US LHC Accelerator Research Program

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Electron Cloud Activities

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LARP Collaboration Mtg.
Napa Embassy Suites, Oct. 19-21, 2004

Developments since FNAL LARP mtg. (June 2004)

- Participation in SPS EC runs (June 21-26, 2004)
  - CERN: Arduini, Jiménez, Baglin, Schulte; LARP: Iriso, Pivi, Furman
  - initial results: LHC-MAC mtg. #14 (Jul. 12-13, 2004)
  - ongoing analysis of results (US and CERN)
- more RHIC results
  - Hseuh, Iriso, Zhang
  - initial results: Workshop on RHIC experiments (Sep. 16-17, 2004)
- M. Jiménez visited BNL (late Sept. 2004)
  - formal proposal for e-detectors in RHIC
- Iriso to leave BNL April 05
- We'll participate in the CARE HHH-2004 wkshp. (CERN, Nov. 8-11, 2004)
- ECLOUD04 proceedings almost done!
- …

SPS EC runs (mostly June 2004)

- 1-4 batches
- 1 batch=a train of 72 bunches spaced by 25 ns (nominal)

  or

  a train of 24 bunches spaced by 75 ns
- a few runs with interleaved batches (25-75-25-75)
  - varied batch separation (225 ns [nom.]; 550 ns; 800 ns; and 1050 ns)
- E=27 GeV (mostly); N=1.4x10^{11} (mostly)
- our simulations are in progress (Pivi-Furman)
  - more slowly than I'd wanted…

SPS observations: weak dependence on batch spacing

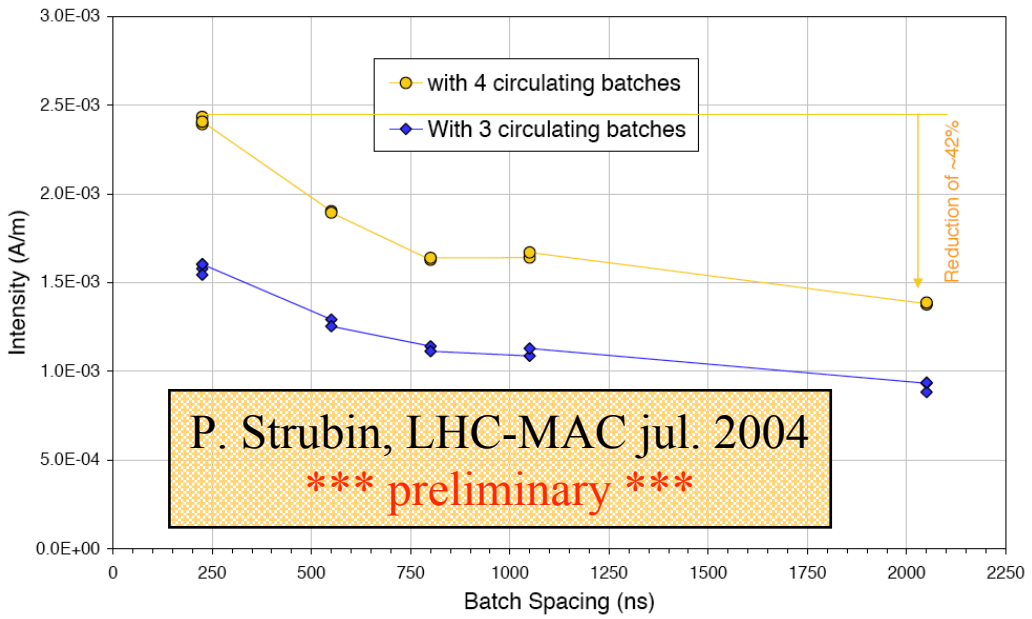
- qualitatively similar results for:
  - FF, dipole, and quad.
  - e-det. or calorimeters
  - 25 ns or 75 ns
- consistent with simulations *if* one assumes a large value for $\delta(0)$ (ie., $\delta(0)$~0.5-1)
- However, COLDEX (FF calorimter) shows that 25-75-25-75 interleaved pattern has ~1/3 less EC "activity" than uniform pattern with same no. of bunches
  - might be more a more favorable operation configuration (?)

