Background at HERA

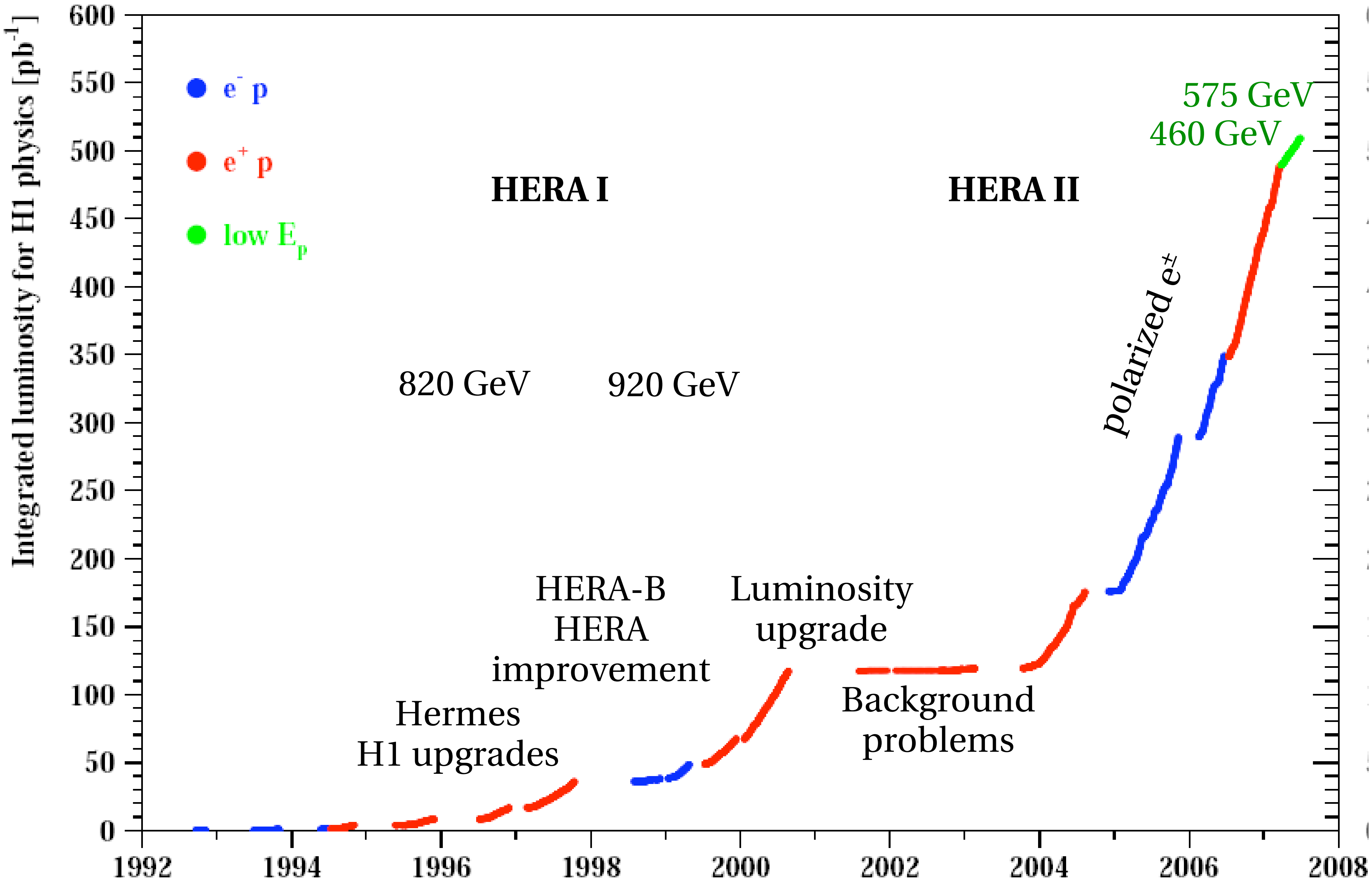
Perspective of the Experiments

Workshop on Experimental Conditions and Beam Induced Detector Backgrounds

Carsten Niebuhr

DESY

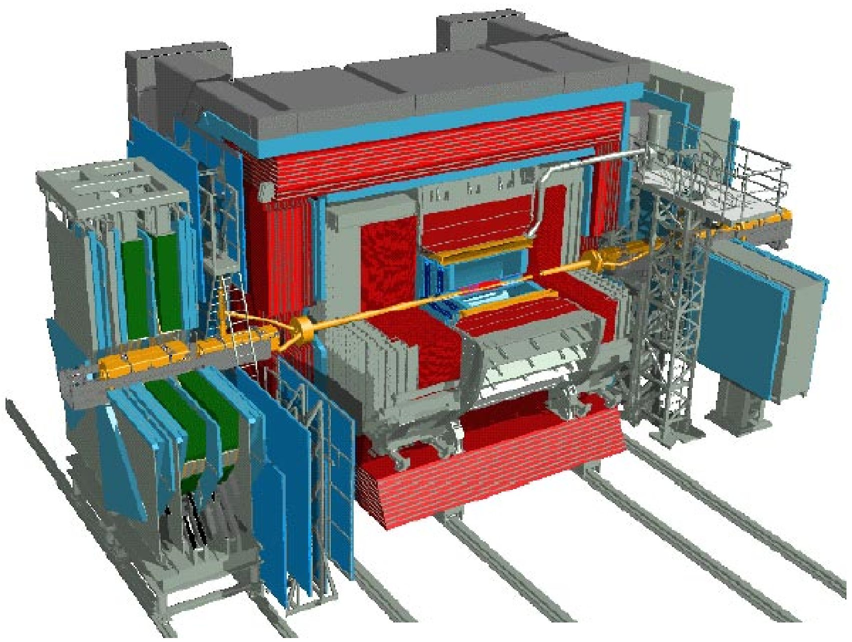
15 Years of HERA Operation

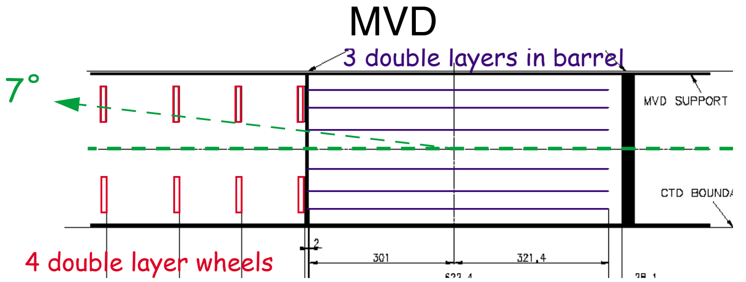


- Will focus on most significant background problems at H1 and ZEUS after luminosity upgrade
- Will not cover other specific background problems
  - FPS/LPS versus HERA-B wire target
  - Hermes

Sensitive Components close to Beamline

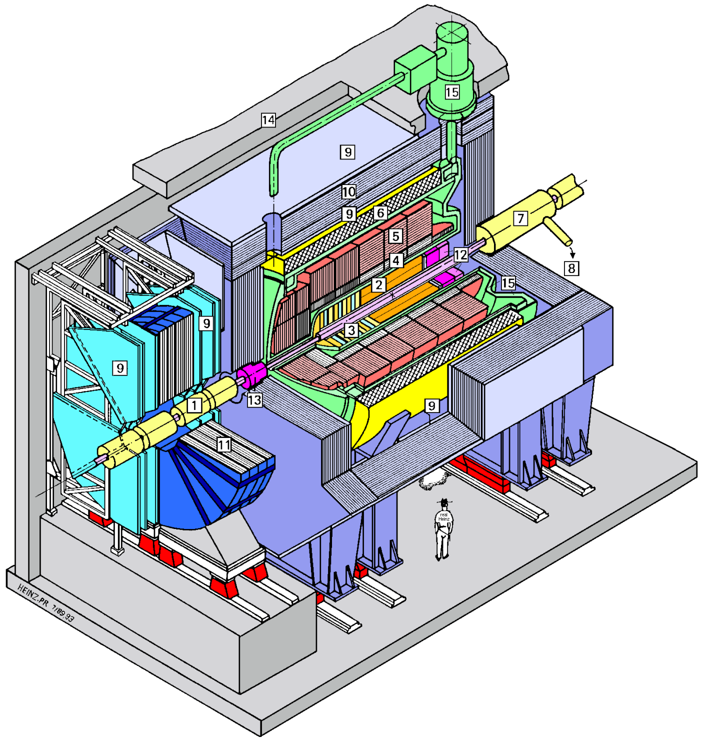
ZEUS

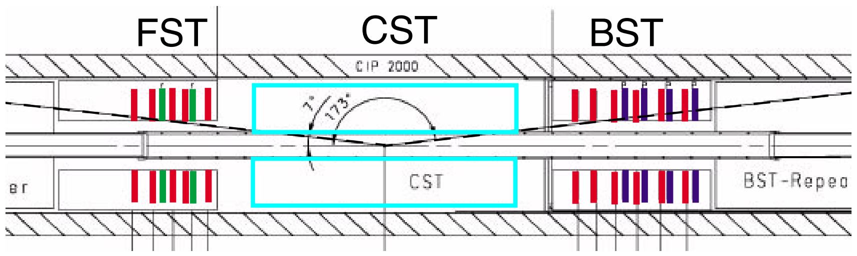




- Gaseous Tracker (CTD, RTD, STT)
  - I_{CTD} < **350 μA**
- Micro Vertex Detector MVD
  - Si sensor and CMOS r/o chip (HELIX) can tolerate up to a **2-5 kGy**

H1





- Gaseous Tracker (CJC,COZ,CIP,FTD)
  - severe aging seen in CJC in HERA I => I_{CJC} < **200 μA**
- Silicon Tracker (CST, BST, FST)
  - CST **DMILL** up to **100 kGy**
  - FST/BST **SACMOS** up to **150 Gy** –> 2005 replaced by **DSM** design (**500 kGy**)

