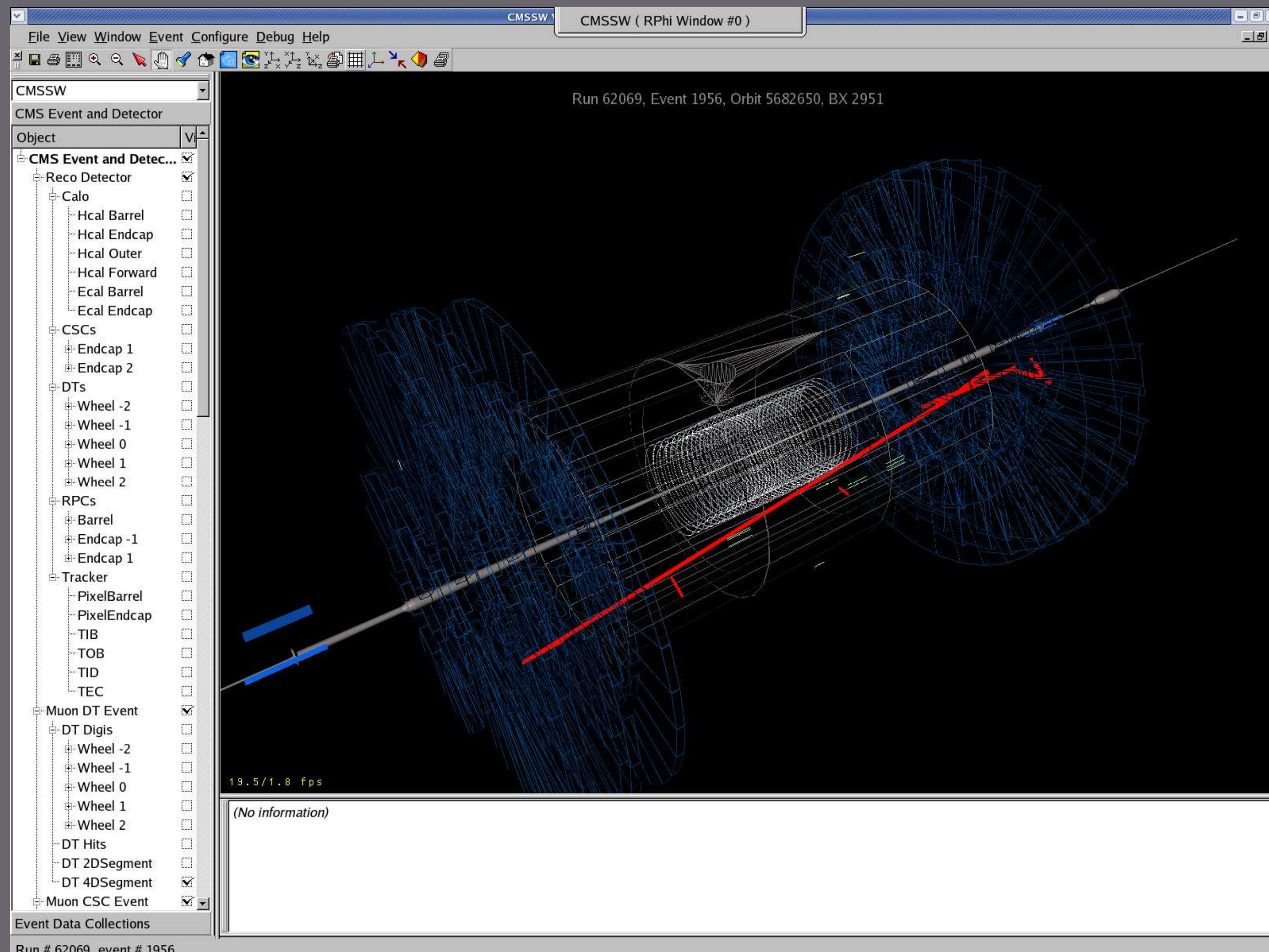
- 10:26 hrs Beam 1 (clock-wise beam)
- First & second turn only
- Beam 1 simultaneously detected by all 4 experiments

# First Circulating Beam
# ATLAS

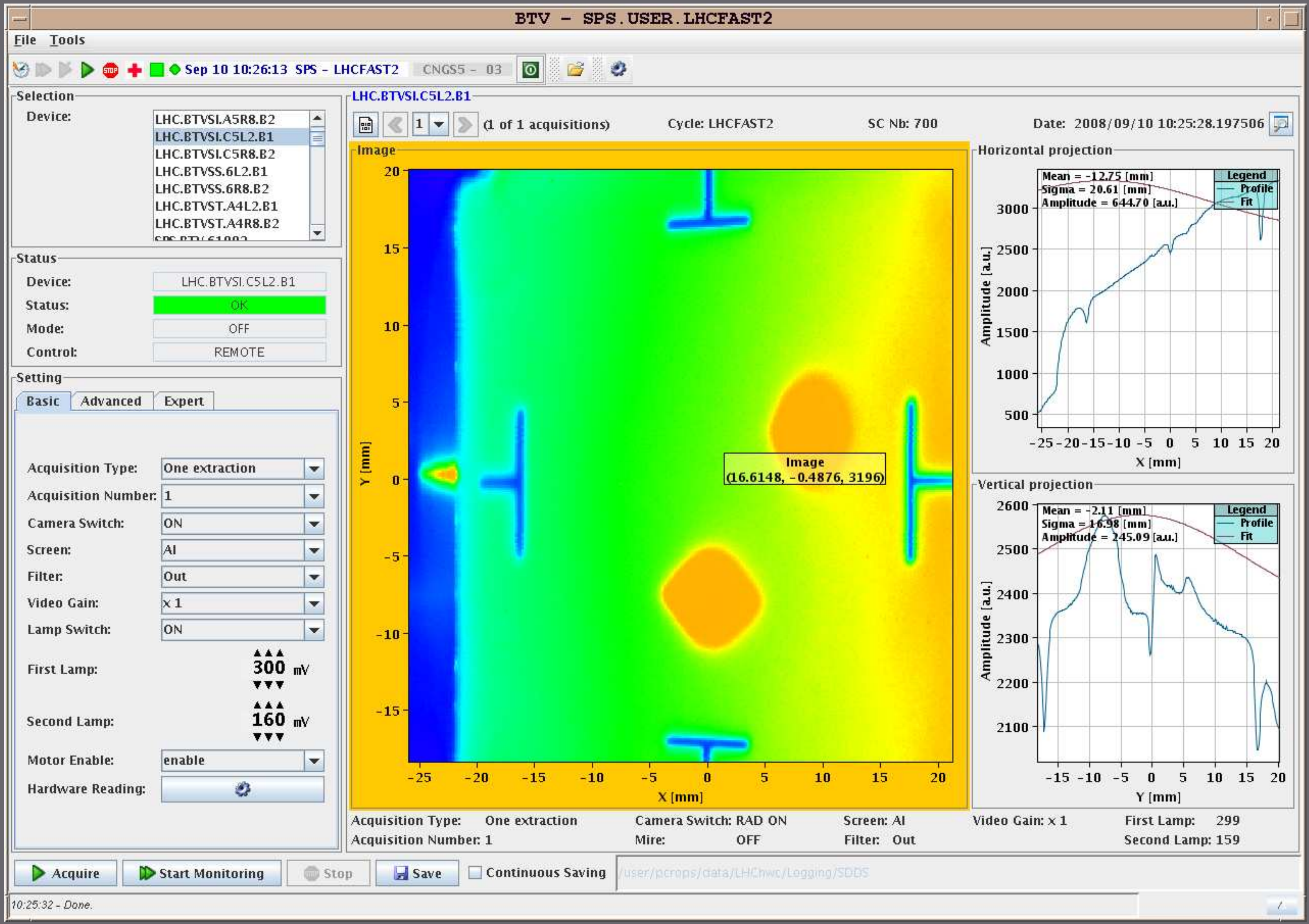


# First Circulating Beam CMS

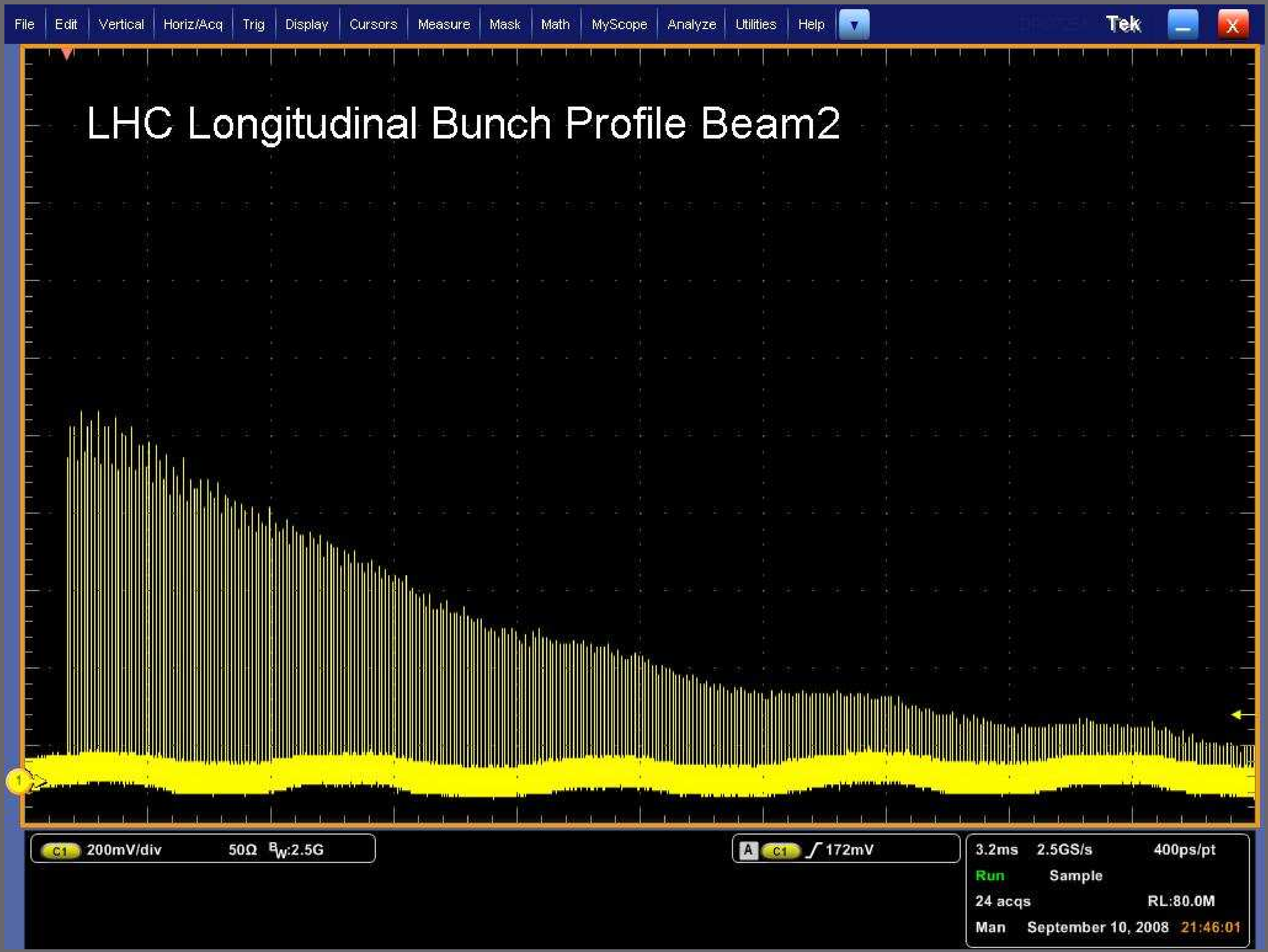
Event showing beam halo muon from Beam-2 through CMS