Accelerator Technology Department

Effect of Batch Spacing

Dipole field (30-50 K), 25ns bunch spacing

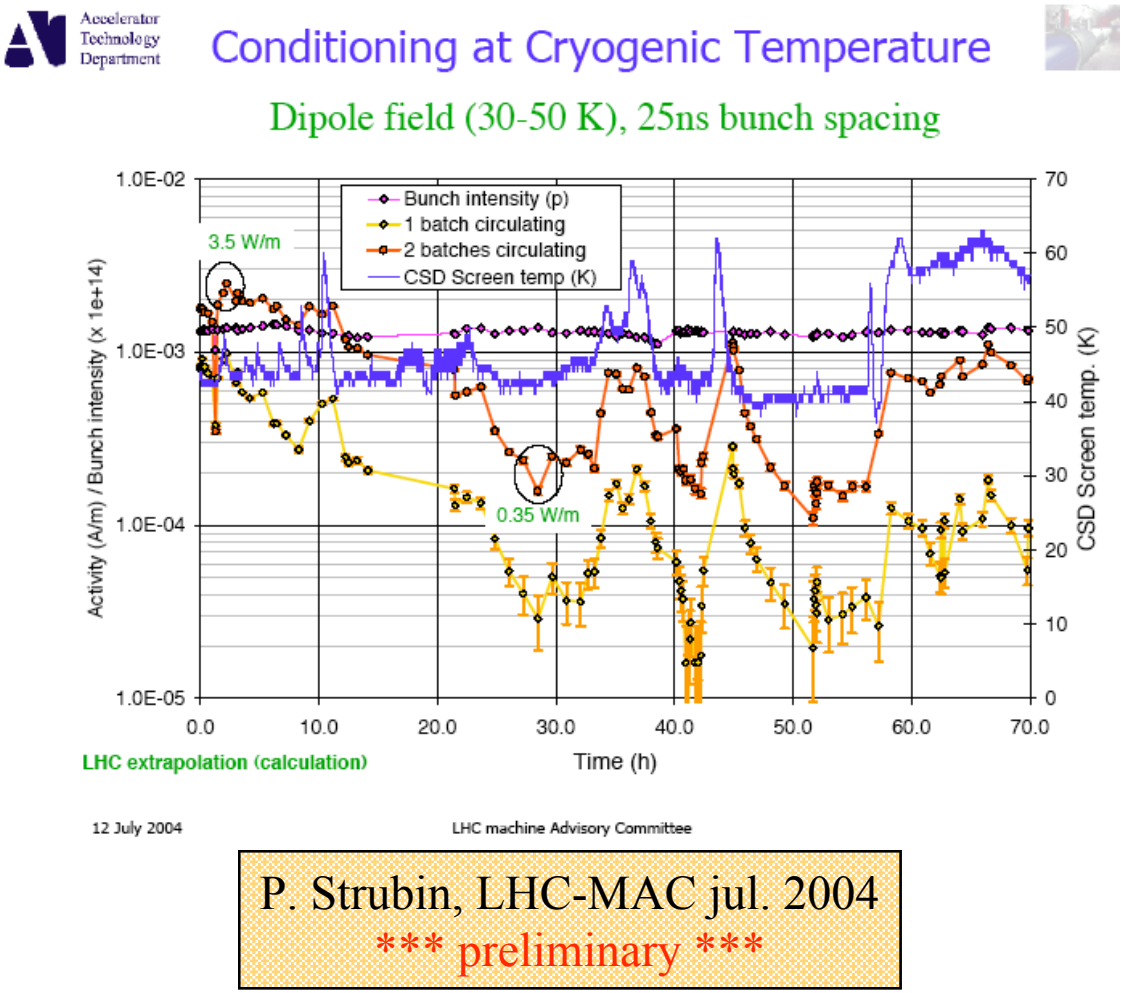
Similar behaviour as for quadrupole



12 July 2004 LHC machine Advisory Committee

SPS observations: cold Cu "beam screen" conditions like RT surfaces

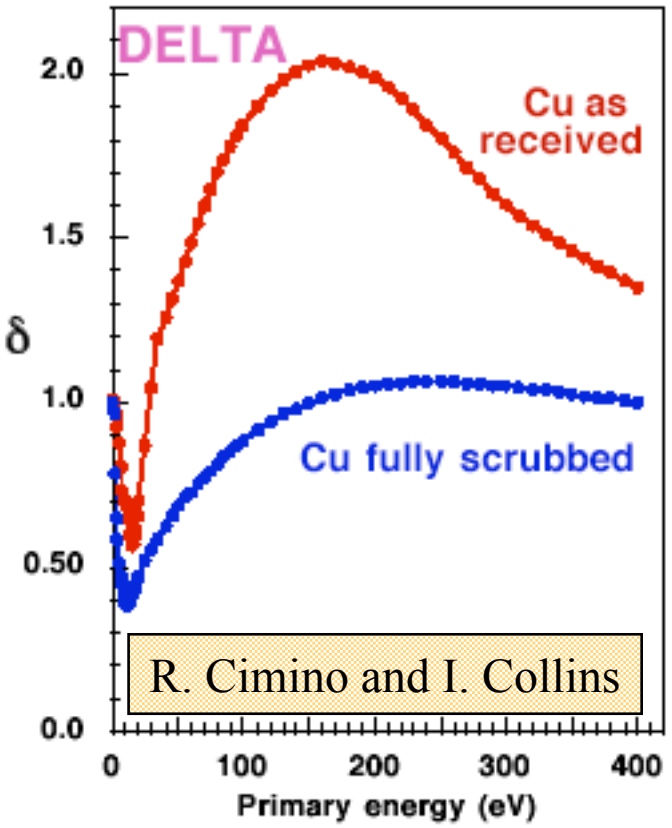
- desorbed gas composition:
  - mostly H2O and CO
  - H2O layer is bad (high SEY)
- extrapolation of these results to the LHC might need more work (IMHO)
- conditioning mechanism at cryogenic T might be different from RT conditioning



P. Strubin, LHC-MAC jul. 2004
*** preliminary ***

Conditioning of $\delta(E_0)$ for $E_0 \approx 0$

- Long survival time of low-energy electrons at SPS
  - consistent with PSR experience
  - consistent with bench results for Cu (Cimino-Collins)
  - the upturn of $\delta(E_0)$ as $E_0 \rightarrow 0$ seems unconventional
  - SPS experience needs better understanding



VOLUME 93, NUMBER 1 PHYSICAL REVIEW LETTERS week ending 2 JULY 2004

Can Low-Energy Electrons Affect High-Energy Physics Accelerators?

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Present and future accelerators' performances may be limited by the electron cloud (EC) effect. The EC formation and evolution are determined by the wall-surface properties of the accelerator vacuum

SPS e-detectors at RHIC

- e-detectors identical to those at SPS
- baseline (RT):
  - 1 strip detector (SD) in an adjustable magnet
  - 1 retarding field det. (RFD)
- ultimate: 1 SD in a cold magnet
- total est. cost:
  6.3 m-months+89 kCHF
- baseline delivery & installation:
  - June-August '05
  - this is ~8 months later than we would have ideally liked
- goal: study e-cloud as a function of bunch intensity, bunch spacing and bunch pattern in a **cold** environment

CERN