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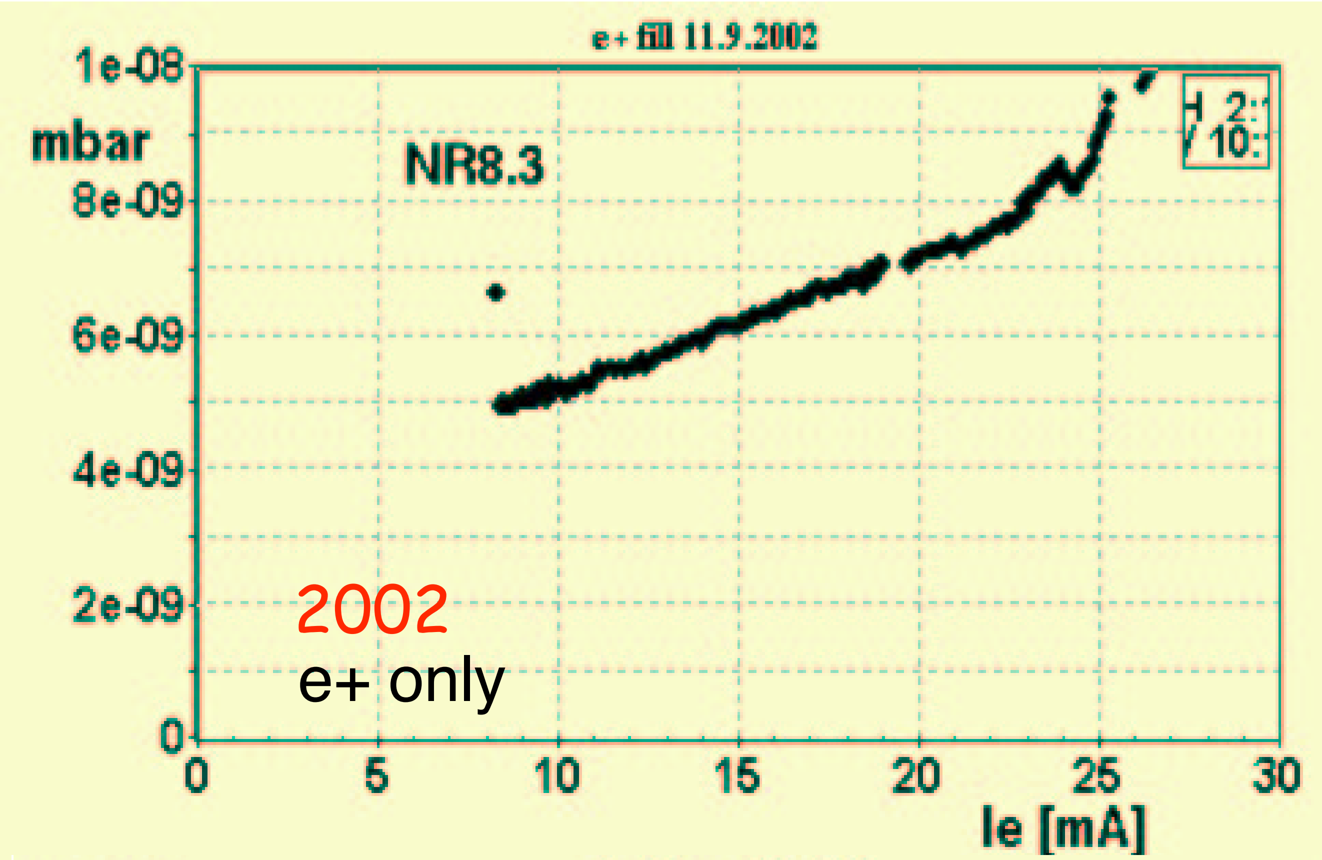
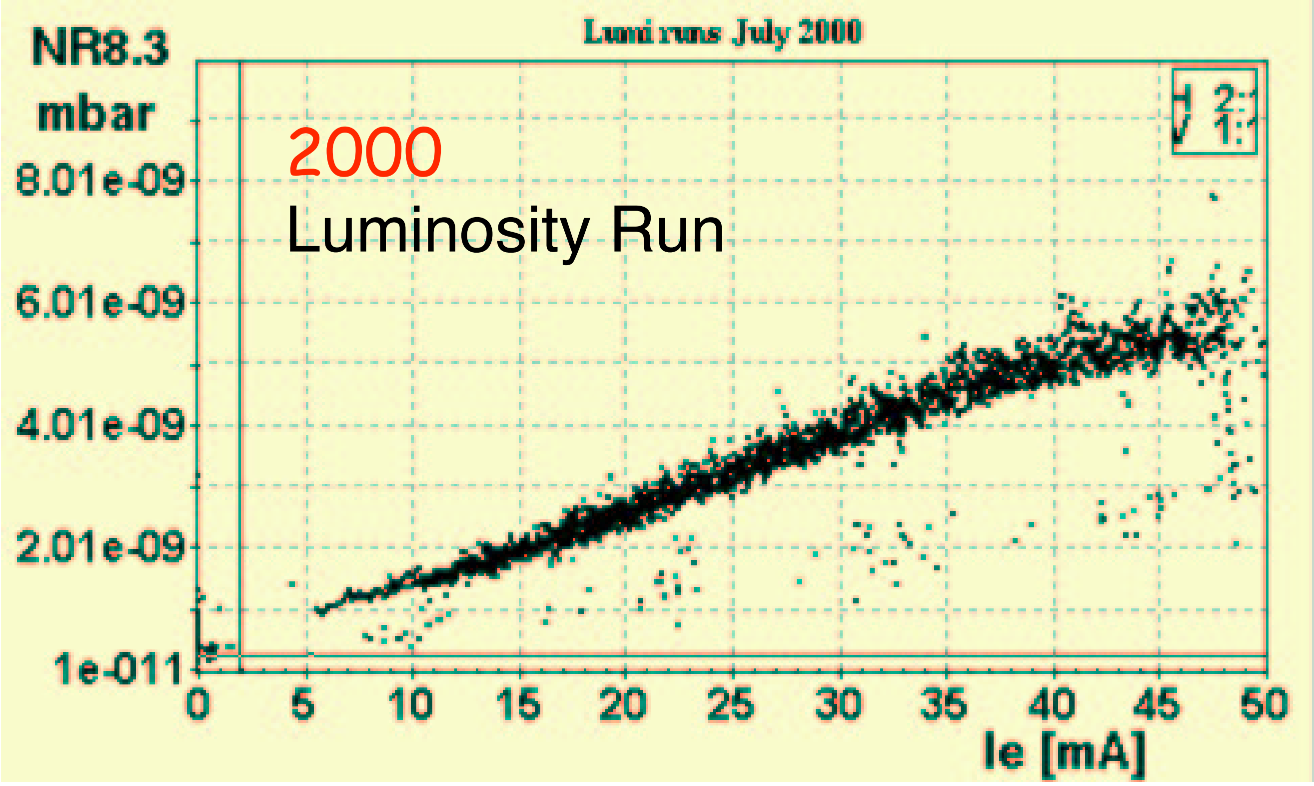
Luminosity Runs 2002





- e+ only run 2002
  - base pressure 2-3x10^{-9} mbar
  - strong increase with increasing I_e
    - not possible to run at design currents 105 mA x 50 mA

- Luminosity run 2000
  - base pressure 10^{-10} mbar
  - dynamic pressure increase leads to p=6x10^{-9} mbar at I_e = 50 mA

HERA Background Workshop and Reviews

Workshop on Synchrotron Radiation- and Particle Background in HERA

July 23-24 2002

at DESY in Hamburg

HERA, the electron proton collider at DESY in Hamburg turned on last year after a major upgrade of the interaction regions which should give at least a factor of 3 in luminosity in each of the experiments H1 and ZEUS.

While there where no unusual problems in recommissioning the accelerator, the background problems have been found more difficult than expected.

After the situation has been analyzed and studied, a point is reached where it appears to be desirable to review the HERA background problems and compare them to backgrounds at other accelerators.

For this reason, a short workshop is being organized which will be held at DESY on July 24-23

Agenda

Tuesday, July 23

9:00h	HERA Luminosity Upgrade	F. Willeke	30min
9:30h	Background Supression Design of the HERA IRs	D. Pitzl	30min
10:00h	H1 Background Studies	C. Niebuhr	30min
10:30h	Coffeebreak		30min
11:00h	ZEUS Background Studies	U. Schneekloth	30 min
11:30h	Synchrotron Radiation Simulation	I. Bloch	20 min
11:50h	Beam-Based Alignment	J. Keil	20 min
12:10h	Beam Tail Measurements	W. Decking	20 min
12:30h	Lunchbreak		
14:00h	Discussion of HERA Background Measurements and Calculations and Comparison with the corresponding finfdings at other accelerators	H.Burkhardt, S.Uno M.Sullivan, W.Kozanecki	3:30h (incl. break)
19:00h	Dinner in the DESY Bistro		

Wednesday, July 24

9:30h	Summary and Recommendations	all	2:30h
12:00	Adjourn		

Coordination

C. Niebuhr, H1 (carsten.niebuhr@desy.de)
U. Schneekloth, ZEUS, (uwe.schneekloth@desy.de)
F. Willeke, HERA (ferdinand.willeke@desy.de)

Committee Members:
Helmut Burkhard, CERN
Michael Hauschild CERN
Witold Kozanecki, CEA
Michael Sullivan, SLAC
Shoji Uno, KEK

Review on HERA Background and Vacuum Issues
October 21-23, 2002
at DESY

Draft Agenda

Monday, October 21

9:00h - 9:10h	Welcome	A. Wagner tbc
9:10h - 9:30h	Introduction and Charge	R. Klanner tbc
9:30h - 9:50h	HERA Luminosity Upgrade and Status	F. Willeke
9:50h - 10:10h	Vacuum Systems in the HERA IR	M.Seidel
10:10h -11:00h	Overview of Detector and Background Conditions at H1	D. Pitzl
11:00h - 11:20h	*Coffee*	
11:20h - 11:50h	Overview of Detector and Background Conditions at ZEUS	U. Schneekloth
11:50h -12:20h	Synchrotron Radiation Background at ZEUS	I. Bloch
12:30h – 14:00h	*Lunch*	
14:00h – 14:30h	Particle Background at ZEUS	R.Carlin
14:30h – 15:10h	Proton Background at H1	S. Levonian
15:10h – 15:30h	*Coffee*	
15:40h – 18:00h	Executive Session	
19:00h	*Dinner for Committee and Speakers*	

Tuesday, October 22

Second Review of Backgrounds in HERA II

January 16–17, 2003

Committee Membership
Reinhard Brinkmann, DESY MPY
Richard Hseuh, BNL
Witold Kozanecki, CEA Saclay
Andy Miller, TRIUMF
Brett Parker, BNL
Andreas Schwarz, DESY F15

Principal Charges

- Do H1 and ZEUS understand their backgrounds quantitatively?
- Have solutions to the background problems been identified?
- Are preparations adequate for applying these solutions during the March 2003 shutdown?
- What measures should be taken to clarify any remaining questions?

Background reports

Technical Report on the Beam Induced Backgrounds in the H1 Detector

H1 background working group

V. Andreev, W. Bartel, J. Bracinik, A. Buniatian, E. Elsen, R. Felst, J. Ferencei, P. Fleischmann, J. Gayler, T. Greenshaw, M. Kapishin, M. Klein, C. Kleinwort, V. Lendermann, S. Levonian, B. List, R. Lopez-Fernandez, L. Lytkin, N. Malden, C. Niebuhr, D. Pitzl, E. Rizvi, A. Schöning, H.-C. Schultz-Coulon, A. Specka, R. Stamen, F. Tomasz, I. Tsurin, K. Urban, P. Van Mechelen, K. Wacker.

Abstract

This report describes studies of the beam induced backgrounds that presently prevent operation of the H1 detector with the design HERA II beam currents. Measurements are presented and compared with Monte Carlo simulations that provide a reasonable description of the backgrounds in H1 arising from synchrotron radiation and proton beam-gas interactions. A detailed evaluation is given of various measures that reduce these backgrounds. Significant improvements require a substantially better vacuum in the region around the H1 interaction region, extending to at least $z \simeq -12\,\mathrm{m}$.

ZEUS–02–018

Study of beam-induced backgrounds in the ZEUS detector from 2002 HERA running

Version 1.0, 26/Sep/2002

ZEUS Background Working Group

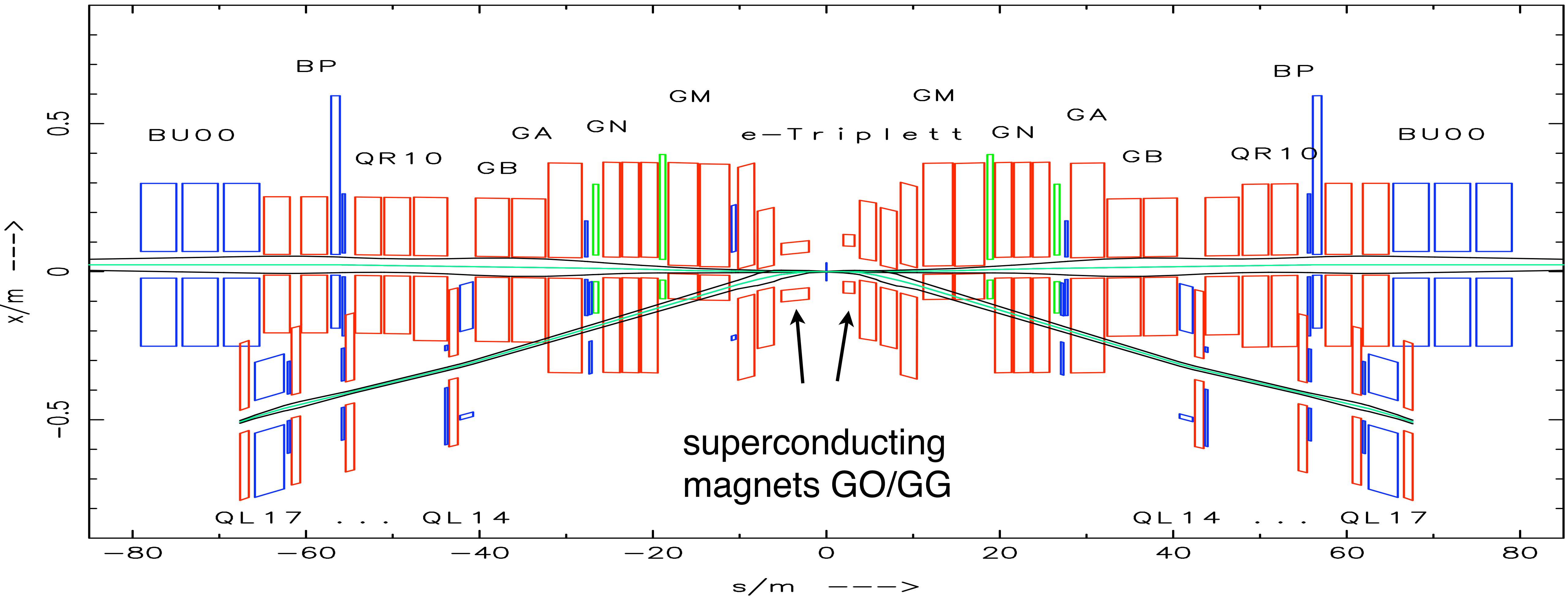
D. Bailey, G. Barbagli, I. Bloch[1], N. Brummer, A. Bruni, R. Carlin, C. Catterall, S. Chekanov, J. Cole, N. Coppola, J. Fourletova, S. Goers, T. Haas[1], R. Hall-Wilton, J. Hamilton, D. Kcira, K. Klimek, U. Koetz, M. Kuze[1], G. Levman, B. Loehr, E. Lohrmann, J. Loizides, S. Padhi, S. Paganis, R. Renner, S. Schlenstedt, W. Schmidke, U. Schneekloth[1], M. Sutton[1], E. Tassi, K. Tokushuku, T. Tsurugai, G. Wolf, Y. Yamazaki[1], W. Zeuner