# Circulating Beam



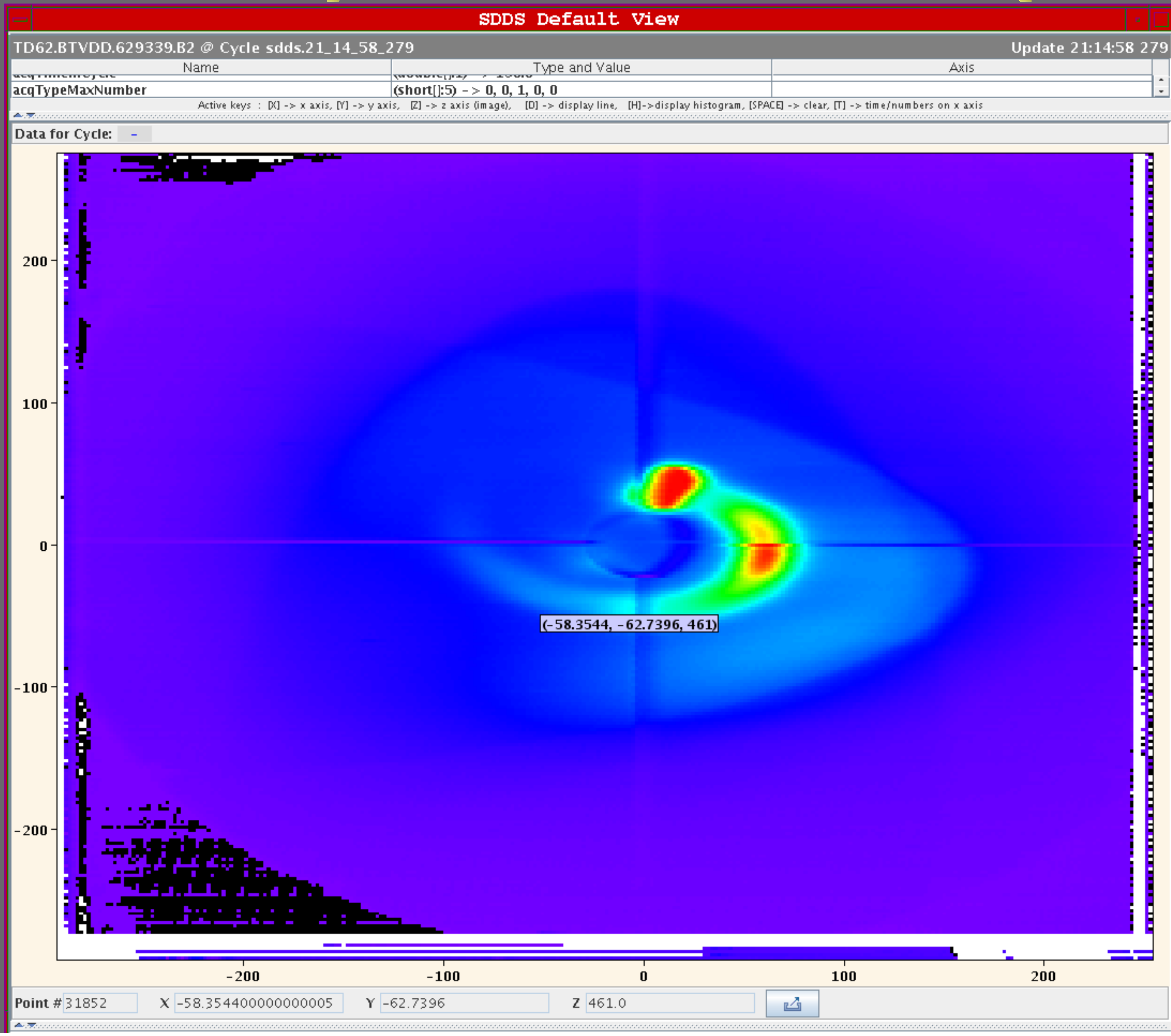
# Few 100 Turns






Courtesy R. Bailey

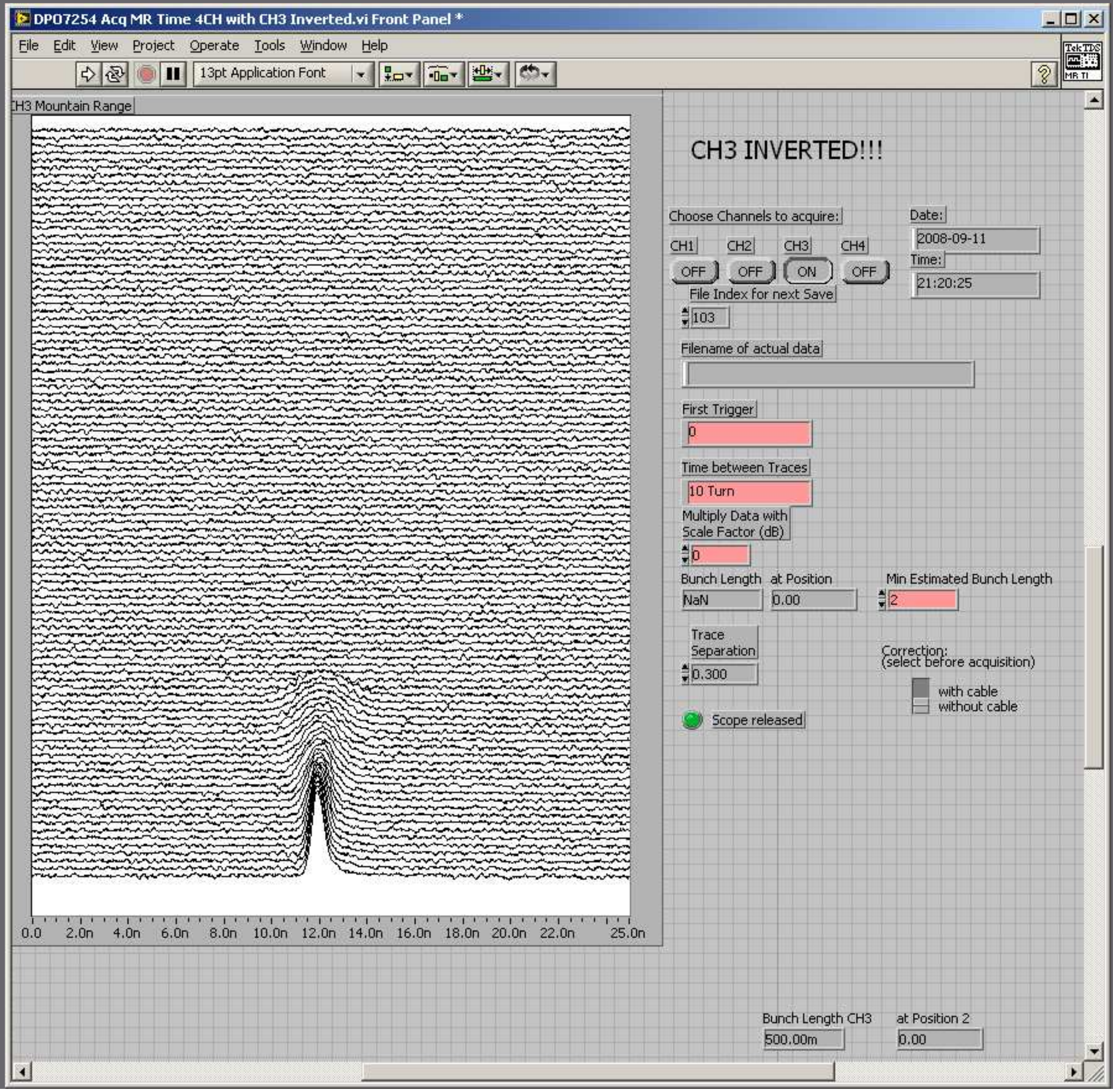
# Dump Dilution Sweep



# Circulating Beam

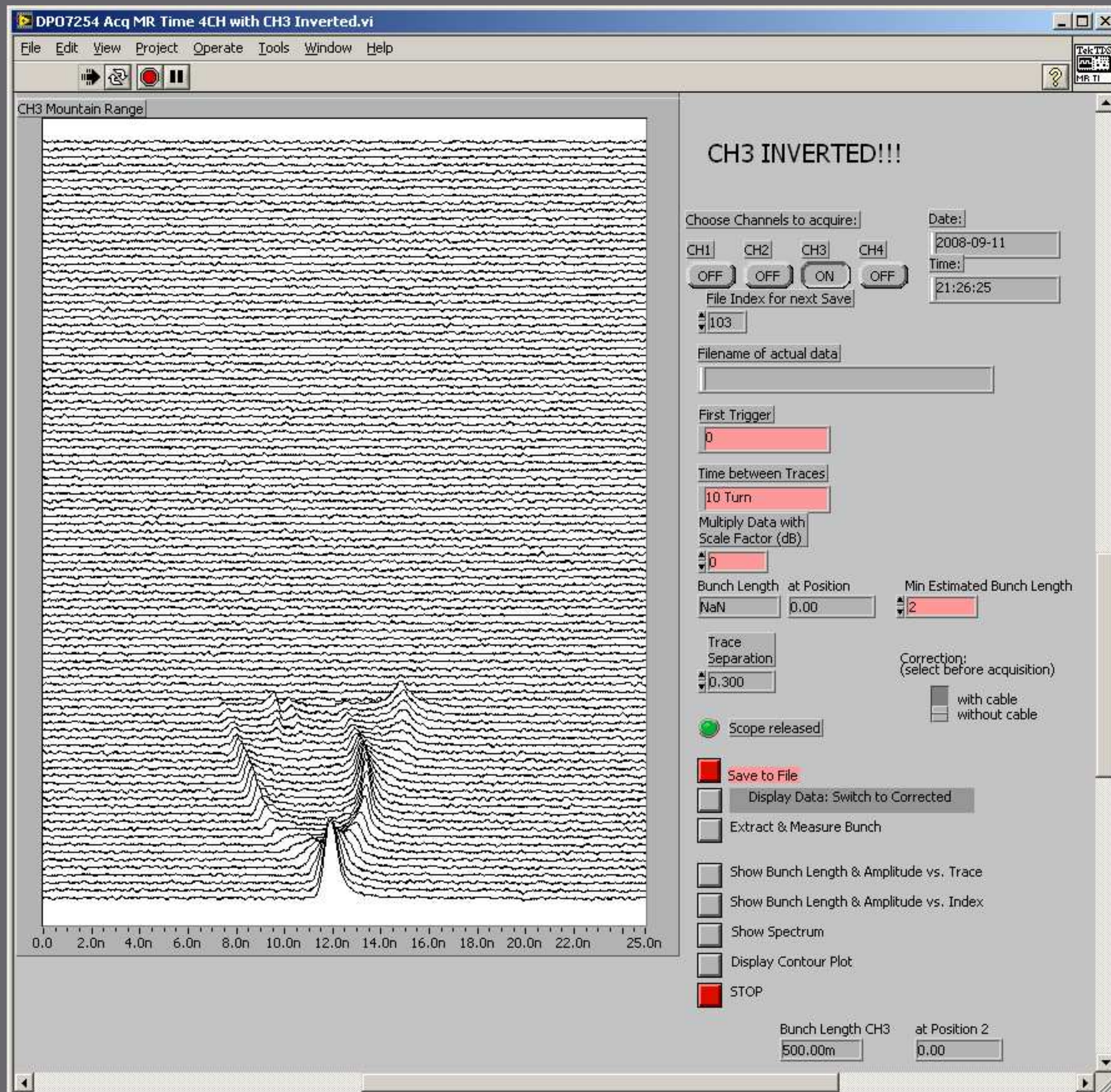
No RF

Debunching
in 25*10
Turns
(~25 ms.)