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the **Large Hadron Collider** project

LHC Project Document No.
LHC-
CERN Div./Group or Supplier/Contractor Document No.
-
EDMS Document No.
-

Date: 2002-04-15

DRAFT

Collaboration Agreement

ELECTRON CLOUD STUDIES IN RHIC USING STRIP DETECTORS

Abstract

Despite the impressive amount of experimental data collected in the SPS and in the laboratories, the extrapolation from the SPS to the LHC can only be based on the refined simulations. This situation results from the difference on the bunch length and on the filling pattern between the SPS and the LHC.

In the SPS and with 4 circulating batches, a fraction of the electrons from the cloud reflected by the vacuum chamber walls after the bunch passage, could survive the gap between two successive batches (225 ns). These reflected electrons are thought to be lost in the 14.6 μs between the 4th batch passage and a new passage of the 1st batch from the following cycle. In the LHC, the situation could be less favourable since the ring will be full of batches and the maximum spacing between batches will not exceed 3 μs (rise time of the LHC dump kickers) or 1 μs between two successive injection of SPS trains (3 or 4 batches). If the electrons from the cloud survive these gaps, the build up may be significantly enhanced.

In order to study this effect and the efficiency of the filling scheme as an alternative solution to decrease the electron cloud activity while keeping the luminosity at its highest level, it is proposed to install strip detectors in the RHIC machine (BNL Laboratory – USA). This machine is able to provide proton beams with intensities above the electron cloud multipacting threshold and a filling scheme on demand.

These detectors will also be available for specific RHIC studies linked to the luminosity upgrade.