http://www-h1.desy.de/publications/bgrep.pdf

http://www-h1.desy.de/publications/bgrep2.pdf

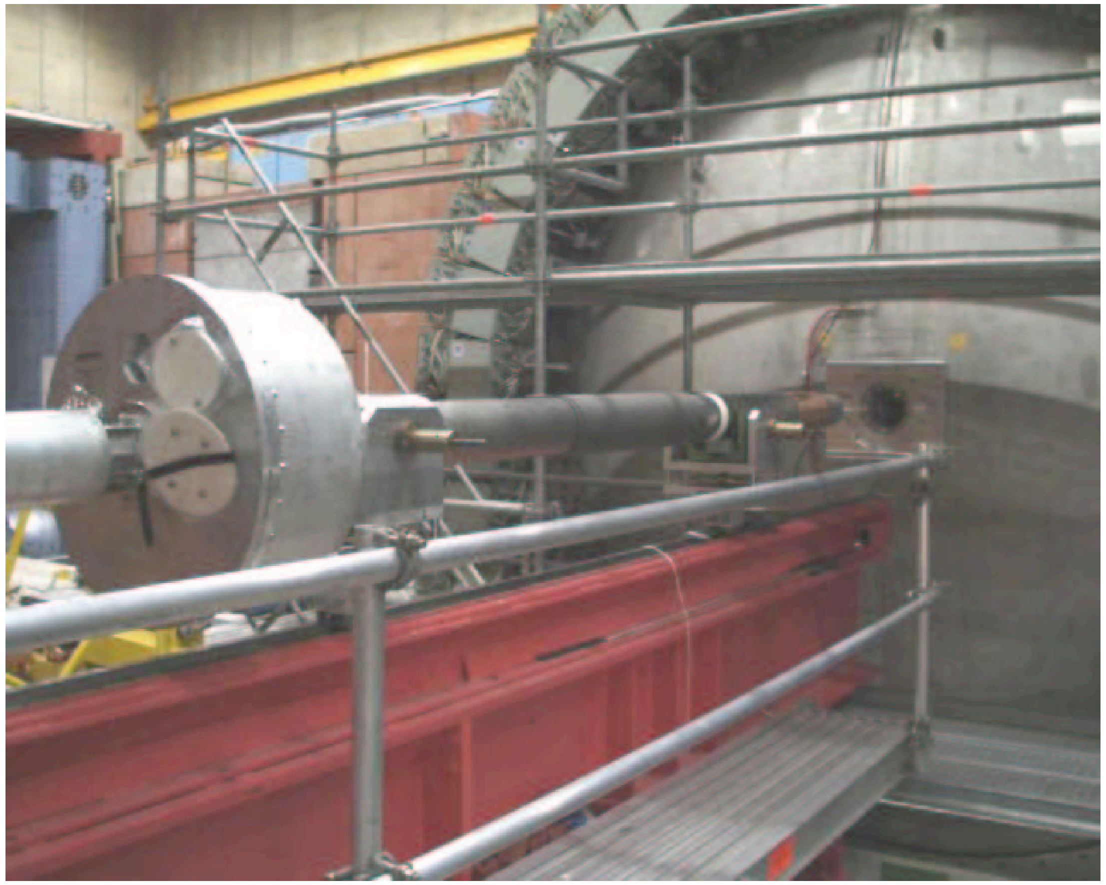
http://www-zeus.desy.de/~kuze/zeusbg/

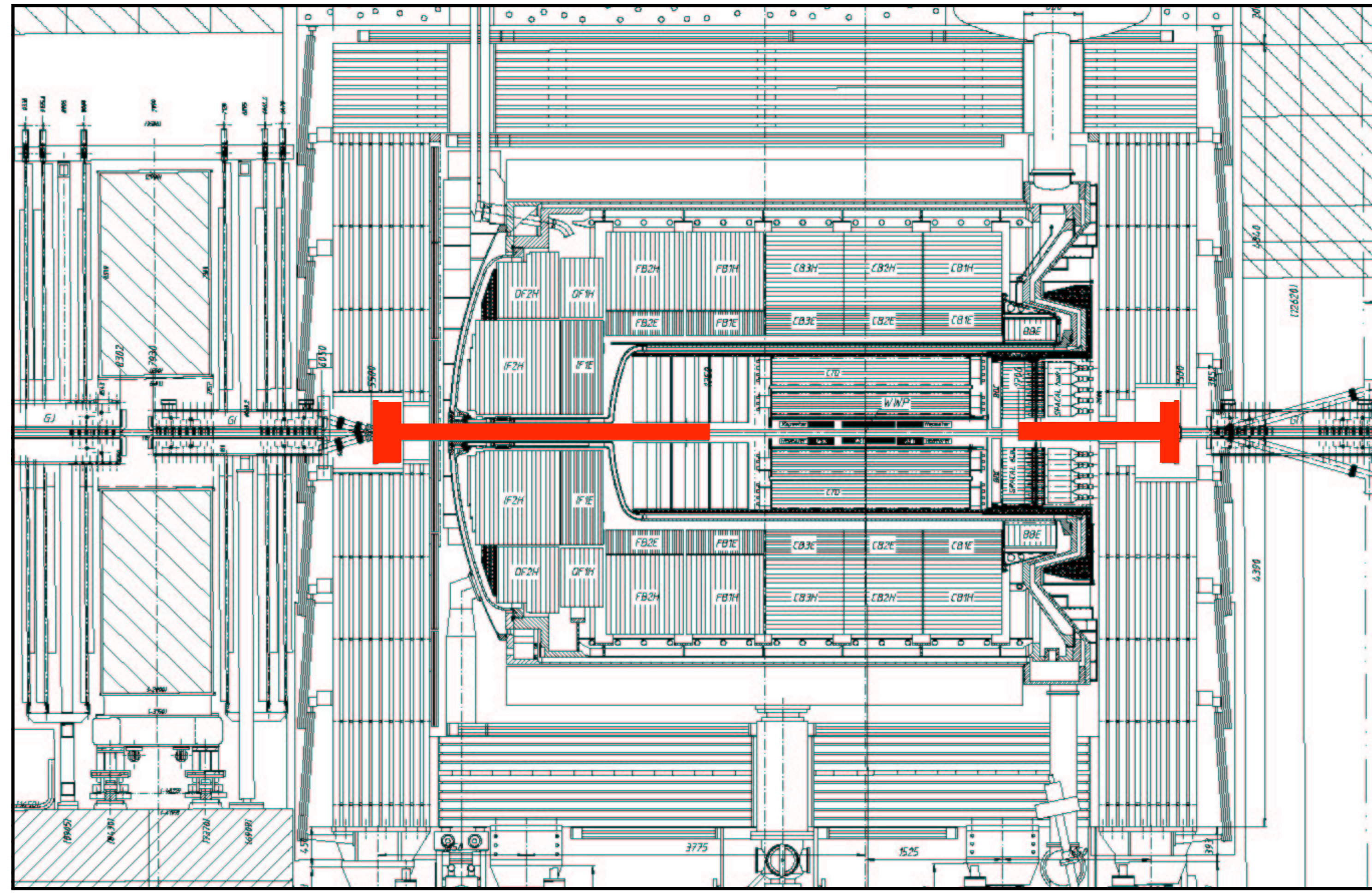
HERA Luminosity Upgrade



- Stronger focussing of protons by moving quadrupoles closer to IP: 26m –> 11m
  - early beam separation by superconducting magnets inside detectors
  - 2 x 220 m new vacuum beam pipe
  - 2 x 26 new normal conducting + 2 x 2 superconducting magnets
  - reduced e-bending radius: 1200m –> 400m => increased synchrotron radiation power:
    - $P_{tot} \approx 25$ kW @ I_e=50mA
    - ~10^{18} γ/s @ $E_{crit} \approx 120$ keV
  - radiation has to pass through detector and is absorbed at 11m, 19m and 25m behind IP

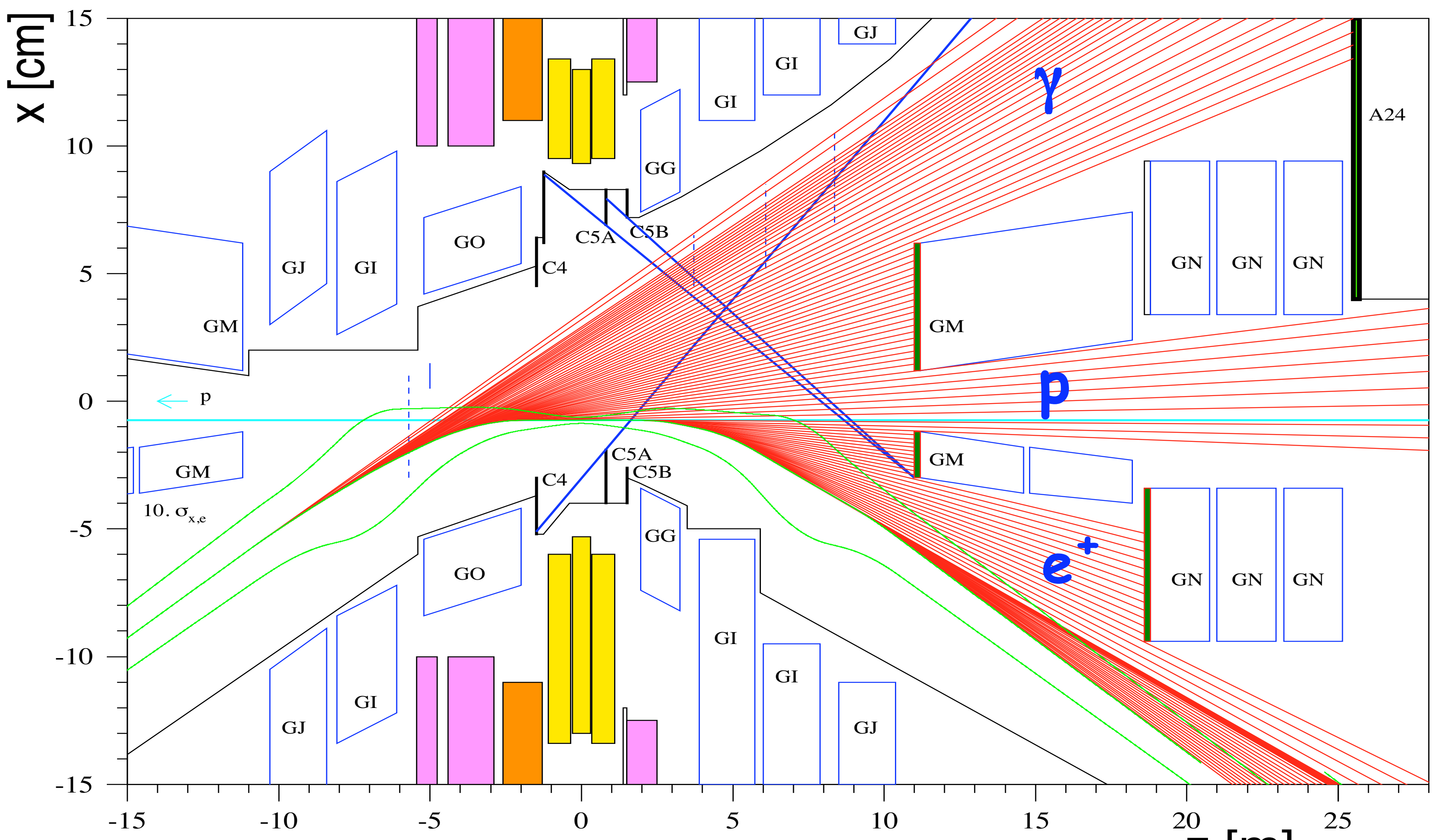
Superconducting Magnets inside the Experiments