Courtesy E. Ciapala

# Beam Capture

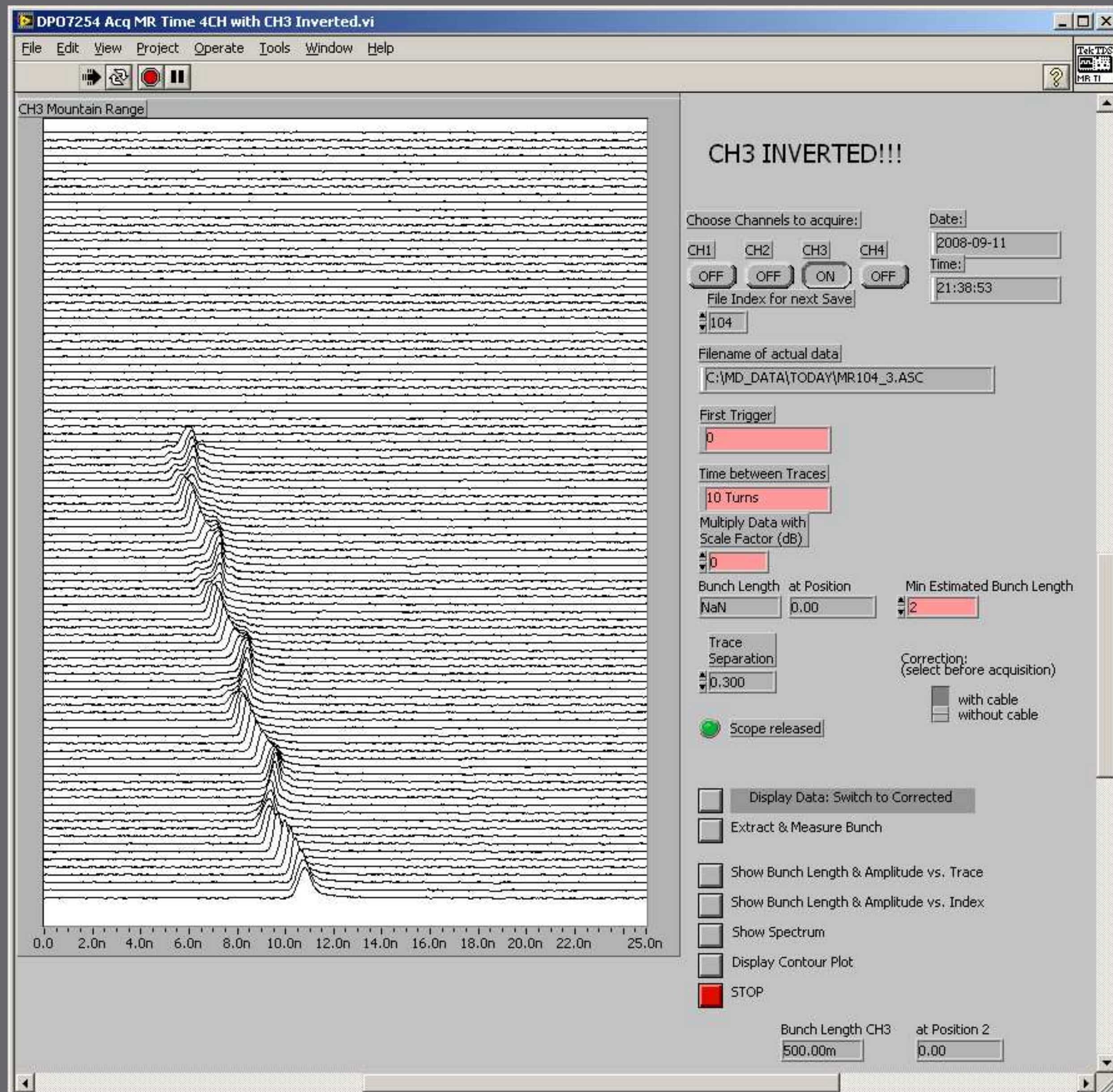



First attempt
to capture

At wrong injection
phase

Courtesy E. Ciapala

# Beam Capture

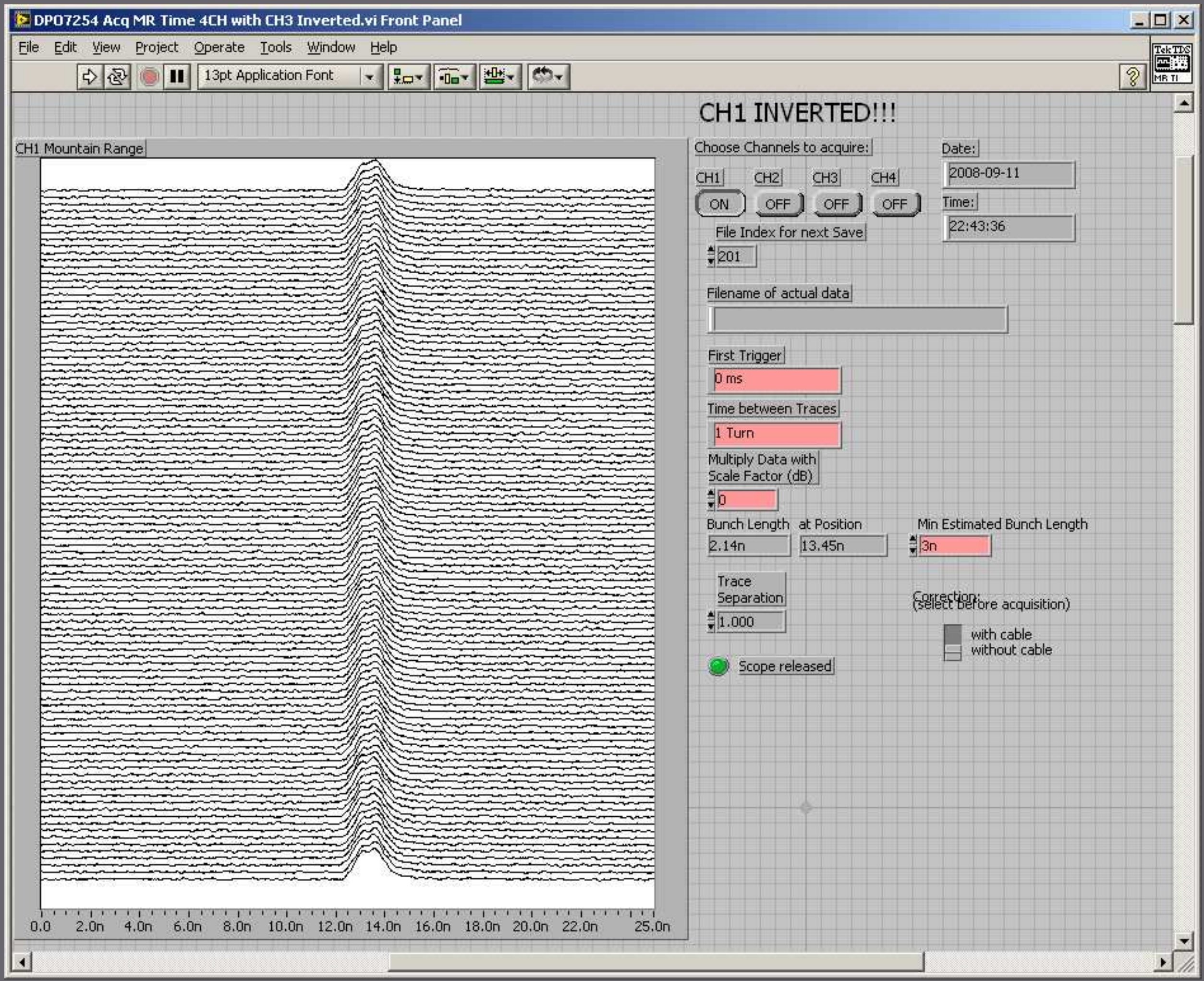



Capture
with corrected
injection phase

Courtesy E. Ciapala

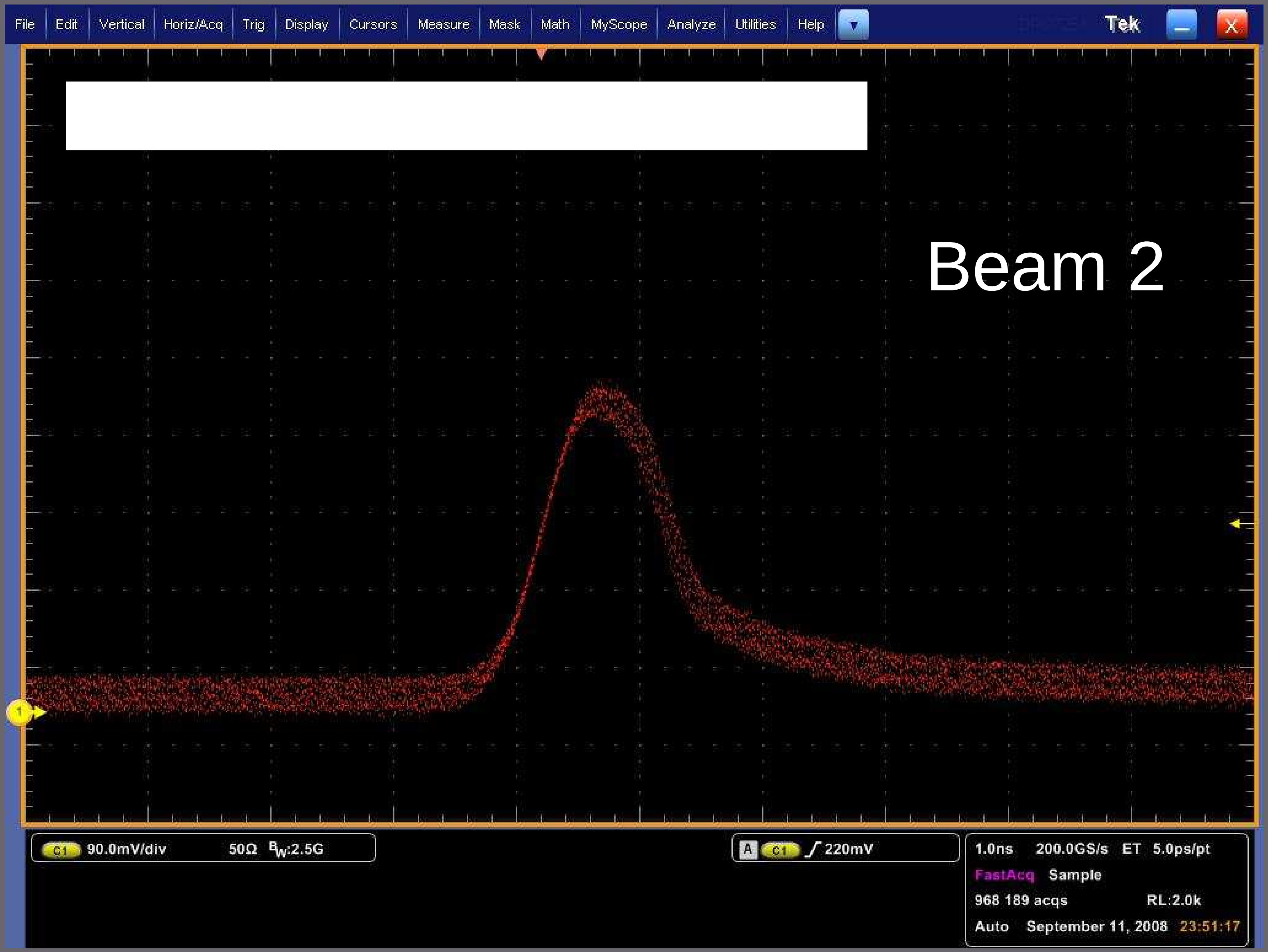
# Beam Capture

Capture with optimum injection phasing and correct reference




Courtesy E. Ciapala

# LHC Longitudinal Bunch Profile



# SECTOR 3-4 INCIDENT

# Situation on 10th September

- 7 out of 8 sectors fully commissioned for 5 TeV operation and 1 sector (3-4) commissioned up to 4 TeV.

# Incident during powering

The magnet circuits in the seven other sectors of the LHC had been fully commissioned to their nominal currents (corresponding to beam energy of 5.5 TeV) before the first beam injection on 10 September 2008. For the main dipole circuit, this meant a powering in stages up to a current of 9.3 kA. The dipole circuit of sector 3-4, the last one to be commissioned, had only been powered to 7 kA prior to 10 September 2008. After the successful injection and circulation of the first beams at 0.45 TeV, commissioning of this sector up to the 5.5 TeV beam energy level was resumed as planned and according to established procedures.

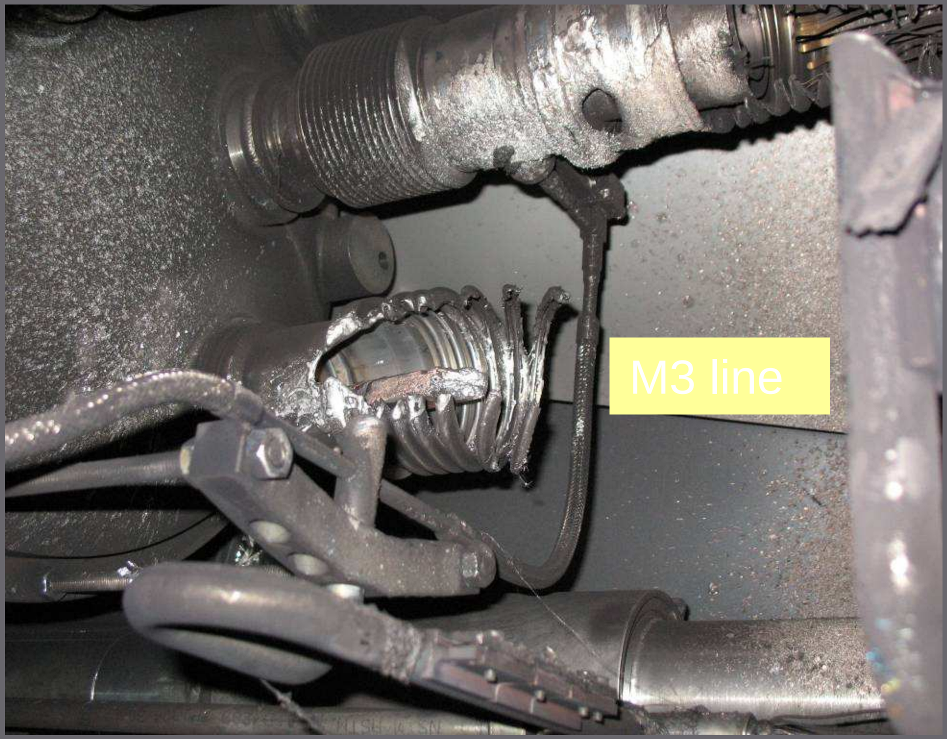
On 19 September 2008 morning, the current was being ramped up to 9.3 kA in the main dipole circuit at the nominal rate of 10 A/s, when at a value of 8.7 kA, a resistive zone developed in the electrical bus in the region between dipole C24 and quadrupole Q24. The first evidence was the appearance of a voltage of 300 mV detected in the circuit above the noise level: the time was 11:18:36 CEST. No resistive voltage appeared on the dipoles of the circuit, individually equipped with quench detectors with a detection sensitivity of 100 mV each, so that the quench of any magnet can be excluded as initial event. After 0.39 s, the resistive voltage had grown to 1 V and the power converter, unable to maintain the current ramp, tripped off at 0.46 s (slow discharge mode). The current started to decrease in the circuit and at 0.86 s, the energy discharge switch opened, inserting dump resistors in the circuit to produce a fast power abort. In this sequence of events, the quench detection, power converter and energy discharge systems behaved as expected.