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Some RHIC observations

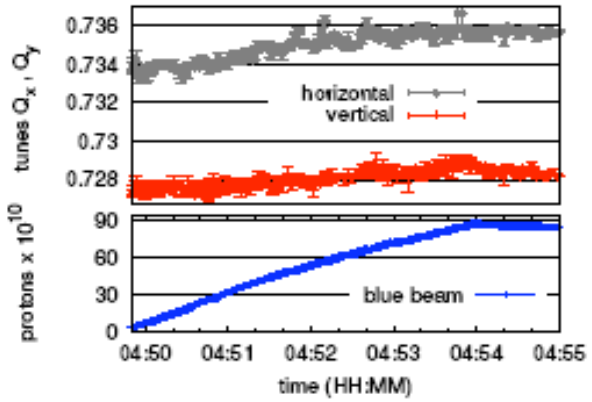
- e-cloud directly observed in warm SS
- indirectly observed in cold arcs (P↙)
- measure tune shift to disentangle

$$\Delta Q = \frac{r_p}{\gamma} \oint \beta\rho \; ds \qquad (\rho\text{=e-cloud density})$$

- observe $\Delta Q_h = 2\Delta Q_v \approx 0.002$ in arcs
- "⇒" e-cloud in arc dipoles
- however, ΔQ from warm SS is ~0.005, so conclusion not firm
- installed more TiZrV-coated chambers
  - "works better than solenoids"

One attempt last year: Fill # 5350.

→ 60 bunches at injection
→ $N_b = 1.56 \cdot 10^{11}$ protons (average)
→ $s_b = 108$ns
→ ΔQ measured with PLL *
→ Flux into the wall measured at IR12



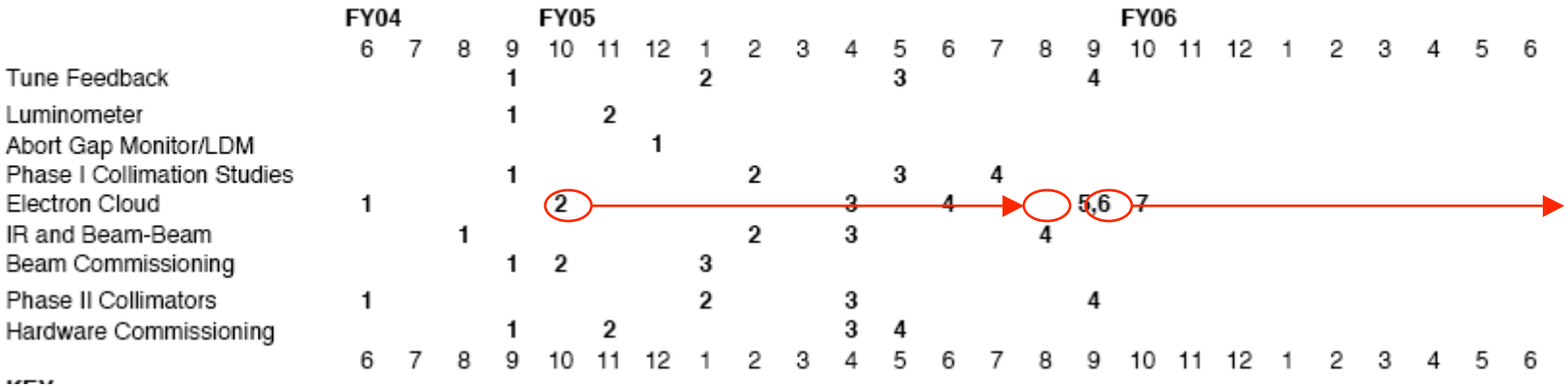
NOTE: $\Delta Q_h = 0.002, \; \Delta Q_v = 0.001$

*Thanks Pete Cameron!

U. Iriso, RHIC expts. wkshp. 9/04

EC schedule

Accelerator Systems Milestones **June 14, 2004**



Electron Cloud

1) Participate in SPS EC experiments and studies (when?)
2) Install cold EC detector in RHIC
3) Report on simulated reproduction of measured spectrum & spatial distribution of SPS ECs
4) Report first cut at defining optimal LHC conditioning scenario
5) Report on applicability of map simulation technique to LHC
6) Report on cold EC in RHIC
7) Report on simulated EC at IR4 diagnostic bench

Comments & conclusions

- Continue and increase SPS analysis via simulations
  - plan to hire an UG student 1/2 time for this (soon, I hope)
  - code benchmarking as part of the process (LARP-CARE informal collaboration)
- Iriso-Peggs map technique: needs continuity after UI leaves
  - who?
- Hopefully RHIC will not fully suppress the e-cloud with coated chambers!
  - we need an e-cloud in the warm regions for better testing our simulations
  - make sure we reach the point of installing the cold SD in RHIC
- I feel a lack of “critical mass” in the e-cloud effort
  - leads to infrequent communication with CERN people
  - it’s a nontrivial effort to keep up with CERN’s and other’s activities
  - maybe it’s a temporary state…