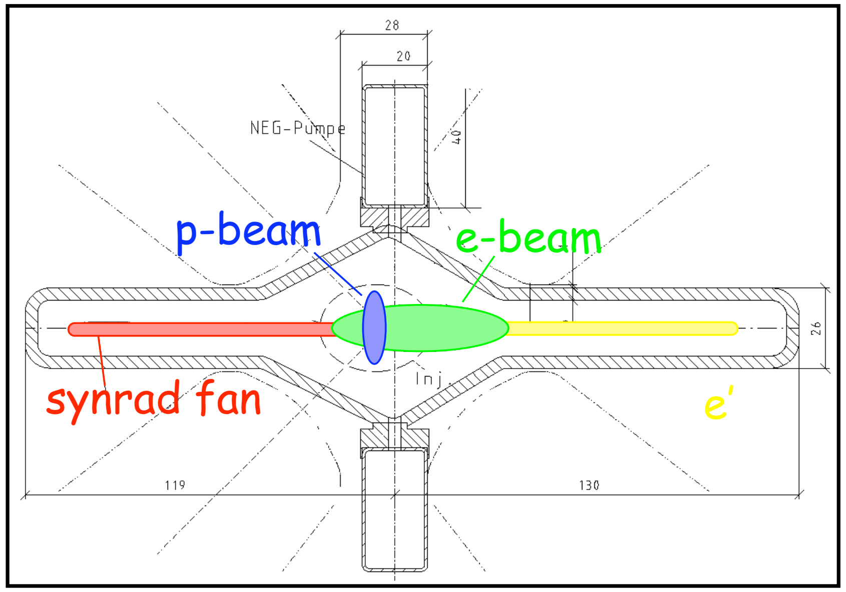
- Severe space constraints due to existing detector components
  - outer magnet diameter limited to < 180mm
- Requires complicated movable supports inside detectors
  - changing forces during ramping of the machine on LAr cryostat
  - direction of forces reverses between electron and positron operation
    - impact on alignment accuracy, especially at H1

Challenge: Synchrotron Radiation



Total synrad power: 20-30 kW @ I_e = 50 mA

Need rather complicated beampipe (steel) to accommodate 3 different beams



- Concept
  - no hits of direct synchrotron radiation on beam pipe
  - use combination of downstream absorbers (11, 19, 25m)
  - and integrated collimators to shield against backscattered synchrotron radiation

Sources for Background at HERA

- Electrons / Positrons
  - during injection (HOM) and ramp
  - synchrotron radiation
    - backscattering, photo desorption
    - => resulting in degradation of vacuum
  - interaction with rest gas in beam pipe
    - => off momentum electrons/positrons
    - high density runs at Hermes
- Protons
  - during injection an ramp
  - interaction with rest gas in beam pipe
    - secondary interaction with aperture limitations (i.e. synchrotron masks)
- Other
  - hardware failures
    - RF => coasting beam
    - magnet failures => spikes
    - beam losses
    - unclean dumps
  - trapped dust particles (electrons)
  - mis-steered beams

Background Sources and Parameterization

- Synchrotron radiation: doubly backscattered radiation from 11, 19, 26m

$$I_{SR} = \alpha_{SR} I_e$$

- Off-momentum positrons/electrons from upstream e-gas interactions

$$I_{e\ gas} = \alpha_e I_e p_{_L} = \alpha_e \beta I_e^2$$

  - assume dynamic pressure increase $p_{_L} = \beta I_e$ (neglecting base pressure)
  - flat sensitivity up to ~ -60m

- Proton-gas interactions inside and proton-upstream of H1/ZEUS

$$I_{p\ gas} = \alpha_p I_p p_{_R} = \alpha_p \gamma I_p I_e$$

  - assume dynamic pressure increase $p_{_R} = \gamma I_e$ (photo desorption, negl. base press.)

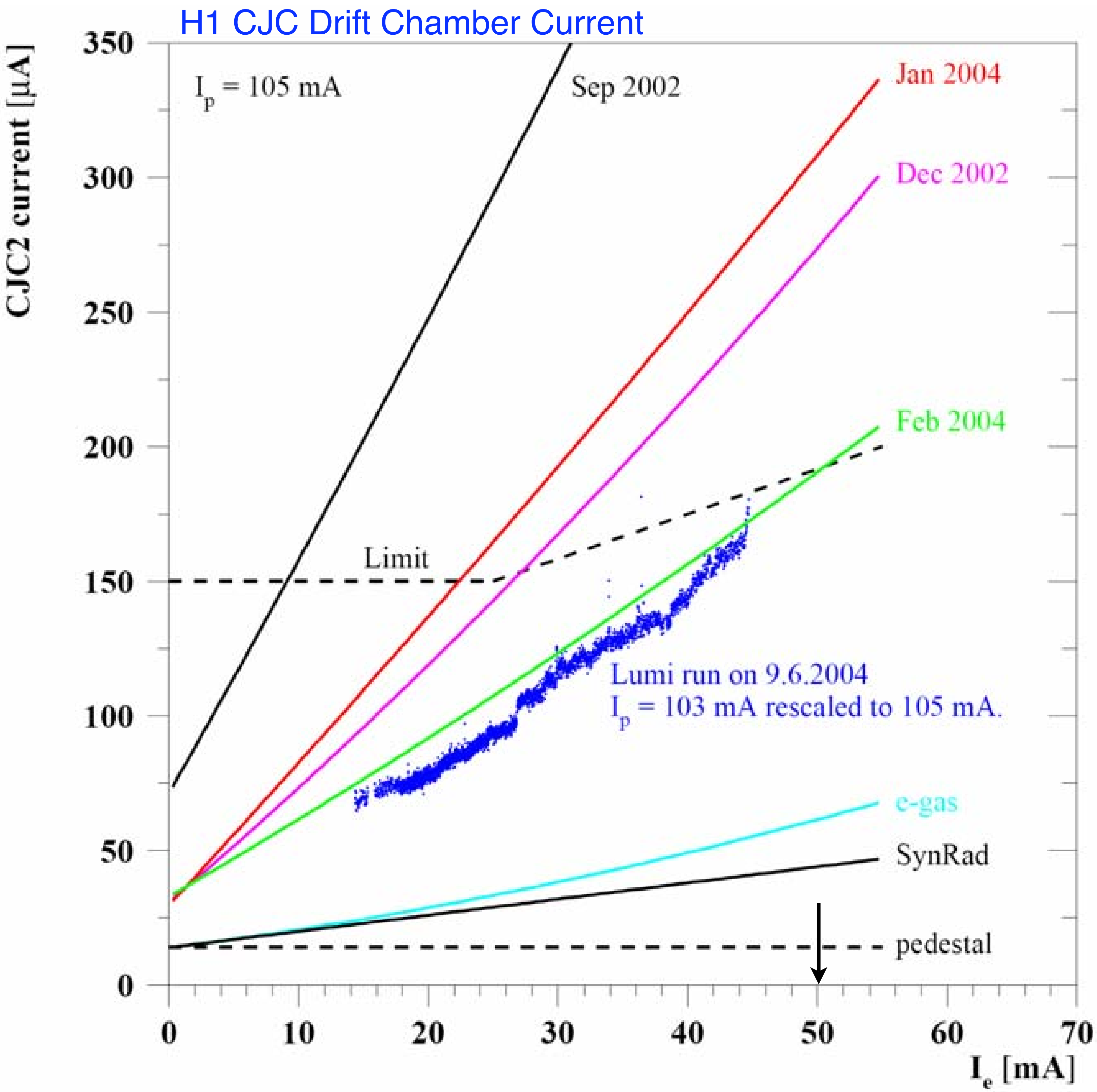
- At 12 GeV there is additional HOM heating $\Delta p \sim I_e^2$

- All contributions together:

$$I_{CJC} = I_0 + I_{SR} + I_{e\ gas} + I_{p\ gas} = I_0 + \alpha_{SR} I_e + \alpha_e \beta I_e^2 + \alpha_p \gamma I_e I_p$$

Chamber Currents

$$I_{CJC} = I_0 + \alpha_{SR} I_e + \alpha_e \beta I_e^2 + \alpha_p \gamma \boldsymbol{I_e I_p}$$



- Parameters are obtained from fits to special measurements
  - e+ only runs
  - proton only runs
  - luminosity runs
- Extrapolation to design currents
  - $I_p \times I_e$ = 105 mA x 50 mA
- Only after spring 2004 back-ground no longer limits the machine currents
  - BUT setbacks due to many vacuum leaks!

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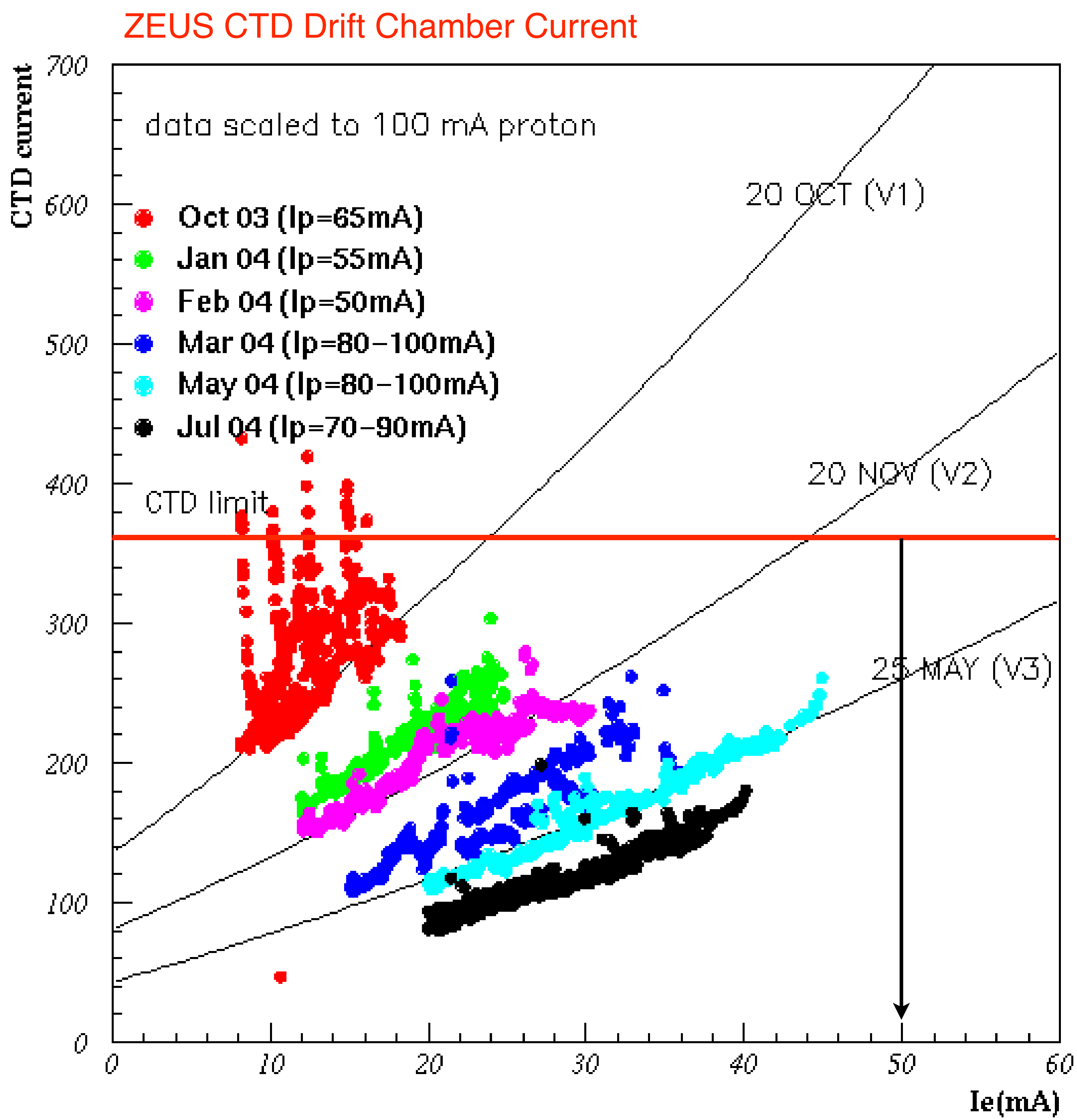
ZEUS CTD Current Evolution