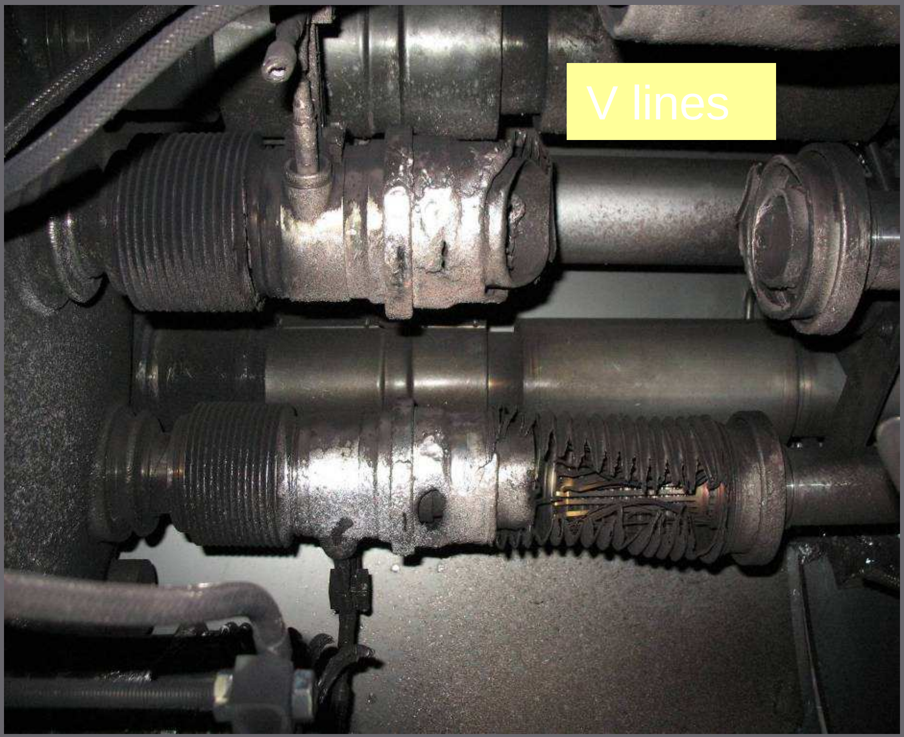
## Sequence of events and consequences

Within the first second, an electrical arc developed and punctured the helium enclosure, leading to release of helium into the insulation vacuum of the cryostat.

The spring-loaded relief discs on the vacuum enclosure opened when the pressure exceeded atmospheric, thus relieving the helium to the tunnel. They were however unable to contain the pressure rise below the nominal 0.15 MPa absolute in the vacuum enclosures of subsector 23-25, thus resulting in large pressure forces acting on the vacuum barriers separating neighboring subsectors, which most probably damaged them. These forces displaced dipoles in the subsectors affected from their cold internal supports, and knocked the Short Straight Section cryostats housing the quadrupoles and vacuum barriers from their external support jacks at positions Q23, Q27 and Q31, in some locations breaking their anchors in the concrete floor of the tunnel. The displacement of the Short Straight Section cryostats also damaged the “jumper” connections to the cryogenic distribution line, but without rupture of the transverse vacuum barriers equipping these jumper connections, so that the insulation vacuum in the cryogenic line did not degrade.

# Electrical arc between C24 and Q24

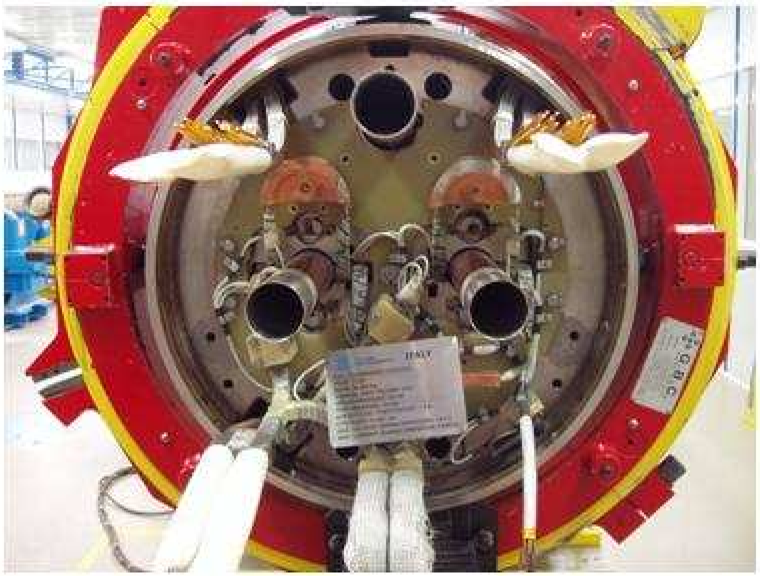


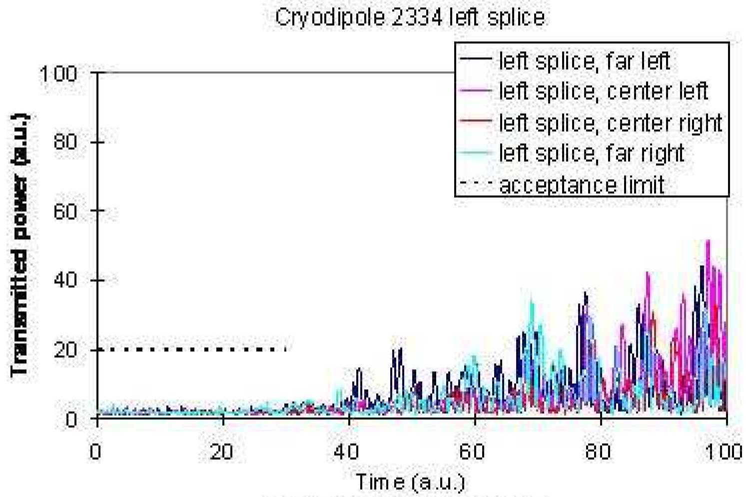



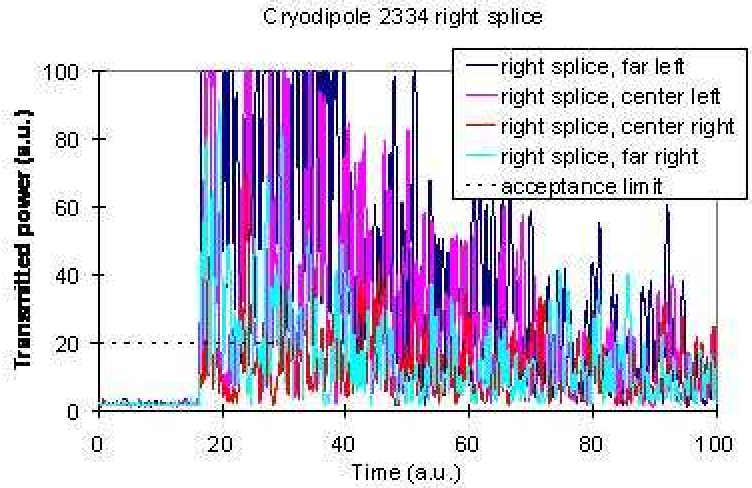
US=UltraSound

# US testing 13 kA splices

US inspection of defective inter-pole splice in MB 2334 has confirmed the US test to be a very useful QC tool.






Courtesy C. Scheurlein

# Inventory of magnets in D-zone

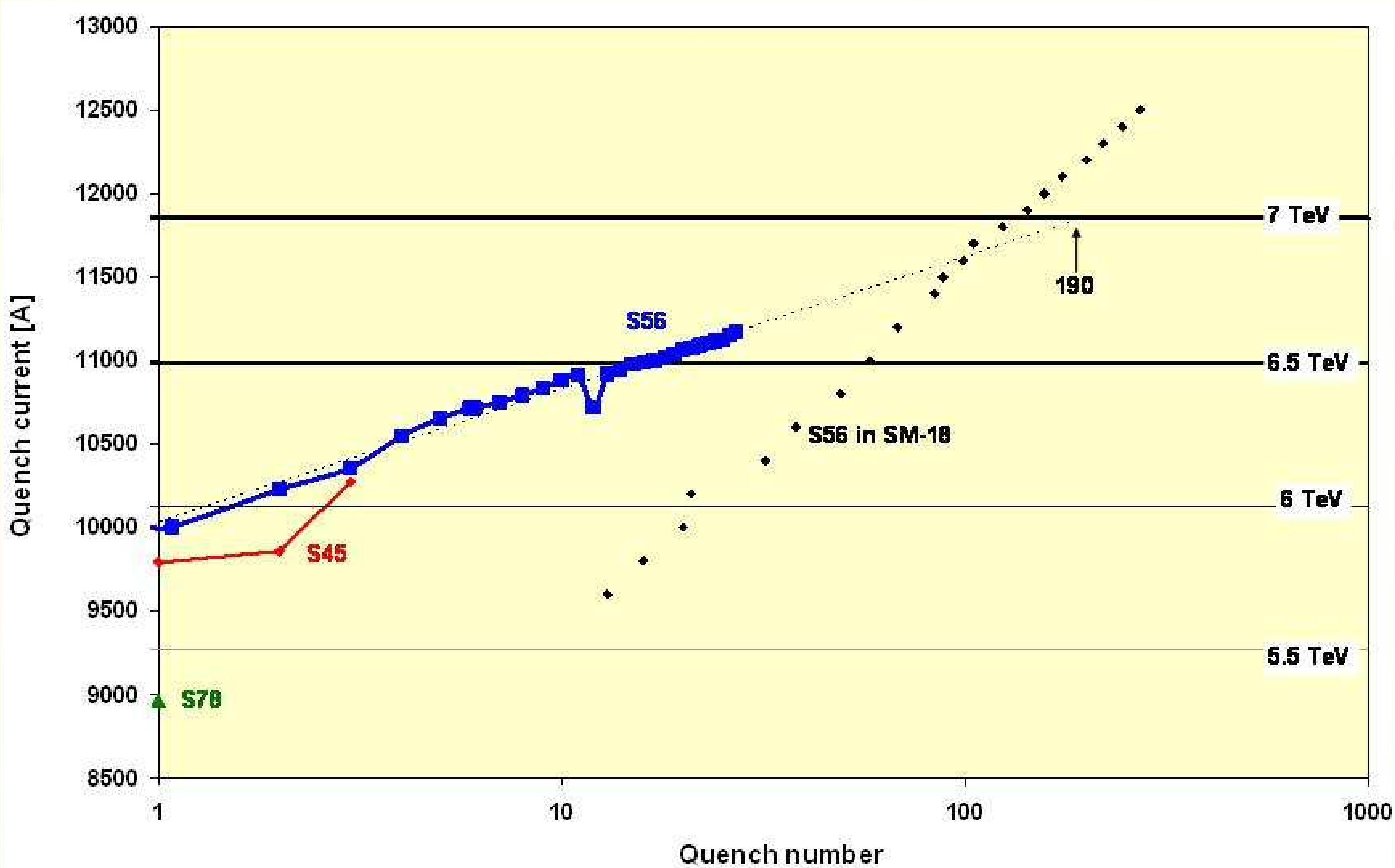
- 15 SSS (MQ)
  - 1 not removed (Q19)
  - 14 removed
    - 8 cold mass revamped (old CM, partial de-cryostating for cleaning and careful inspection of supports and other components)
    - 6 new CMs
    - In this breakdown there is consideration about timing (SSS cryostating tales long time; variants problems).
- 42 Dipoles (MBs)
  - 3 not removed (A209,B20,C20)
  - 39 removed
    - 9 Re-used (old CM, no decryostating -except one?)
    - 30 new CMs
    - New cold masses are much faster to prepare than rescuing doubtful dipoles)

CURRENT ESTIMATE:
ALL MAGNETS TO TUNNEL IN WEEK 15 (April 10)

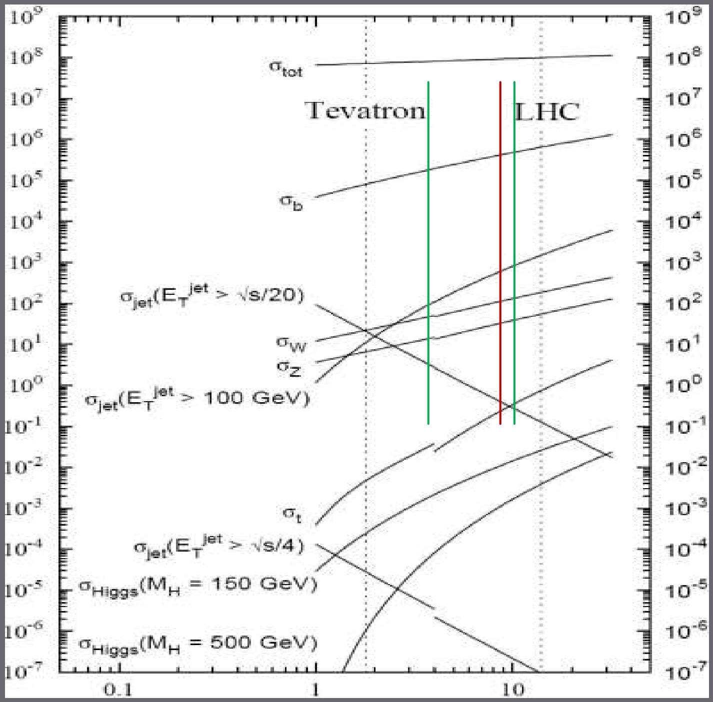
# LHC Improvements

- Probability reduction for “s34-like incident”
  - New QPS and QDS will be deployed now on whole machine (incl. symm quench detection)
- Mitigation of damage in case of new incident
  - SSS relief valves DN100 on all arcs (install now)
  - Dipole relief valves DN200 (install now on warmed-up sectors, other sectors in 2010/2011)
- Calorimetric (precision of 20 nΩ) and electrical measurement of resistance (precision of 1 nΩ).