Additional material

Some Issues

- EC survives for a long time at SPS (~few s)
- e^- flux at wall for dipole magnet ~3x simulations both warm and cold detectors
- Measured e^- spectrum "could agree better with simulations"
- Old vs. new ECLOUD simulations show some discrepancies
  - some comparisons with other codes carried out (after ECLOUD02)
  - qualitative agreement, but differences not explained (for lack of dedicated effort)
- e^- flux dependence on vac. chamber height: peaks at 80 mm (=max. achievable)
- Main "knobs": bunch length, batch spacing, vac. chamber height, N
  - should be plenty to constrain the model significantly
  - need to constrain SEY model; devise experiment (ie., build-up and dissipation of the EC)
  - revisit satellite bunch scheme

Partial List of Electron Cloud Tasks

- Main goal: specify optimal LHC conditioning scenario
  - Conditioning of cold surface at LHC likely to be very different from warm at SPS
  - What to do if beam screen SEY does not condition as hoped
  - First attempt at defining scenario
- Tasks at RHIC (suggested by "all" CERN people)
  - Install CERN EC detector in a RHIC cold magnet (J. M. Jiménez, A. Drees)
  - Measure $\Delta\nu$ along batch (U. Iriso)
  - Simulate ECE at RHIC, calibrate code(s), understand warm vs. cold EC
    - UI to learn POSINST; go to LBNL, and/or MF to BNL
  - Understand conditioning process in cold sections vs. warm
  - Understand global parameter space (eg., EC density vs. a few parameters)
  - Understand physics of map simulation technique

List (contd.)

- SPS
  - Devise experiment to be compared against upcoming SPS measurements to constrain SEY model
    - eg., build-up and decay time of EC vs. N, s_B and batch gap length (FY04-05)
    - Estimate EC build-up and decay in quads (SPS plans to install “sweeping” detector) (FY05+)
  - US-LARP personnel to participate in scrubbing SPS MDs (next week)
  - Reproduce measured spectrum and spatial distribution (FY05)
  - Reproduce calorimeter results (FY05)
  - Understand POSINST-ECLOUD differences (FY05) (suggested by FZ)
  - Think about BTF measurements (requested by GA)
  - Think about microwave transmission measurements of EC density (suggested by FZ)
  - Measure ion desorption count and composition by ion bombardment (requested by JMJ: send one person to CERN for a year to do measurements)

List (contd.)

- Better measurements for simulation input (requested by FZ)
  - SEY at low energy (<20 eV); reproduce CERN data (Cimino-Collins)
  - Photoelectric yield and photon reflectivity (cold vs. RT; B-field effect) for actual sawtooth beam screen samples; resolve existing discrepancies (at ALS?). *Further discussions with CERN needed before proceeding.*
- LHC
  - CERN will install an ECE diagnostic bench in IR4 (J. M. Jiménez) similar to SPS.
  - Simulate and predict! Good for LARP to play important role in this.