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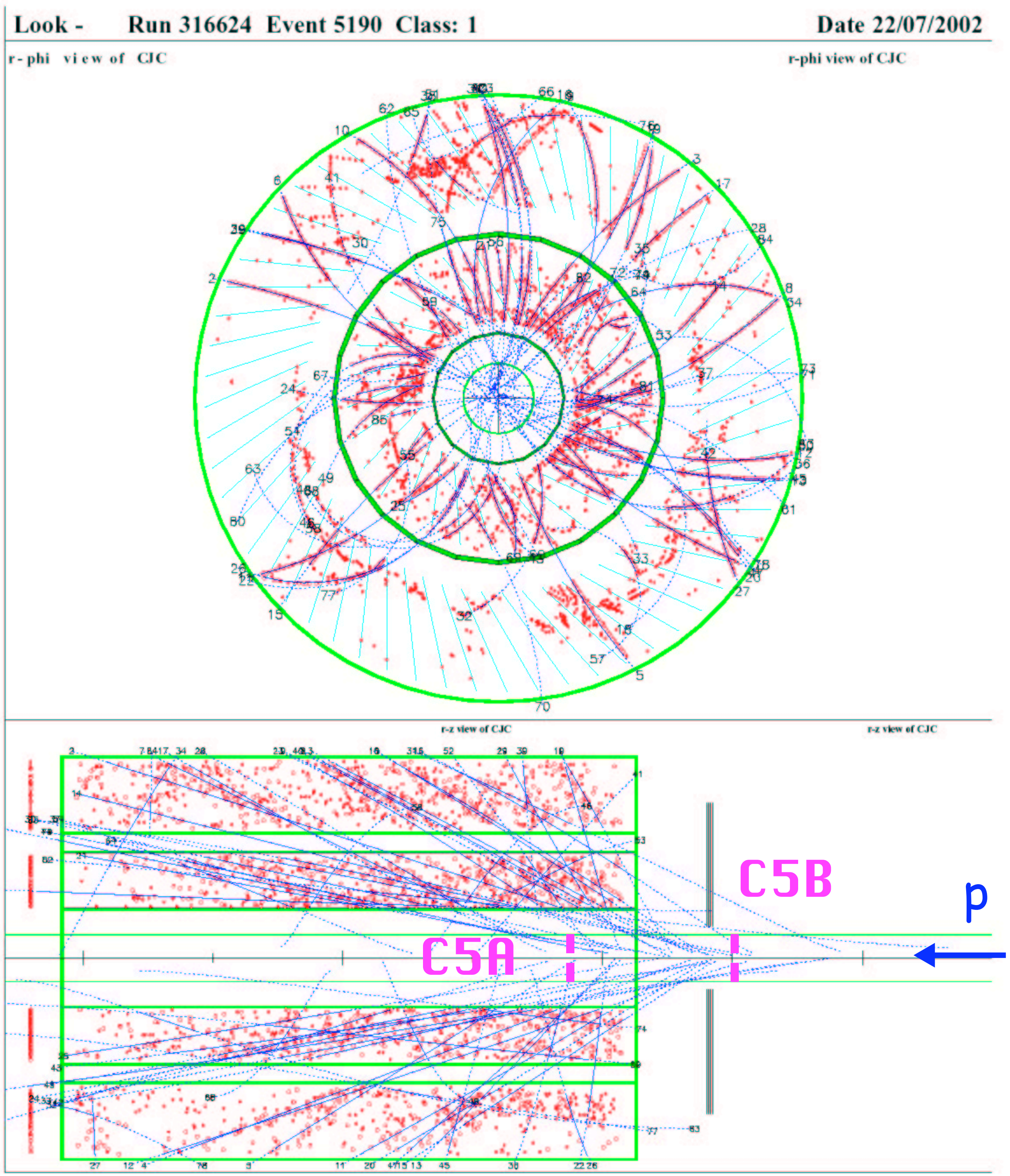
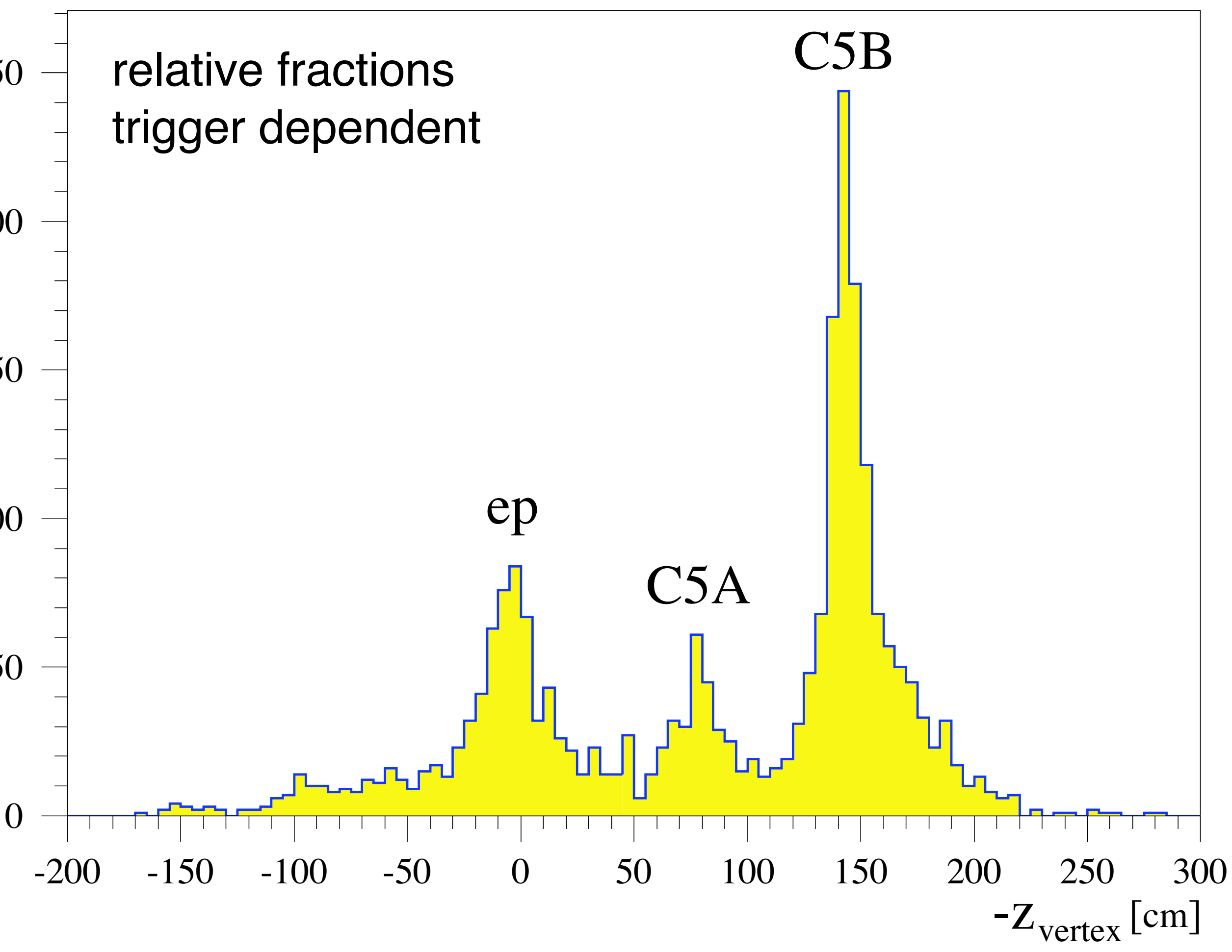
Challenge: Proton Background