# Training during HWC



# COMMISSIONING THE PHYSICS PROGRAMME




# Integrated luminosity × cross section versus energy

- What integrated luminosity should the LHC accumulate to overtake the Tevatron, which aims for 9 $fb^{-1}$ by 2010 ?
- What is the minimum amount of data at given energy that is needed to make the 2009 physics run useful ? (assuming CM energy $8 < s^{1/2} < 10$ TeV)

# Physics of ATLAS/CMS

## Discovery Channels

- Higgs
- W', Z'
- SUSY
- Exotic particles

Try to express these as:

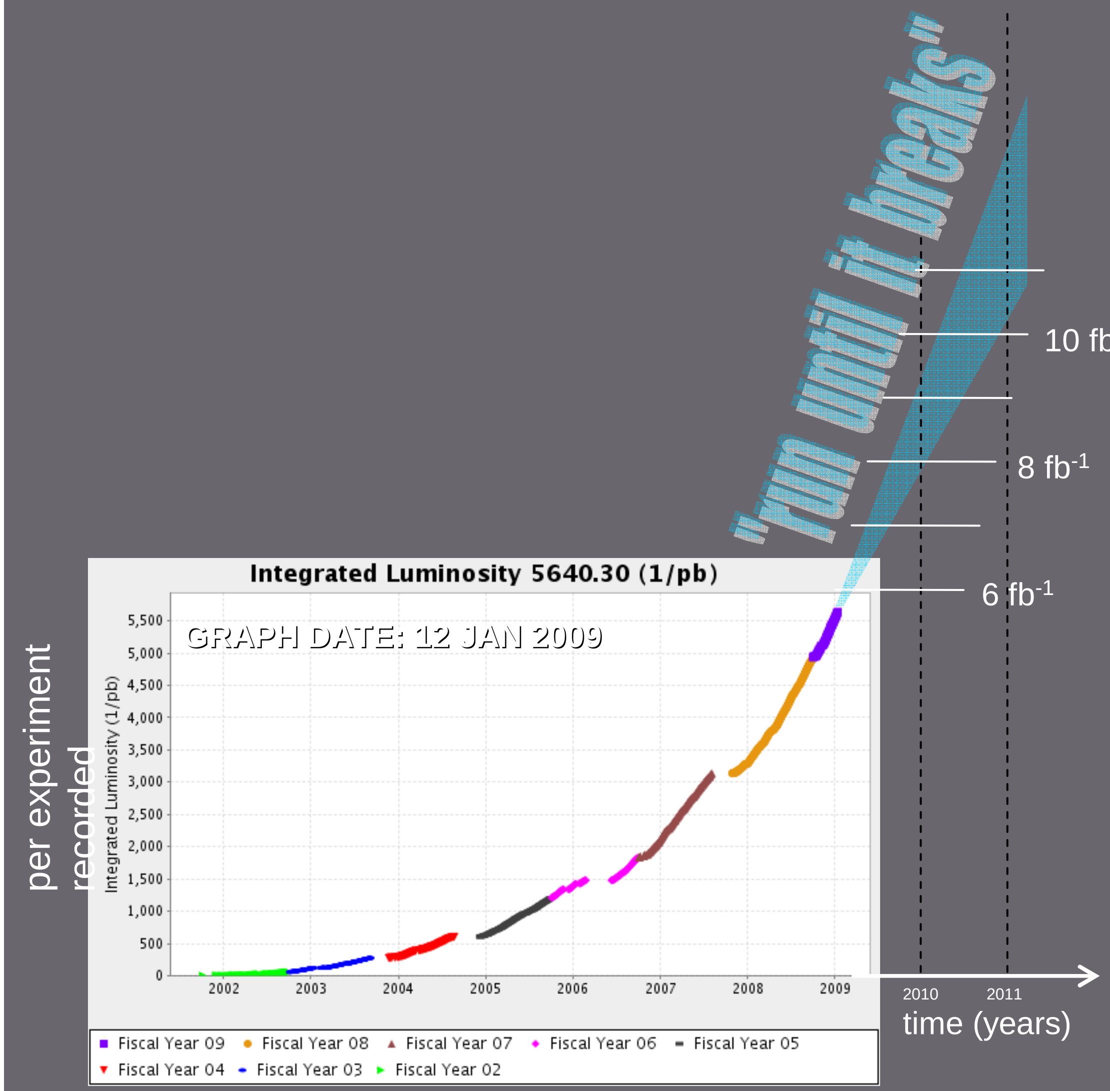
1. Luminosity needed to make a better (exclusion) measurement than Tevatron.
2. Luminosity needed to make a discovery.

## Standard Model Channels

- W, Z
- top
- QCD

An excellent understanding of these is an essential step toward Discoveries.

# Tevatron

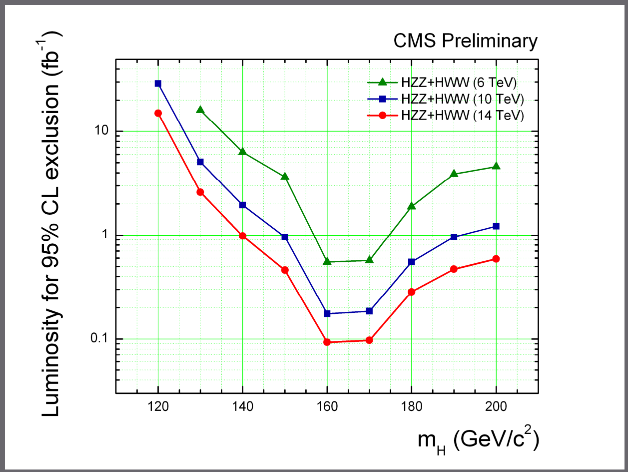



## Projected Integrated Luminosity

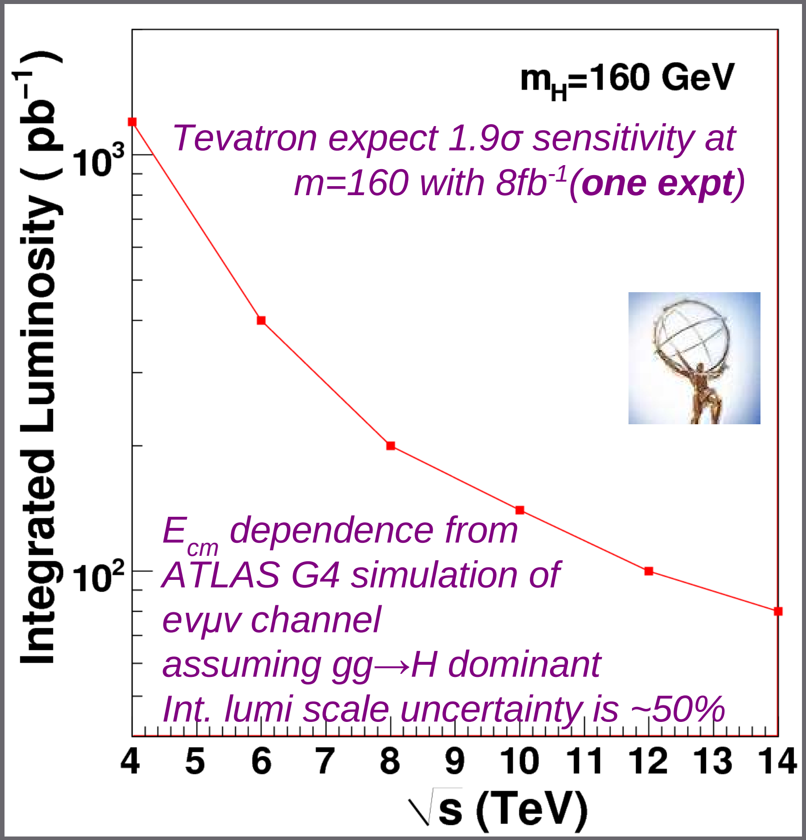
How much by end of 2010 ?

# Higgs 95% CL at LHC
# H → weak bosons

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$^{-1}$

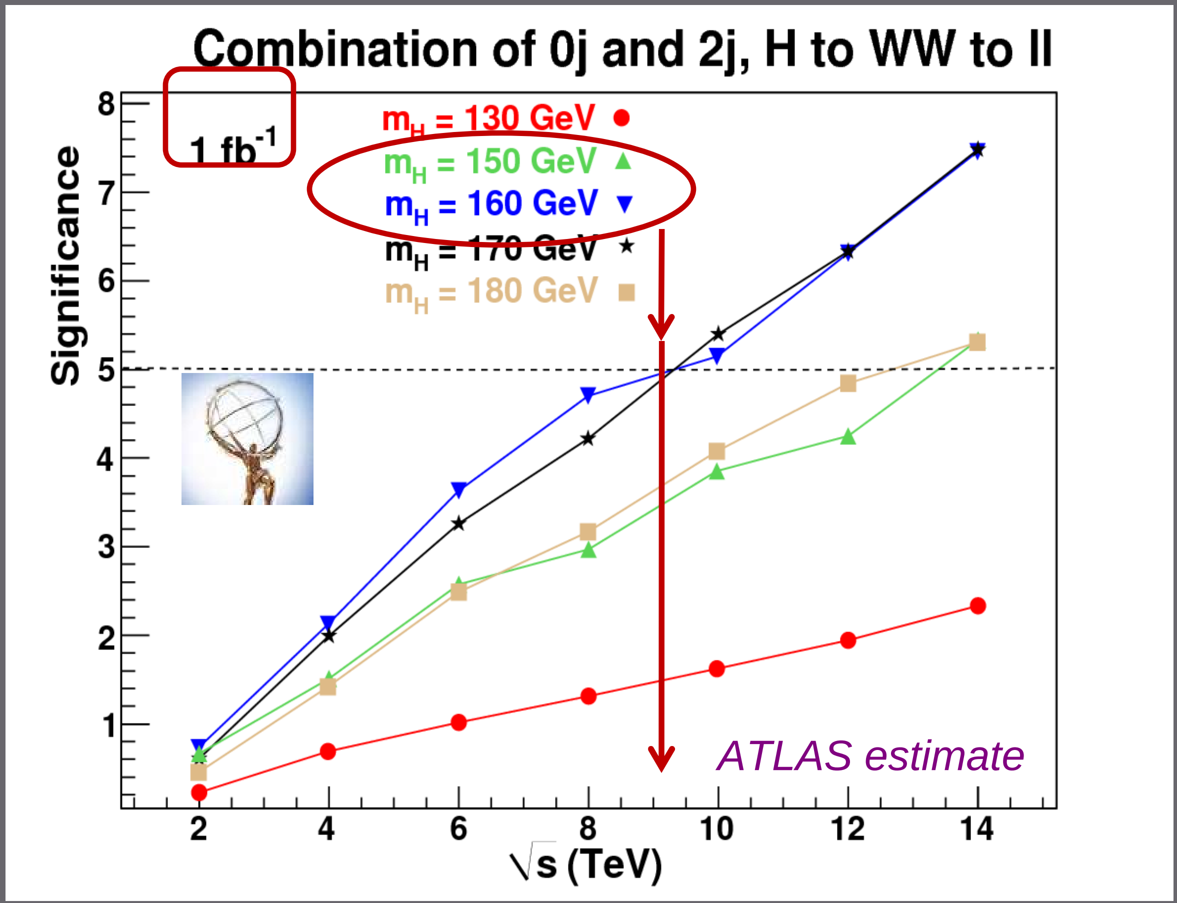



Compare sensitivity to Tevatron with 8 fb$^{-1}$
( only H→WW→ lνlν )

- Massive loss of sensitivity below 6 TeV

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

# Higgs 5σ Discovery




5σ discovery for $m_H$ ~160 GeV is possible with **$s^{1/2}$ = 8-10 TeV** and ~**$1fb^{-1}$ g.d.**

# Luminosities at $s^{1/2}$ = 10 TeV

$$L = \frac{f\, k_b\, N^2\, \gamma}{4\pi\, \varepsilon_N \beta^*}\, F$$

$\beta^*$ = 3 m.

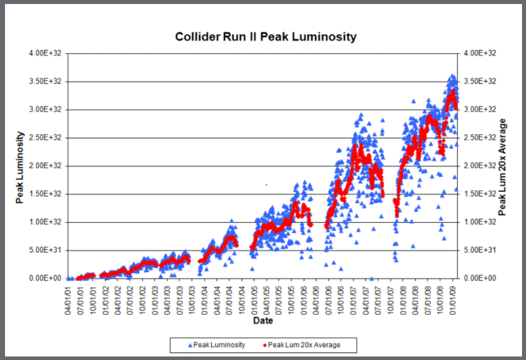
N=$10^{11}$ protons/bunch

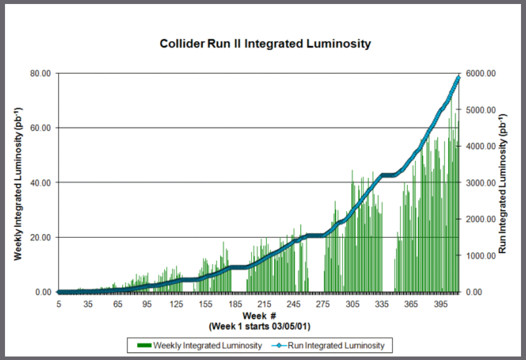
Assume (somewhat arbitrarily)
a “Hübner factor” of 0.2

$k_b$=156 $\Rightarrow$ $6\times10^{31}$ $cm^{-2}\ s^{-1}$ $\Rightarrow$ ~ 1 $pb^{-1}$ / day

$k_b$=1404 $\Rightarrow$ $5\times10^{32}$ $cm^{-2}\ s^{-1}$ $\Rightarrow$ ~ 8 $pb^{-1}$ / day

$\alpha \neq 0$




Note: Tevatron is cruising at
~$3\times10^{32}$ $cm^{-2}\ s^{-1}$
(8 $pb^{-1}$/day , 2 $fb^{-1}$ / year)
$\Rightarrow$ LHC needs high energy!