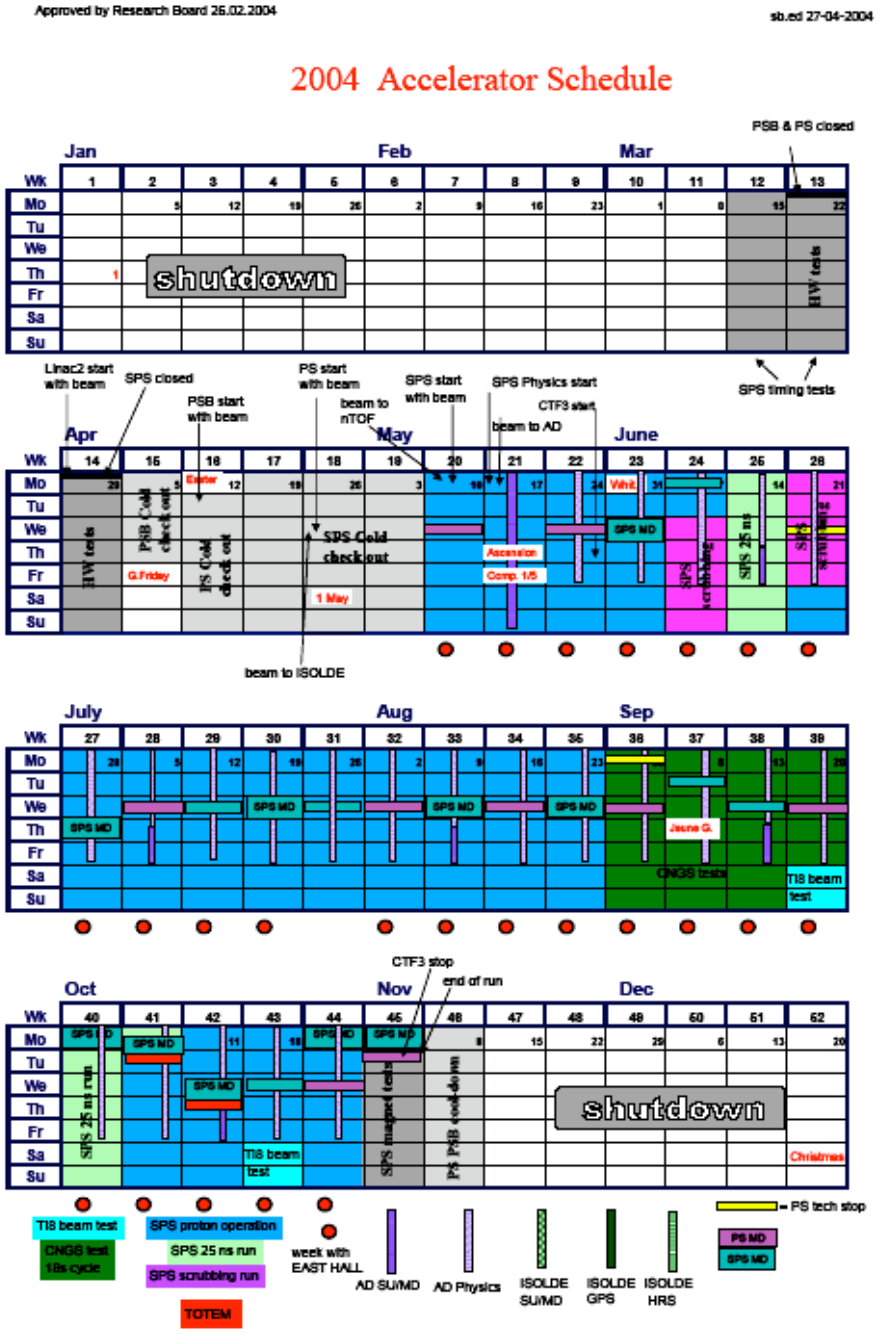
SPS schedule 2004

Scrubbing runs (weeks 24 & 26):

- N=(0.3-1.3)x10^{11}, min. ε, fixed σ_z, 1-4 batches, s_B=25 or 75 ns

Some expected results:

- max. N and fill pattern at 25 and 75 ns for given cooling rate
- improve precision in measurement of conditioning efficiency for cold dipoles
- measure heat load and partial pressures in COLDEX
- EC build-up in quads
- EC build-up in TiZrV-coated chamber before activation (use artificial seed electrons)



More SPS MD details (from G. Arduini and J. M. Jiménez)

- Weeks 24 and 26: scrubbing (MD people have full control of beam)
- Week 27: beam stability, optimize the machine settings to get rid of the last 10-20% in emittance blow-up in order to get the nominal parameters. Measurements with COLDEX and electron clould detectors and calorimeters.
- Weeks 29 and 31: coasts (with RF on) of 1-2 LHC batches at SPS injection energy (p=26 GeV/c). Study the issues of long term emittance blow-up for the nominal LHC beam. Benchmark HEADTAIL or similar codes (which are predicting important emittance blow-up).
- Week 40: coast with 1-2 LHC batches (nominal intensity) at p=270 GeV/c for similar purposes as above.
- Week 45: not yet defined.

Our Plans

- SPS shifts during "scrubbing runs" (next week)
  - Ubaldo Iriso, Mauro Pivi, Miguel Furman
    - CERN contact: Gianluigi Arduini
- Deliverables for FY05:
  1. Participate in SPS EC experiments and studies (next week)
  2. Install cold EC detector in RHIC (10/04)
  3. Report on simulated reproduction of measured spectrum & spatial distribution of SPS e-cloud (4/05)
  4. Report first cut at defining optimal LHC conditioning scenario (6/05)
  5. Report on applicability of map simulation technique to LHC (9/05)
  6. Report on cold EC in RHIC (9/05)
  7. Report on simulated EC at IR4 diagnostic bench (10/05)
- FY05 budget: 0.3 FTE for LBNL plus 0.3 FTE for BNL