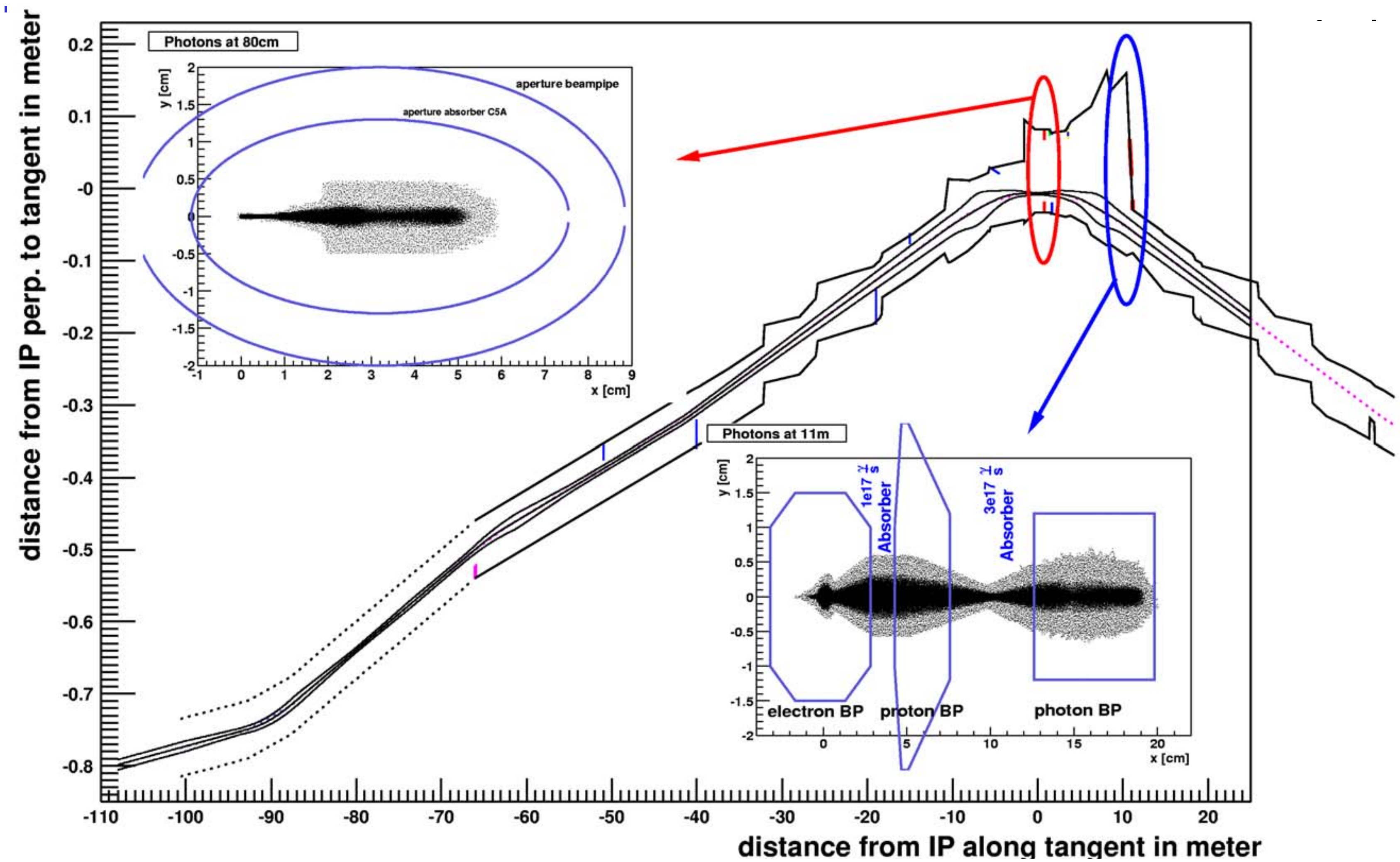


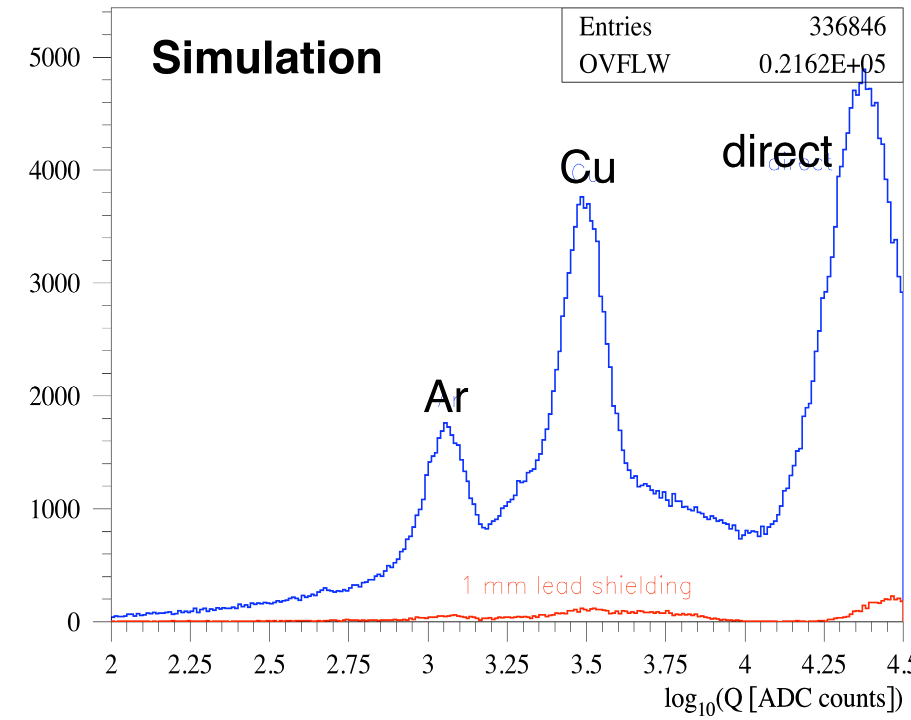


Mechanism:

- desorption by synchrotron radiation => **dynamic pressure increase**
- debris of proton-gas interaction hits aperture limitations (i.e. synchrotron radiation masks C5A & C5B) and scatters into CJC

Full Simulation of Synchrotron Radiation





- Very good qualitative and quantitative understanding of synchrotron radiation background
- Several weak points in the design of synchrotron masks could be identified
- Optimized design of masks derived and validated by simulation

Run 318307 e+ only at 27.5 GeV

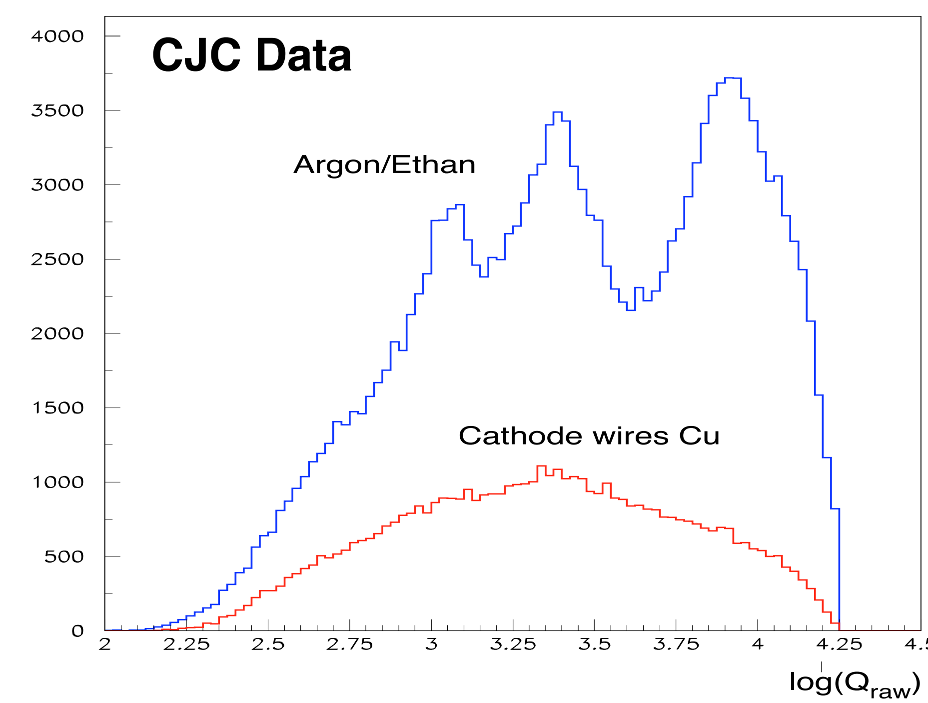
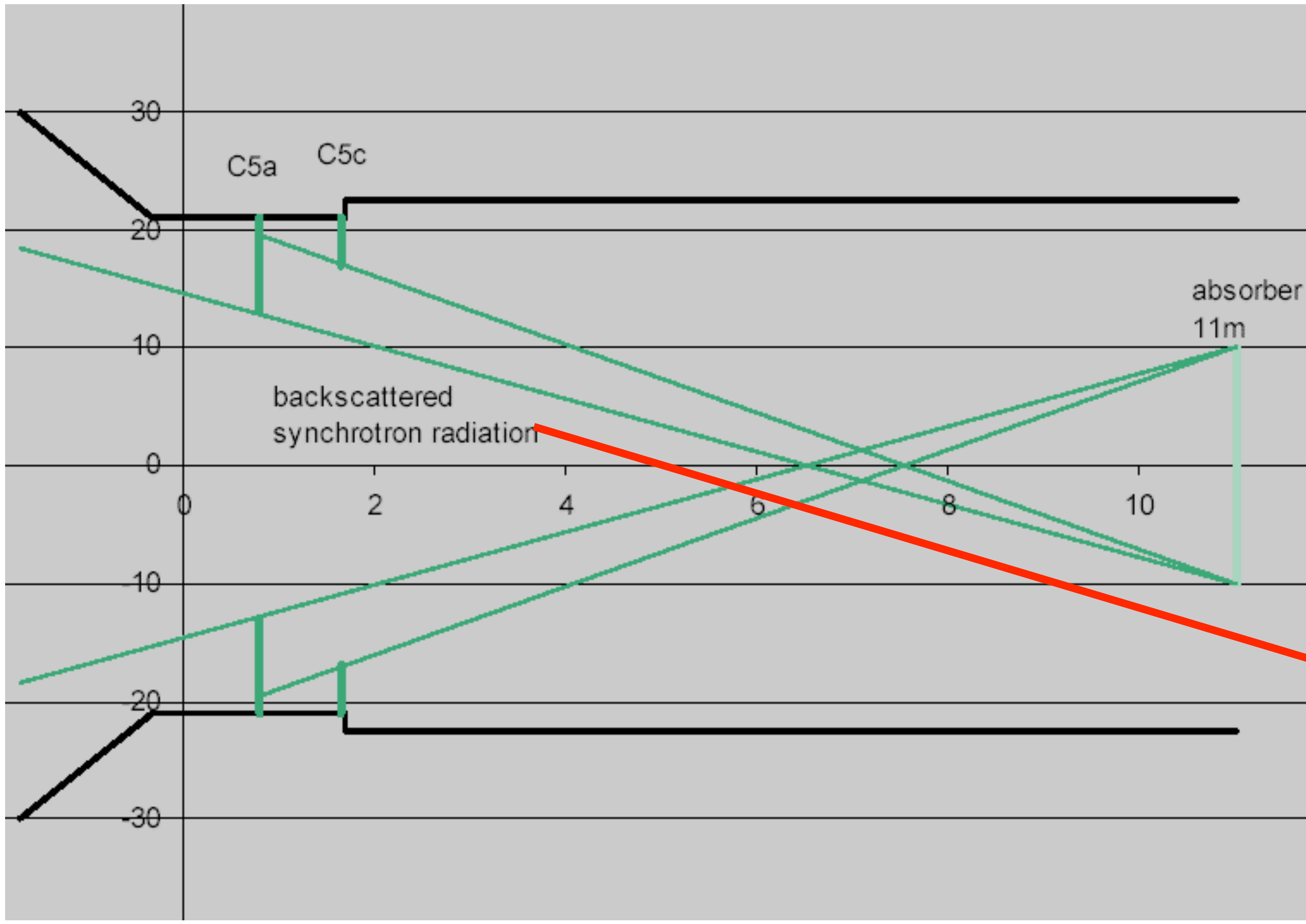
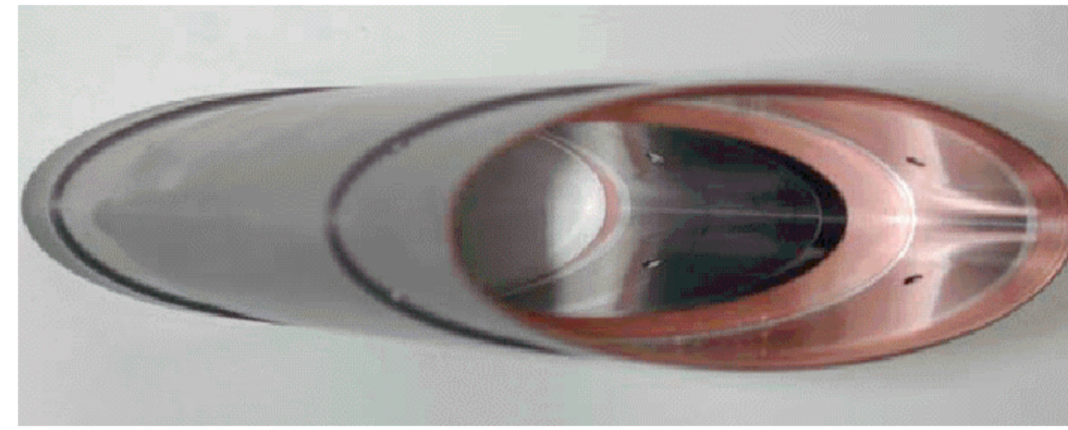


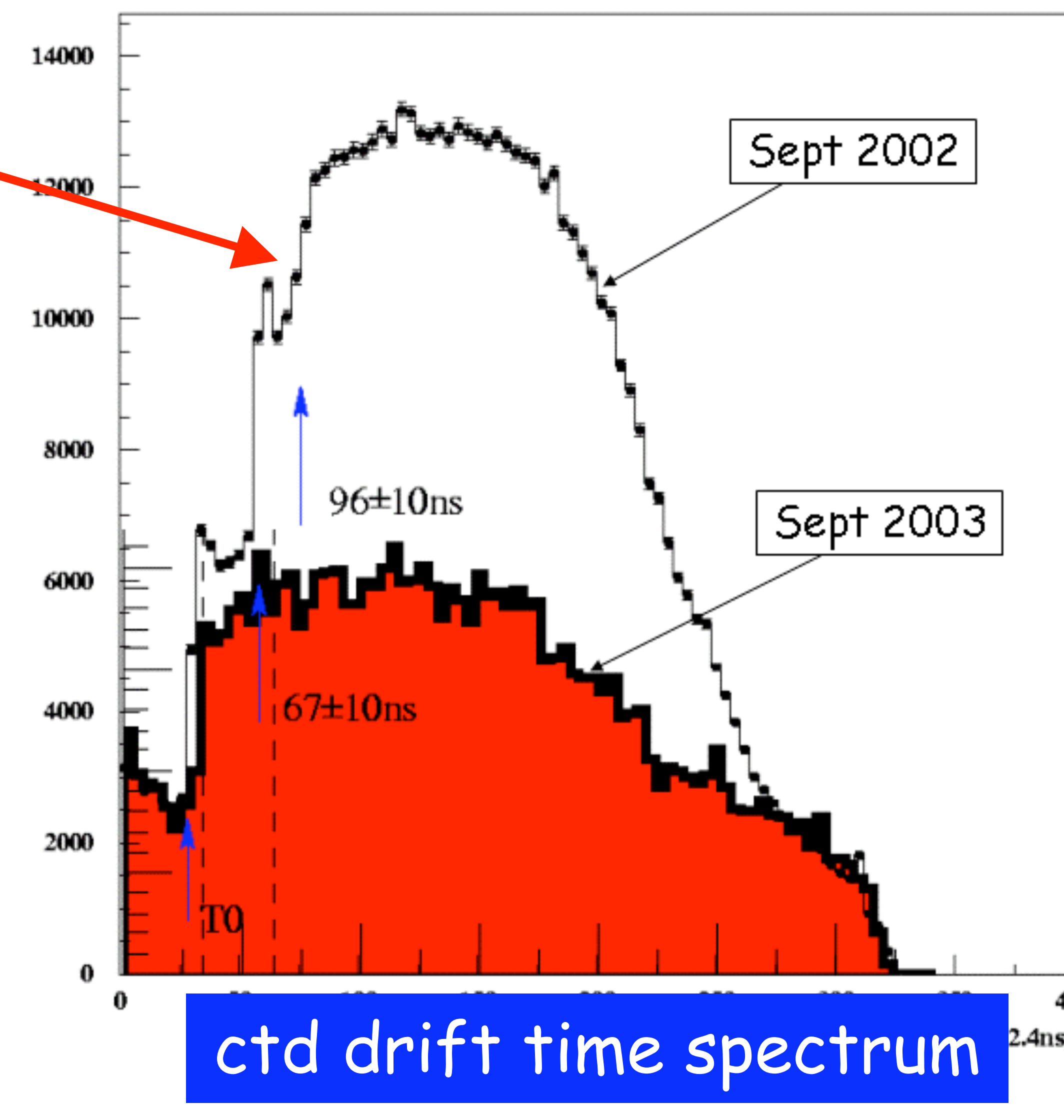
Photo electrons from Ar and Cu fluorescence and direct synchrotron radiation clearly seen.