# ATLAS/CMS Discovery Channels

- Typically, with 50-100 $pb^{-1}$ **good data** at 10-8 TeV ⇒ many new limits set on hypothetical particles (some more stringent than Tevatron), or even discoveries possible!

- With 200-300 $pb^{-1}$ g.d. at 10-8 TeV ⇒ start competing with Tevatron for Higgs masses around 160 GeV

- With 1 $fb^{-1}$ g.d. at 10 TeV ⇒ find Higgs if around 160 GeV mass

- The higher the energy, the faster it goes...

- Note: below ~20-40 $pb^{-1}$ g.d. at 10-8 TeV, or at any lower energy, one would probably start talking about an "engineering run"

# LHCb Running Conditions

- B cross section does not vary as drastically as for high-mass objects.
  - Thus, the request to go to highest possible energy is milder.
- Need **0.3-0.5 fb$^{-1}$** at **$s^{1/2} \geq$ 8 TeV** to surpass Tevatron in $B_s$ physics.
- Need at least 5 pb$^{-1}$ at $s^{1/2} \geq$ 4 TeV to collect good sample of J/psi.

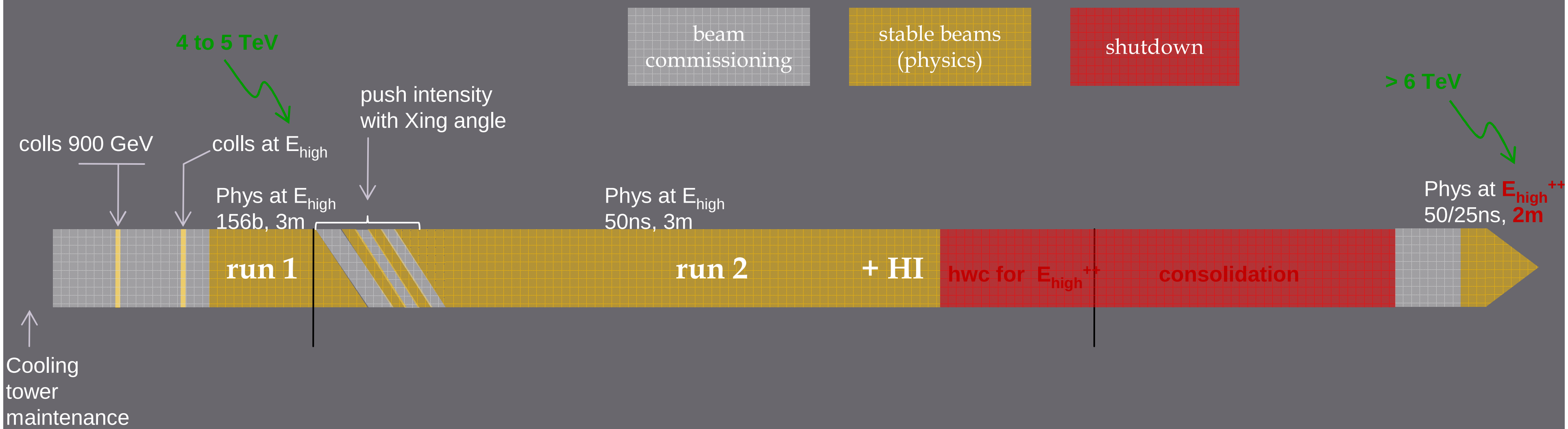
# ALICE and *pp* Running

- ALICE not as strongly interested as ATLAS/CMS in reaching the highest possible energy for *pp*.
- What about $s^{1/2}$ = 5.5 TeV ? (the *NN* equivalent in PbPb @ 14TeV)
  - Not so crucial at this stage, but yes, would request to choose E=2.75 TeV if a beam energy between 2 and 3 TeV was being considered.
- Will collect data at ~$10^{29}$ $cm^{-2}$ $s^{-1}$ (opt) or $3\times10^{30}$ $cm^{-2}$ $s^{-1}$ (max)

# PHYSICS RUN 2009-2010

# The Preferred Scenario

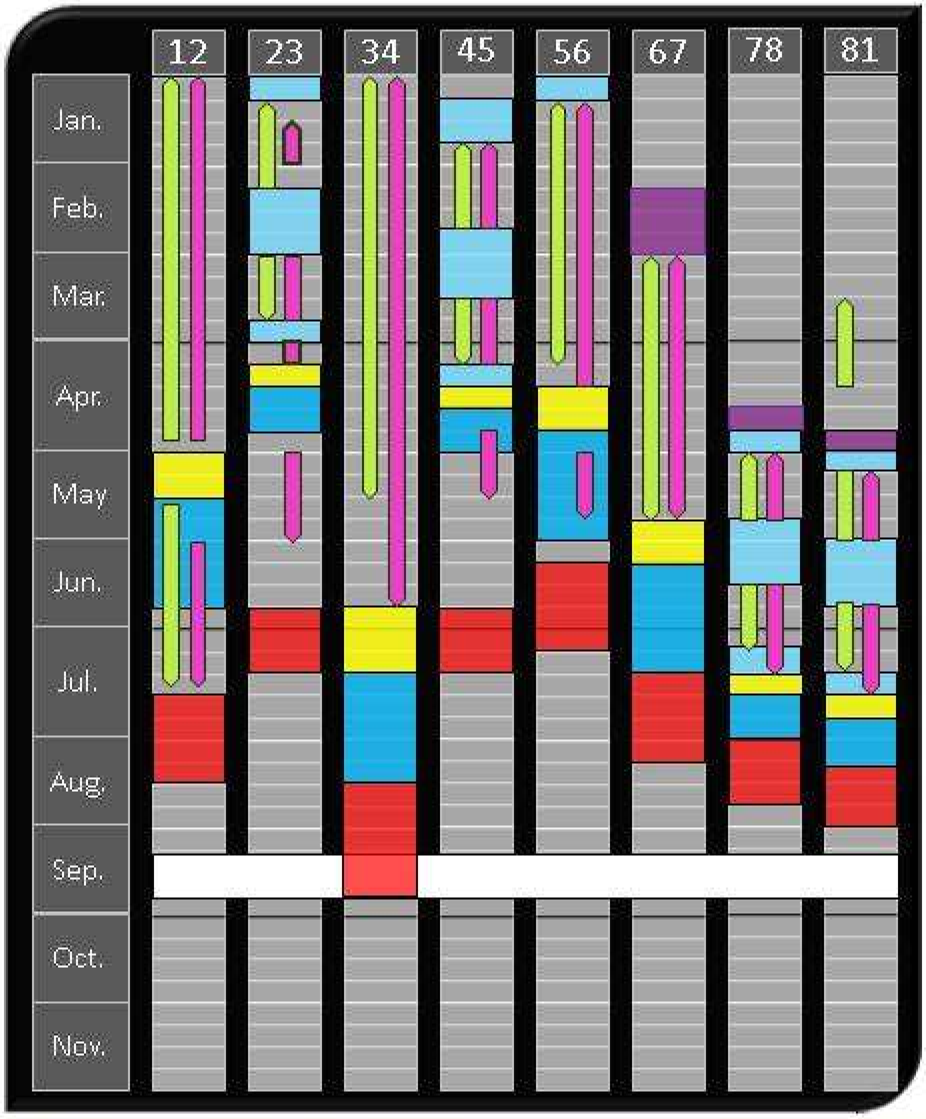
**Start the LHC as soon as possible and run for one year**




## Scenario with greatest flexibility

- Can adapt LHC goals to evolving circumstances
  - Increase 8 => 12 TeV in the course of 2010?
- Heavy -ion run at the end of 2010
  - adjust end date (start of shutdown)

# Shutdown 08-09




- Intermediate cool-down & QRL warm-up (Stand Alone)
- Activities
  - Arc
  - LSS
- Flushing & ELQA at warm
- Cool-down
- Powering tests
- Cold check-out

# Schedule with Running in Winter Months

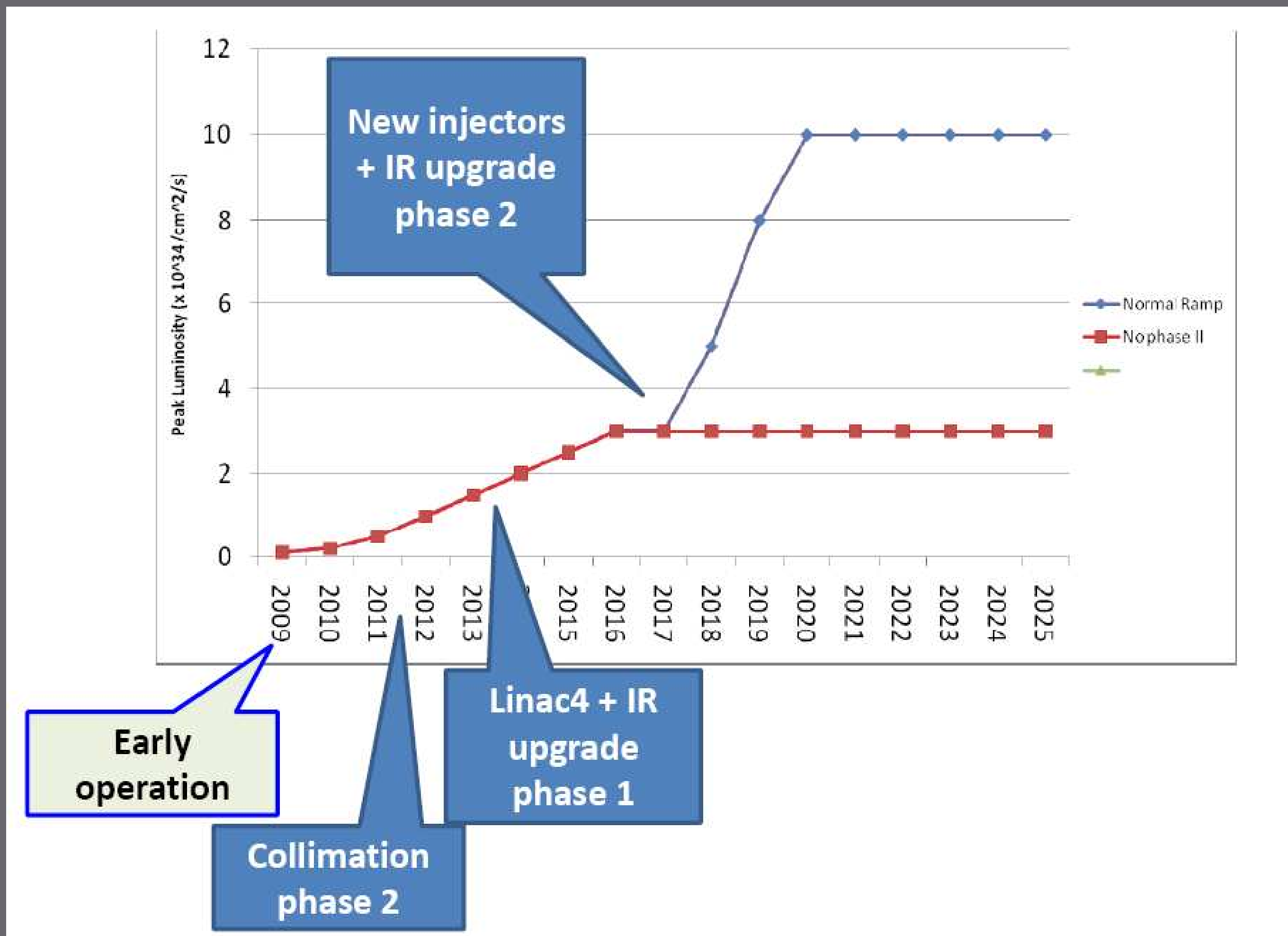
| Year | 2009 | | | | | | | | | | 2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M |
| Baseline | SH | SH | SH | SH | SH | SH | SH | SH | SU | PH | | SH | SH | SH | SH | SH | SH | SU | PH | PH | PH | PH | SH | SH | SH | SH |
| | 24 weeks physics possible | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base ' | SH | SH | SH | SH | SH | SH | SH | SH | SU | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | SH | SH | SH | SH | SH | SH |
| | 44 weeks physics possible | | | | | | | | | | | | | | | | | | | | | | | | | |
| Delay (4W) | SH | SH | SH | SH | SH | SH | SH | SH | SH | SU | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | SH | SH | SH | SH | SH |
| Delay (8W) | SH | SH | SH | SH | SH | SH | SH | SH | SH | SH | SU | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | PH | SH | SH | SH | SH |