Improvements at ZEUS



New C5A mask



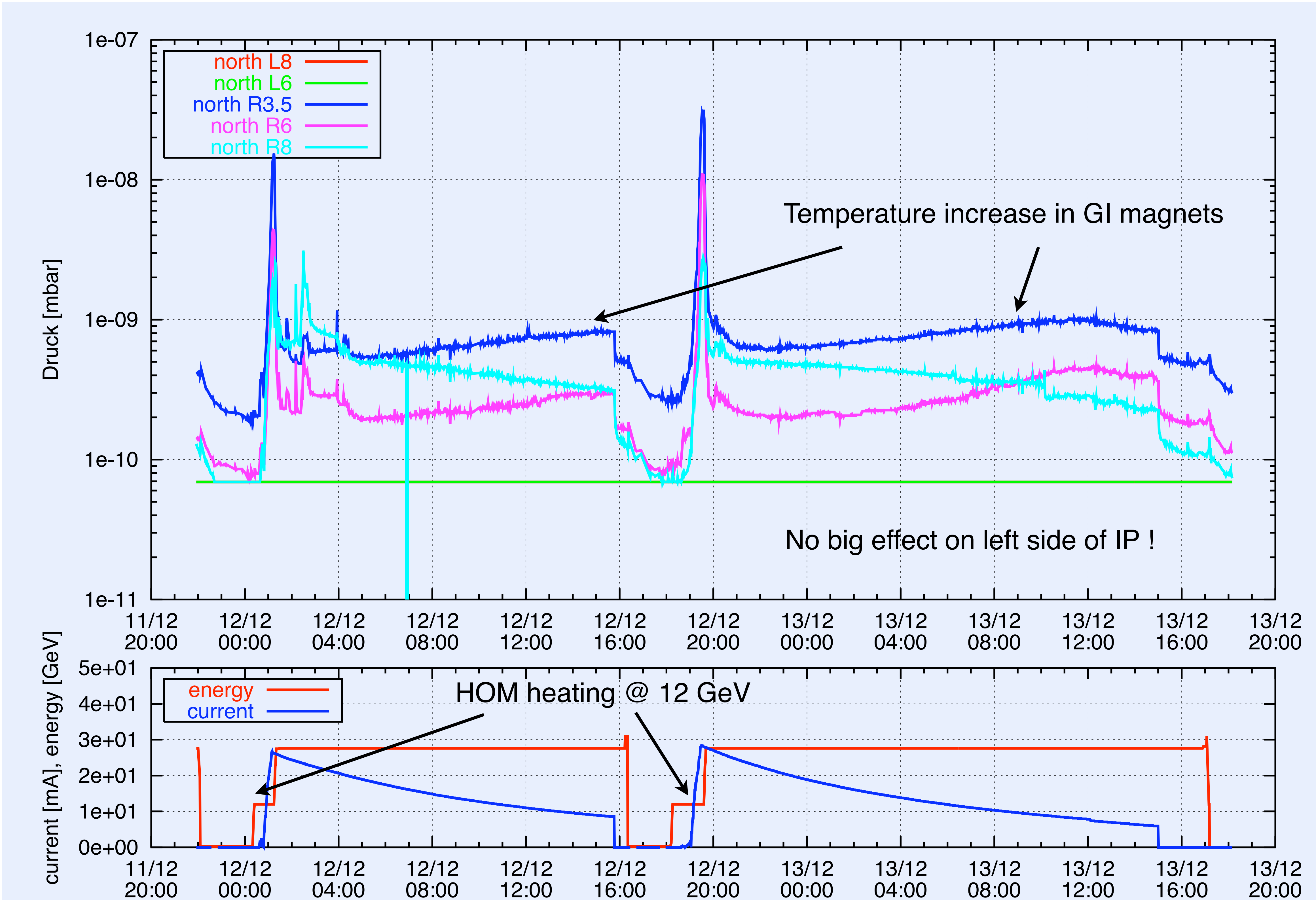


- Successful reduction of backscattered synchrotron radiation by
  - improved design of internal masks
  - adding movable collimator @ z = -65m

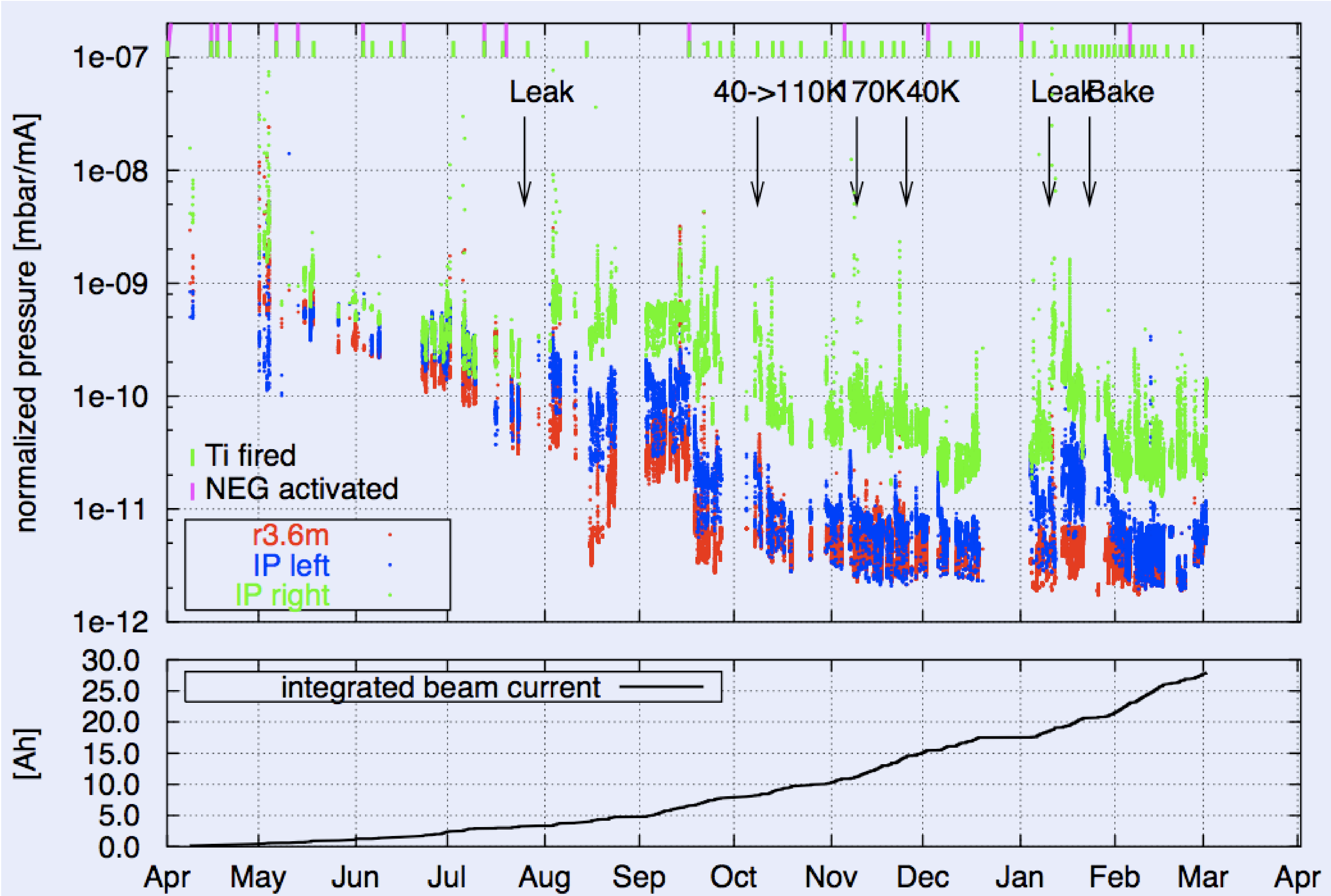
- Identification of source of backscattering by measuring arrival time in CTD (using isolated e-bunch)

Pressure Evolution during Luminosity Fill

Dynamic pressure increase caused by combination of thermal and photo desorption!