Gain 20 weeks of physics in 2010 by running during winter months

HIGH price Electricity

# THE LHC UPGRADE

# Peak Luminosity



# Phase-1 Upgrade Interaction Region

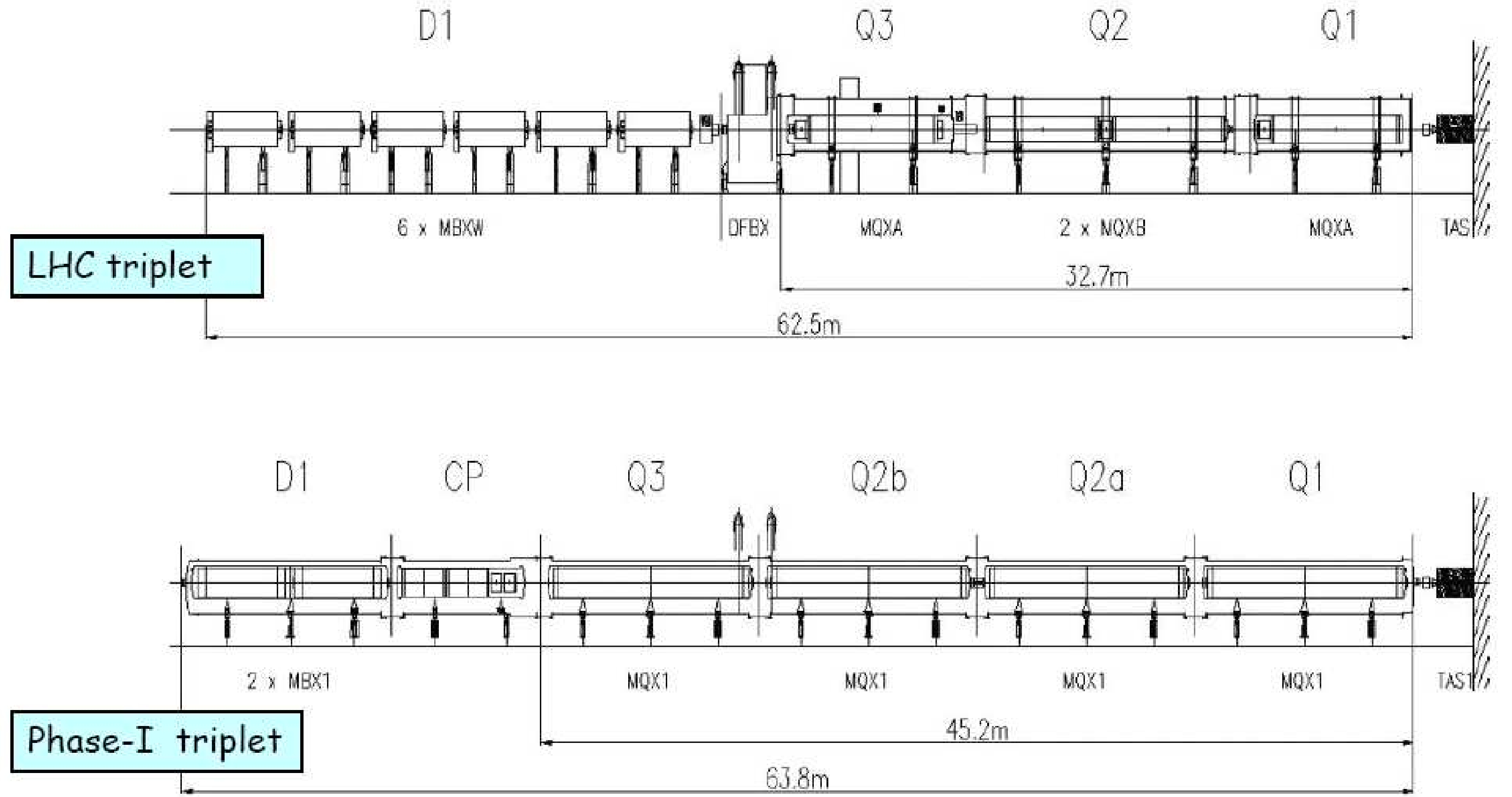
**Goal of the upgrade:**

**Enable focusing of the beams to $\beta^*=0.25$ m in IP1 and IP5, and reliable operation of the LHC at 2 to 3 $10^{34}$ $cm^{-2}s^{-1}$ on the horizon of the physics run in 2013.**

**Scope of the Project:**

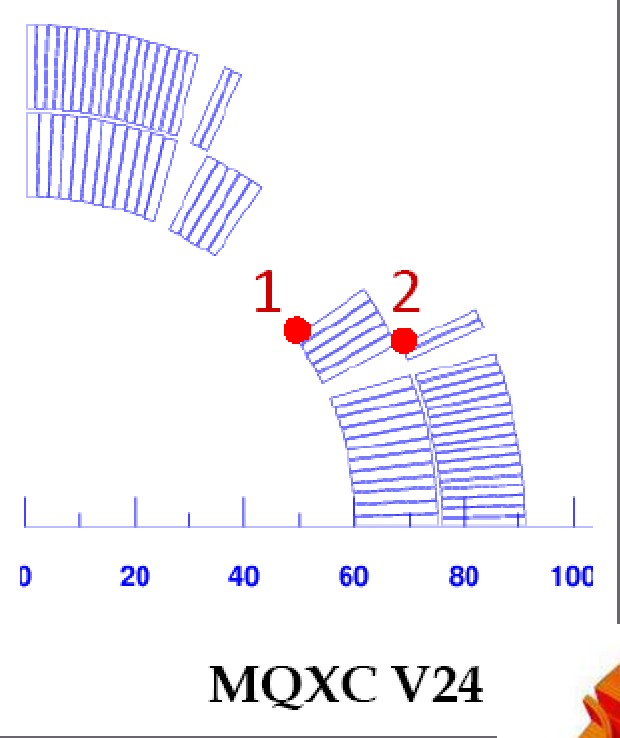
1. Upgrade of ATLAS and CMS interaction regions. The interfaces between the LHC and the experiments remain unchanged.
2. The cryogenic cooling capacity and other infrastructure in IR1 and IR5 remain unchanged and will be used to the full potential.
3. Replace the present triplets with wide aperture quadrupoles based on the LHC dipole (Nb-Ti) cables cooled at 1.9 K.
4. Upgrade the D1 separation dipoles, TAS and other beam-line equipment so as to be compatible with the inner triplets.
5. Modify matching sections to improve optics flexibility and machine protection, and introduce other equipment relevant for luminosity increase to the extent of available resources.

# Phase-1 Upgrade Interaction Region

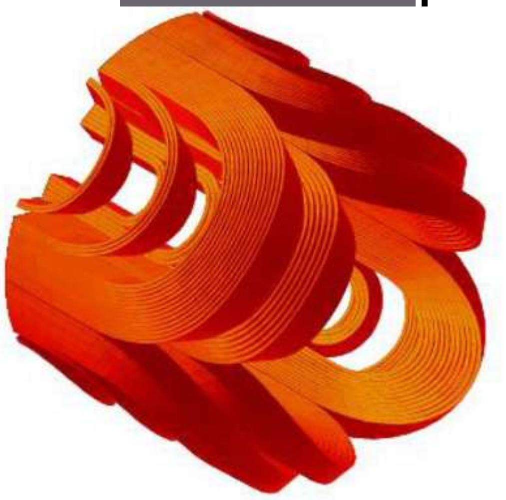



Initial proposal, iterations expected.

# Large-aperture Quadrupoles



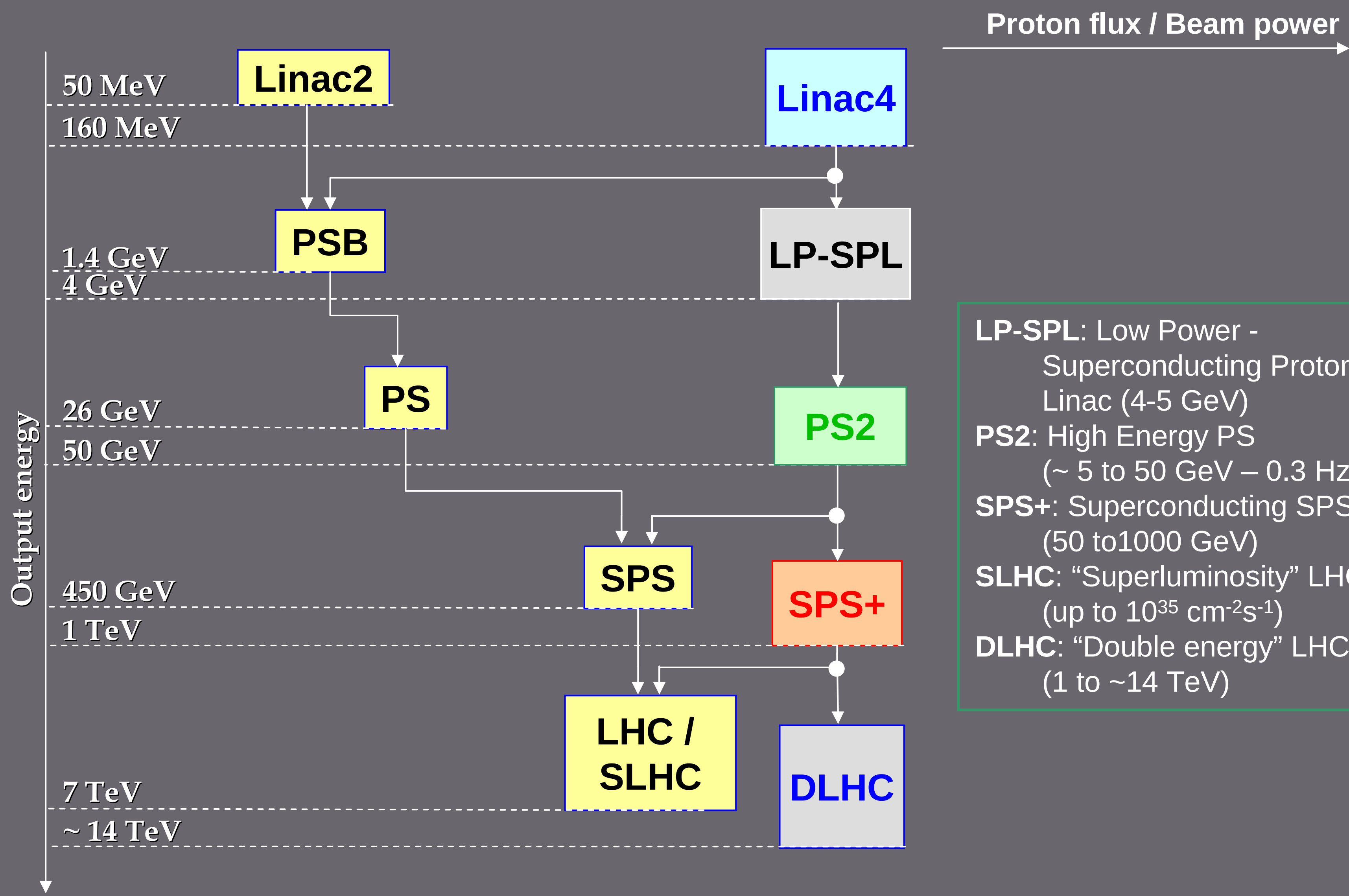

Half aperture = 60 mm
compared to 35 mm now



| | |
|---|---|
| • Coil aperture | 120 mm |
| • Gradient | 120 T/m |
| • Operating temp | 1.9 K |
| • Current | 13 kA |
| • Inductance | 5 mH/m |
| • Yoke ID | 260 mm |
| • Yoke OD | 550 mm |

- LHC cables 01 and 02
- Enhanced cable polyimide insulation
  Self-supporting collars
  Single piece yoke
  Welded-shell cold mass

# Present and Future Injectors




**LP-SPL**: Low Power - Superconducting Proton Linac (4-5 GeV)
**PS2**: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
**SPS+**: Superconducting SPS (50 to1000 GeV)
**SLHC**: "Superluminosity" LHC (up to $10^{35}$ $cm^{-2}s^{-1}$)
**DLHC**: "Double energy" LHC (1 to ~14 TeV)

# Pre-accelerator Upgrade

## Main Performance Limitation:

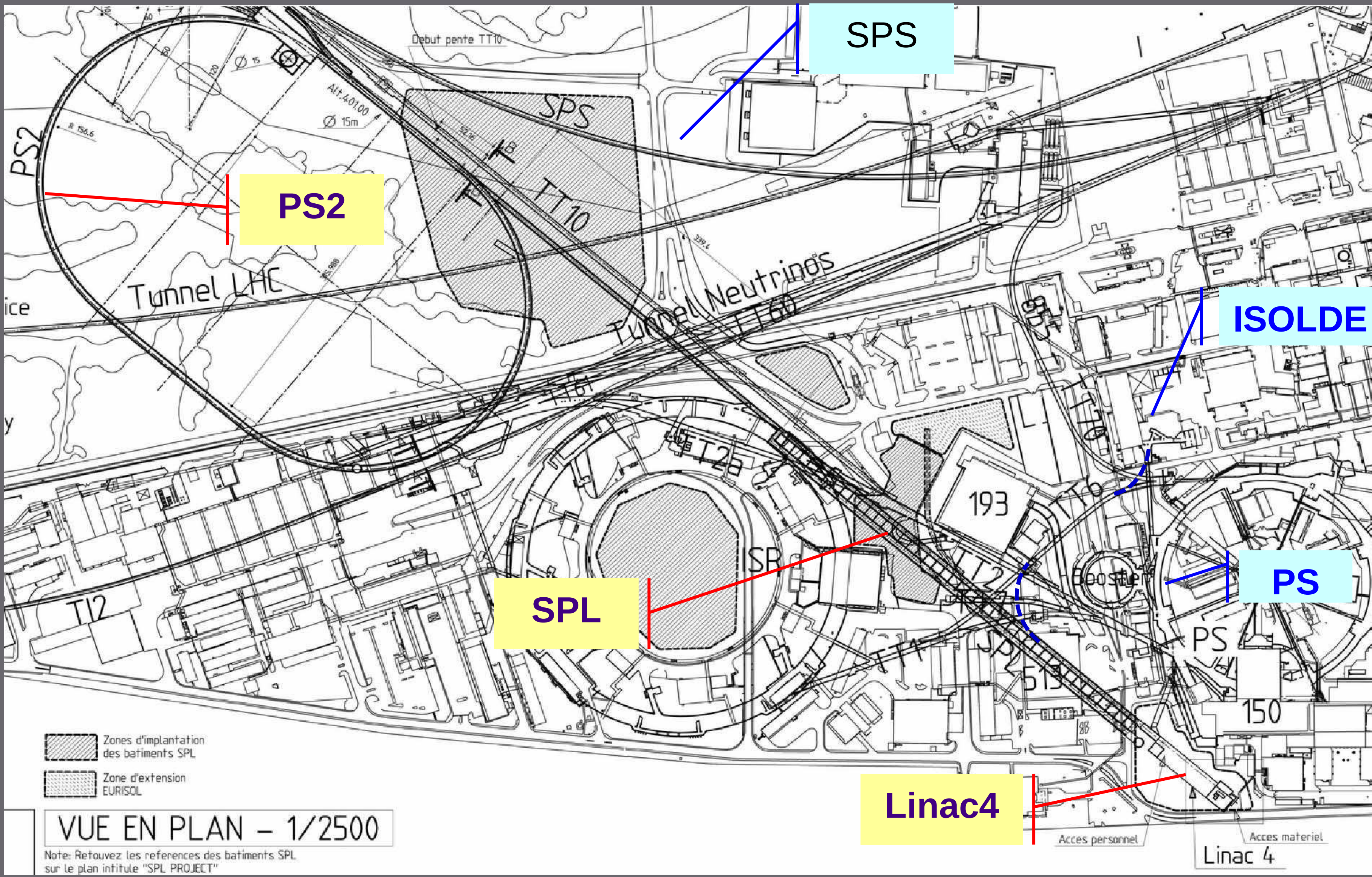
**Incoherent space charge tune spreads $\Delta Q_{SC}$ at injection in the PSB (50 MeV) and PS (1.4 GeV) because of the required beam brightness $N/\varepsilon^*$.**

$$\Delta Q_{SC} \propto \frac{N_b}{\varepsilon_{X,Y}} \cdot \frac{R}{\beta\gamma^2}$$

**$\Rightarrow$ need to increase the injection energy in the synchrotrons**

- **Increase injection energy in the PSB from 50 to 160 MeV kinetic**
- **Increase injection energy in the SPS from 25 to 50 GeV kinetic**
- **Design the PS successor (PS2) with an acceptable space charge effect for the maximum beam envisaged for SLHC: => injection energy of 4 GeV**

# Upgraded Pre-accelerators



# Timetable

| | Interaction Region | Pre-accelerators |
|---|---|---|
| 2008 | IR upgrade design<br>+ Collimation Upgrade | Start design of SPL/PS2<br>Start construction of Linac4 |
| 2011 | | Detailed project proposals for SPL/PS2 (TDR + cost estimates) |
| 2012 | | Start of construction of SPL/PS2<br>Commissioning Linac4 |
| 2013 | Commissioning of IR upgrade | Beam from Linac4/PSB |
| 2017 | | Commissioning of SPL/PS2 |

# LHC Upgrade Phase-2

- early separation (ES)

  $\beta^*$~0.1 m, 25 ns, $N_b$=1.7x$10^{11}$,
  detector embedded dipoles

- full crab crossing (FCC)

  $\beta^*$~0.1 m, 25 ns, $N_b$=1.7x$10^{11}$,
  local and/or global crab cavities

- large Piwinski angle (LPA)

  $\beta^*$~0.25 m, 50 ns, $N_b$=4.9x$10^{11}$,
  "flat" intense bunches

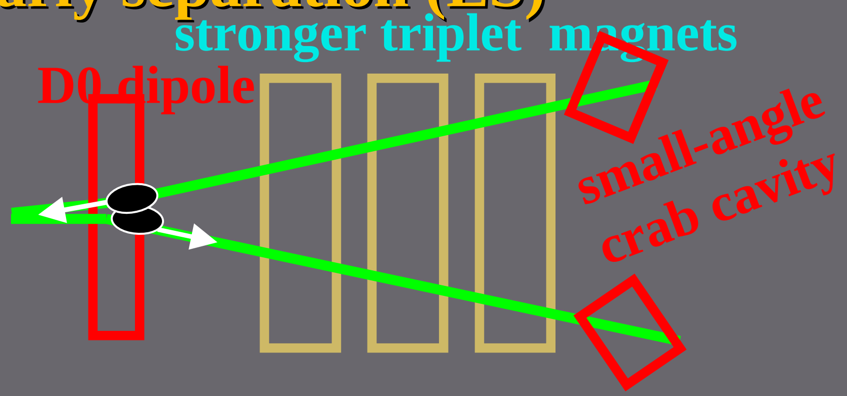
- low emittance (LE)

  $\beta^*$~0.1 m, 25 ns, $\gamma\varepsilon$~1-2 $\mu m$, $N_b$=1.7x$10^{11}$

# Phase-2 IR Layouts

## early separation (ES)

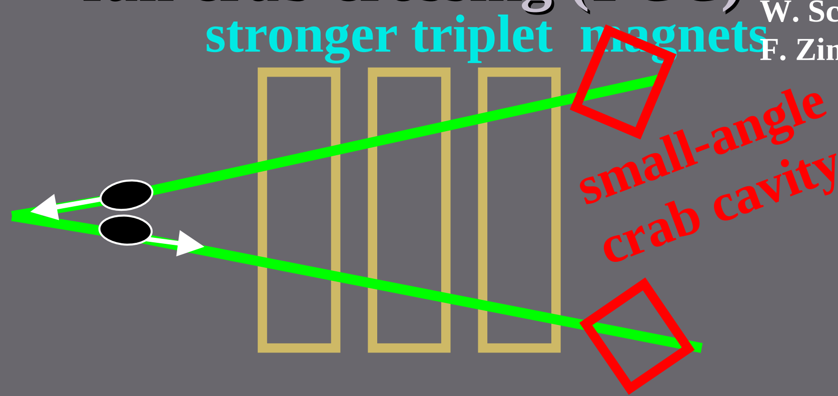
J.-P. Koutchouk




- early-separation dipoles in side detectors , crab cavities
  → hardware inside ATLAS & CMS detectors,
  first hadron crab cavities; off-δ β

## full crab crossing (FCC)

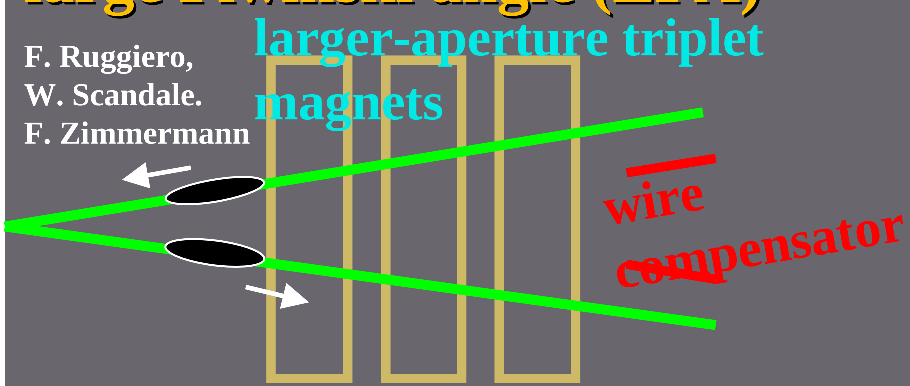
L. Evans,
W. Scandale,
F. Zimmermann




- crab cavities with 60% higher voltage
  → first hadron crab cavities, off-δ β-beat

## large Piwinski angle (LPA)

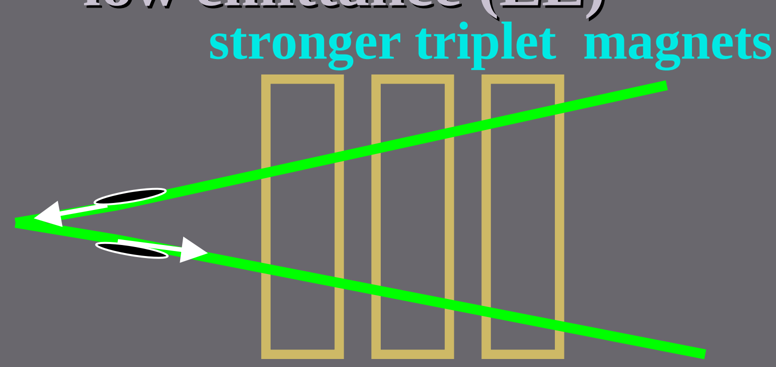
F. Ruggiero,
W. Scandale.
F. Zimmermann




- long-range beam-beam wire compensation
  → novel operating regime for hadron colliders,
  beam generation

## low emittance (LE)

R. Garoby




- smaller transverse emittance
  → constraint on new injectors, off-δ β-beat

| parameter | symbol | nominal | ultimate | ES | FCC | LE | LPA |
|---|---|---|---|---|---|---|---|
| transverse emittance | $\varepsilon$ [$\mu$m] | 3.75 | 3.75 | **3.75** | **3.75** | **1.0** | **3.75** |
| protons per bunch | $N_b$ [$10^{11}$] | 1.15 | 1.7 | **1.7** | **1.7** | **1.7** | **4.9** |
| bunch spacing | $\Delta t$ [ns] | 25 | 25 | **25** | **25** | **25** | **50** |
| beam current | I [A] | 0.58 | 0.86 | **0.86** | **0.86** | **0..86** | **1.22** |
| longitudinal profile | | Gauss | Gauss | **Gauss** | **Gauss** | **Gauss** | **Flat** |
| rms bunch length | $\sigma_z$ [cm] | 7.55 | 7.55 | **7.55** | **7.55** | **7.55** | **11.8** |
| beta* at IP1&5 | $\beta*$ [m] | 0.55 | 0.5 | **0.08** | **0.08** | **0.1** | **0.25** |
| full crossing angle | $\theta_c$ [$\mu$rad] | 285 | 315 | **0** | **0** | **311** | **381** |
| Piwinski parameter | $\phi=\theta_c\sigma_z/(2*\sigma_x*)$ | 0.64 | 0.75 | **0** | **0** | **3.2** | **2.0** |
| geometric reduction | | 1.0 | 1.0 | **0.86** | **0.86** | **0.30** | **0.99** |
| peak luminosity | $L$ [$10^{34}$ cm$^{-2}$s$^{-1}$] | 1 | 2.3 | **15.5** | **15.5** | **16.3** | **10.7** |
| peak events per #ing | | 19 | 44 | **294** | **294** | **309** | **403** |
| initial lumi lifetime | $\tau_L$ [h] | 22 | 14 | **2.2** | **2.2** | **2.0** | **4.5** |
| effective luminosity ($T_{turnaround}$=10 h) | $L_{eff}$ [$10^{34}$ cm$^{-2}$s$^{-1}$] | 0.46 | 0.91 | **2.4** | **2.4** | **2.5** | **2.5** |
| | $T_{run,opt}$ [h] | 21.2 | 17.0 | **6.6** | **6.6** | **6.4** | **9.5** |
| effective luminosity ($T_{turnaround}$=5 h) | $L_{eff}$ [$10^{34}$ cm$^{-2}$s$^{-1}$] | 0.56 | 1.15 | **3.6** | **3.6** | **3.7** | **3.5** |
| | $T_{run,opt}$ [h] | 15.0 | 12.0 | **4.6** | **4.6** | **4.5** | **6.7** |
| e-c heat SEY=1.4(1.3) | P [W/m] | 1.1 (0.4) | 1.04(0.6) | **1.0 (0.6)** | **1.0 (0.6)** | **1.0 (0.6)** | **0.4 (0.1)** |
| SR heat load 4.6-20 K | $P_{SR}$ [W/m] | 0.17 | 0.25 | **0.25** | **0.25** | **0.25** | **0.36** |
| image current heat | $P_{IC}$ [W/m] | 0.15 | 0.33 | **0.33** | **0.33** | **0.33** | **0.78** |
| gas-s. 100 h (10 h) $\tau_b$ | $P_{gas}$ [W/m] | 0.04 (0.4) | 0.06 (0.6) | **0.06 (0.56)** | **0.06 (0.56)** | **0.06 (0.56)** | **0.09 (0.9)** |
| extent luminous region | $\sigma_l$ [cm] | 4.5 | 4.3 | **3.7** | **3.7** | **1.5** | **5.3** |
| comment | | nominal | ultimate | **D0 + crab** | **crab** | | **wire comp.** |

# Summary and Conclusions

- Repair of the Sector 3-4 and consolidation/improvements to the machine are well-underway.
  - The technical parameters of the LHC are beyond precedent and the energy stored in the superconducting magnets is huge.
- It is expected that injection into the LHC will take place at the end of September this year, with collisions following in late October.
  - LHC will then run through to autumn 2010.
  - Schedule also permits possible collisions of Pb ions in 2010.
- The experiments are expected to be ready with their set-ups for the re-start of LHC operation in 2009.
- The LHC will be the most powerful instrument ever built to investigate properties of particles and the physics results from the LHC will determine the future course of high energy physics.
  - Projects already underway to improve the performance of the LHC