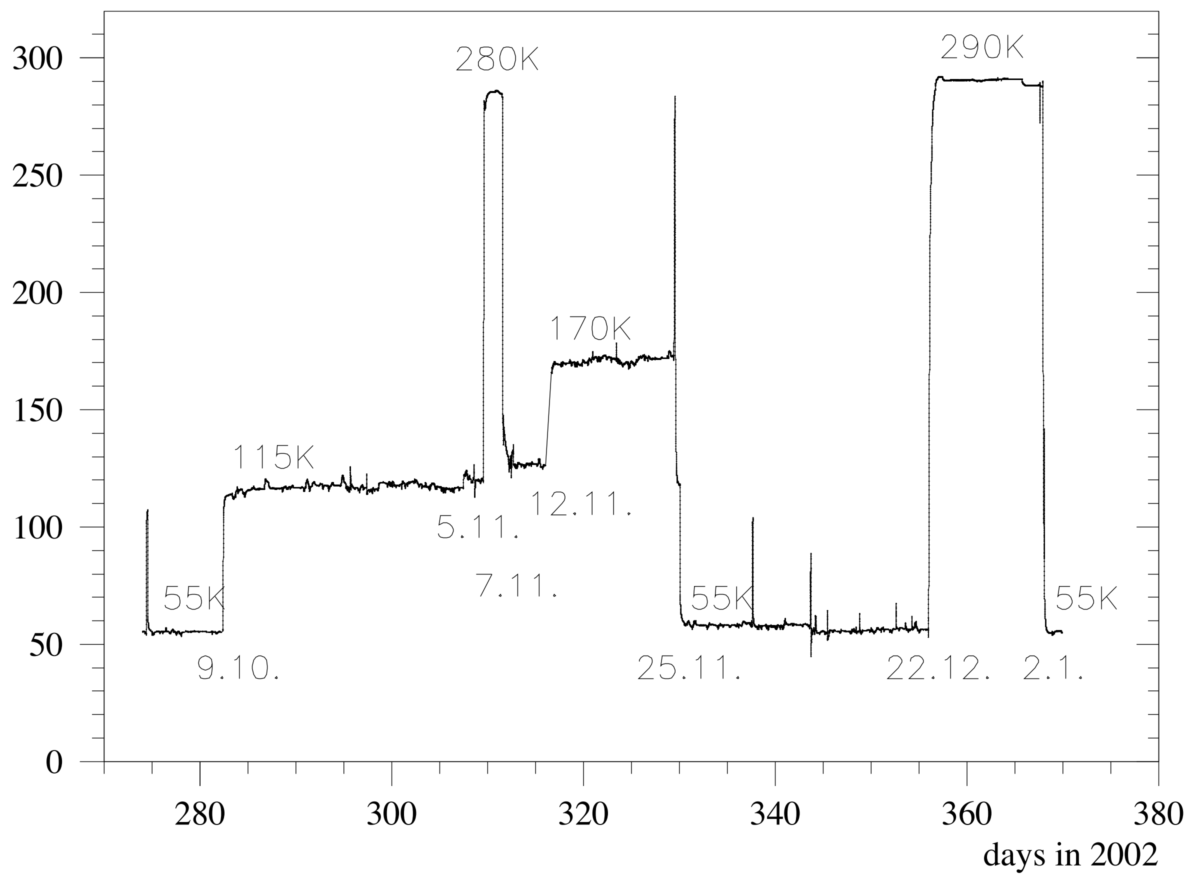


Pressure vs Integrated Current 2002-03

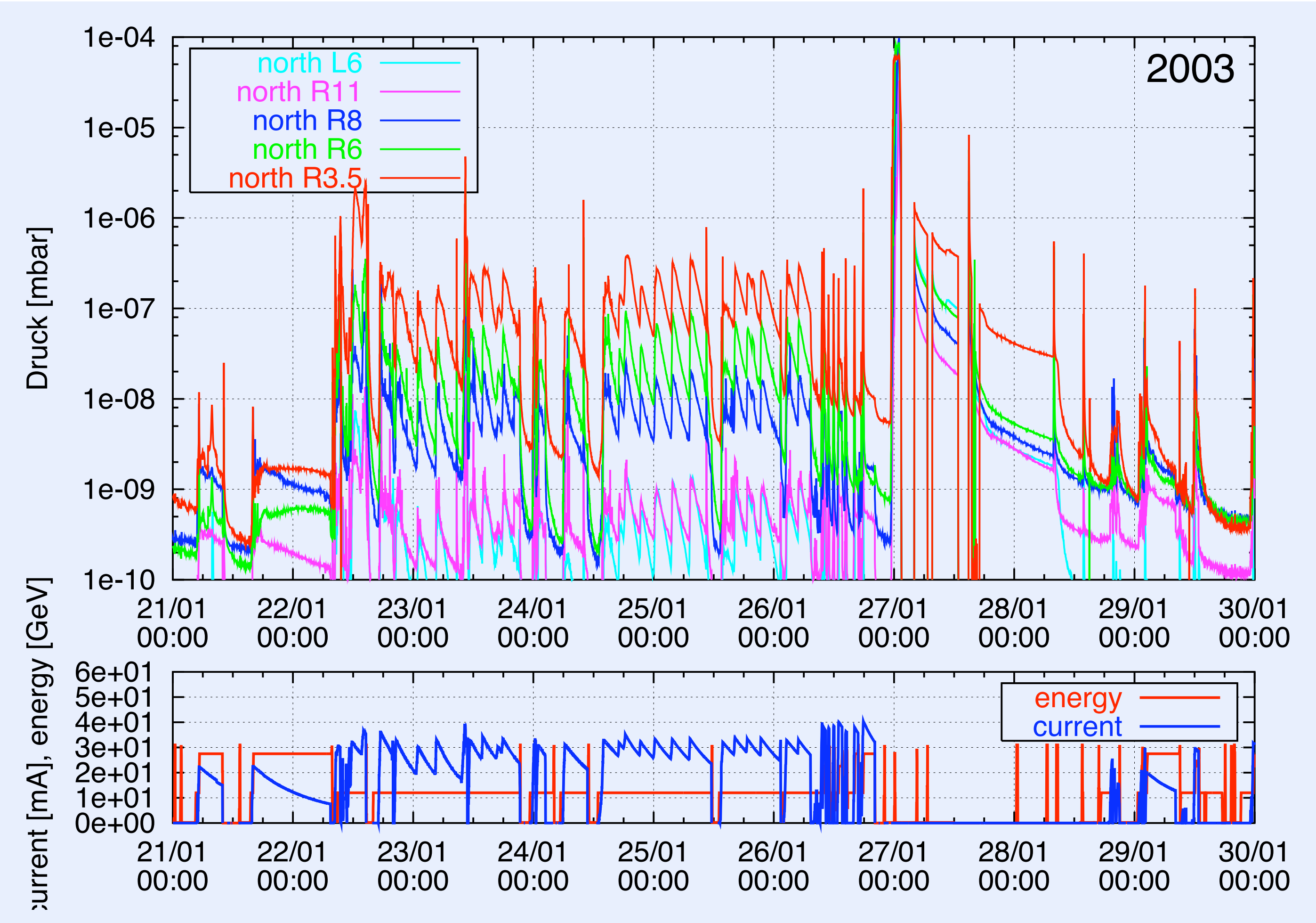


Interplay between HOM Heating and Cold Surfaces

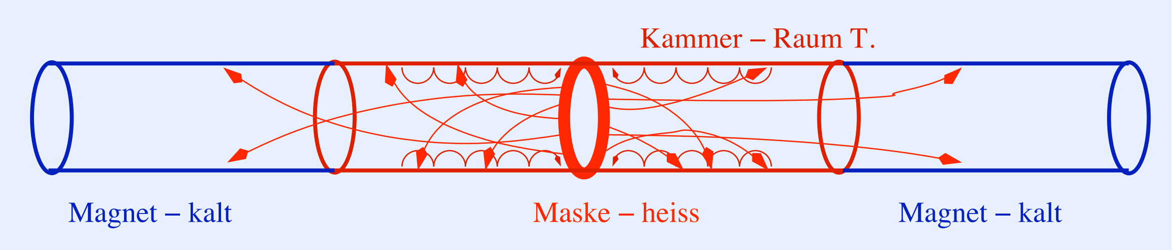
Studies at elevated GG/GO temperatures



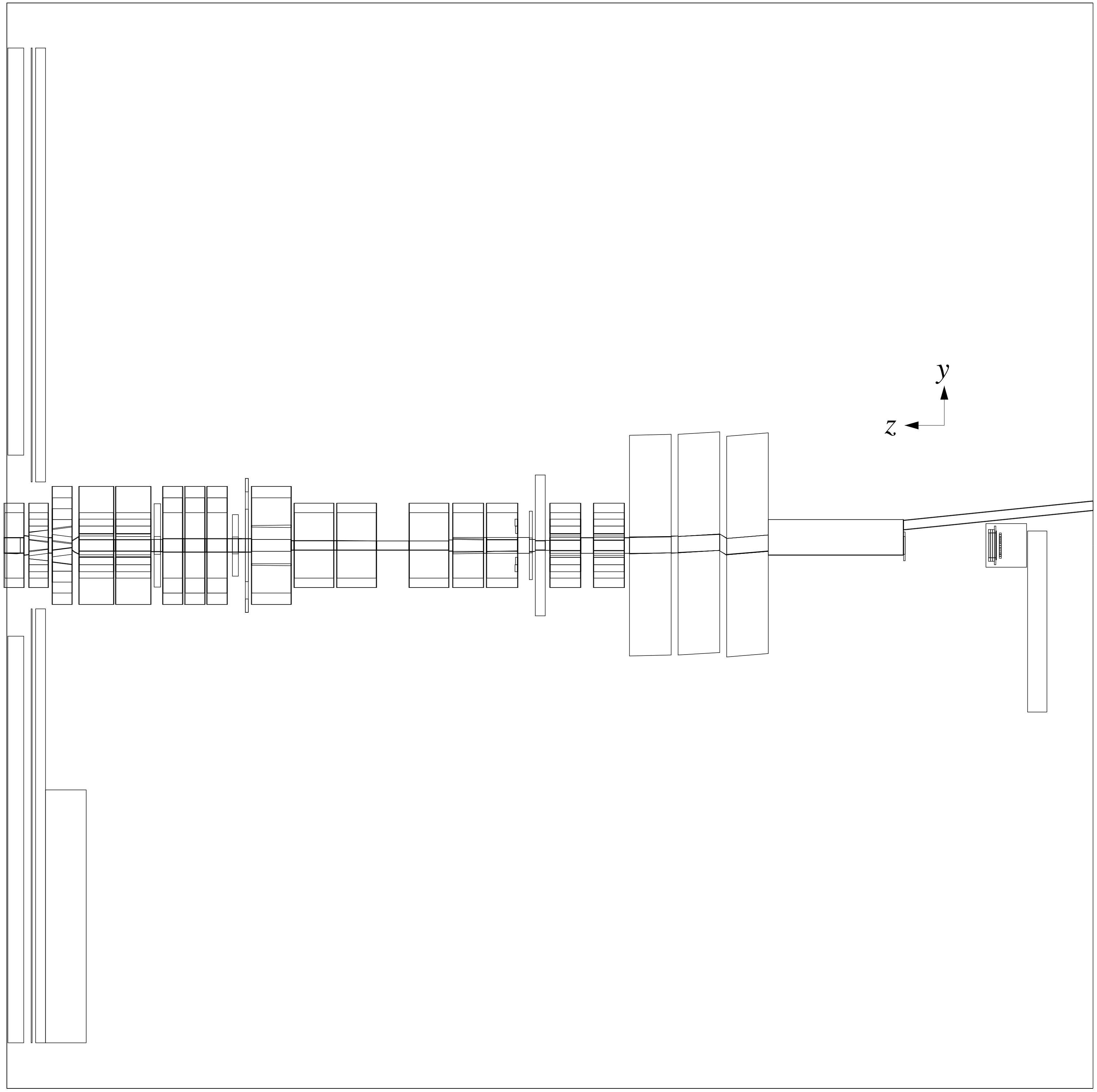
Dedicated back-out period at injection energy 12 GeV



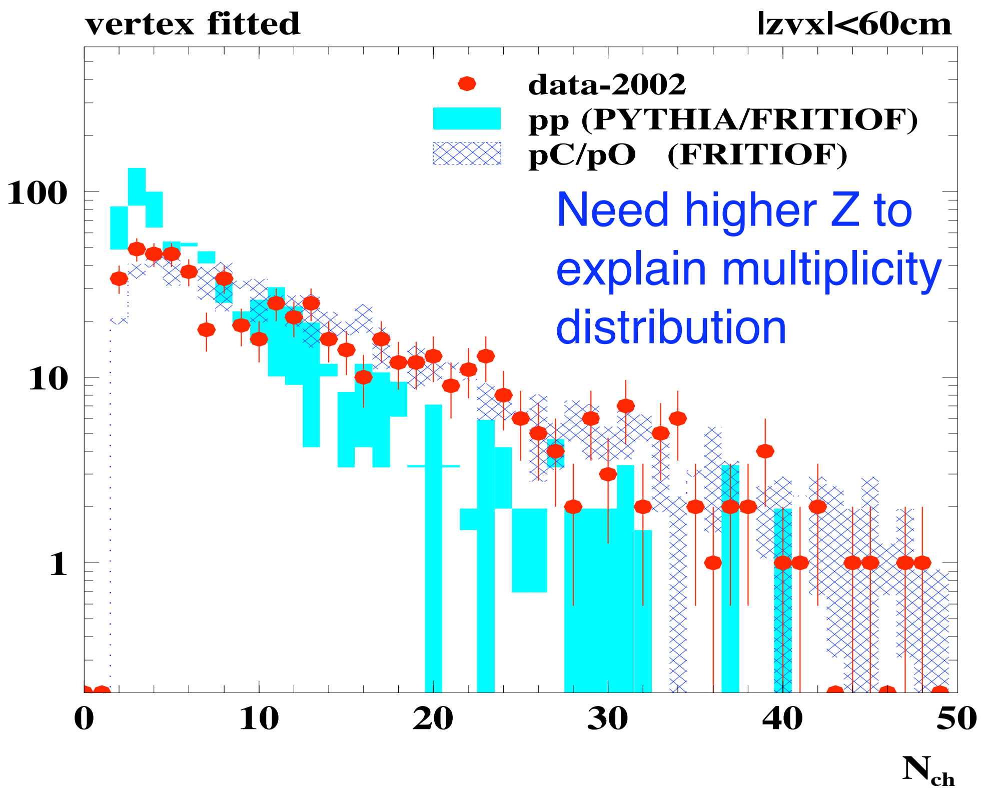
- cold surfaces act as pump/gas storage
- strategy
  - regular warm-up and regeneration
  - continuous monitoring
    - p-background
    - e-gas rate (luminosity monitor)



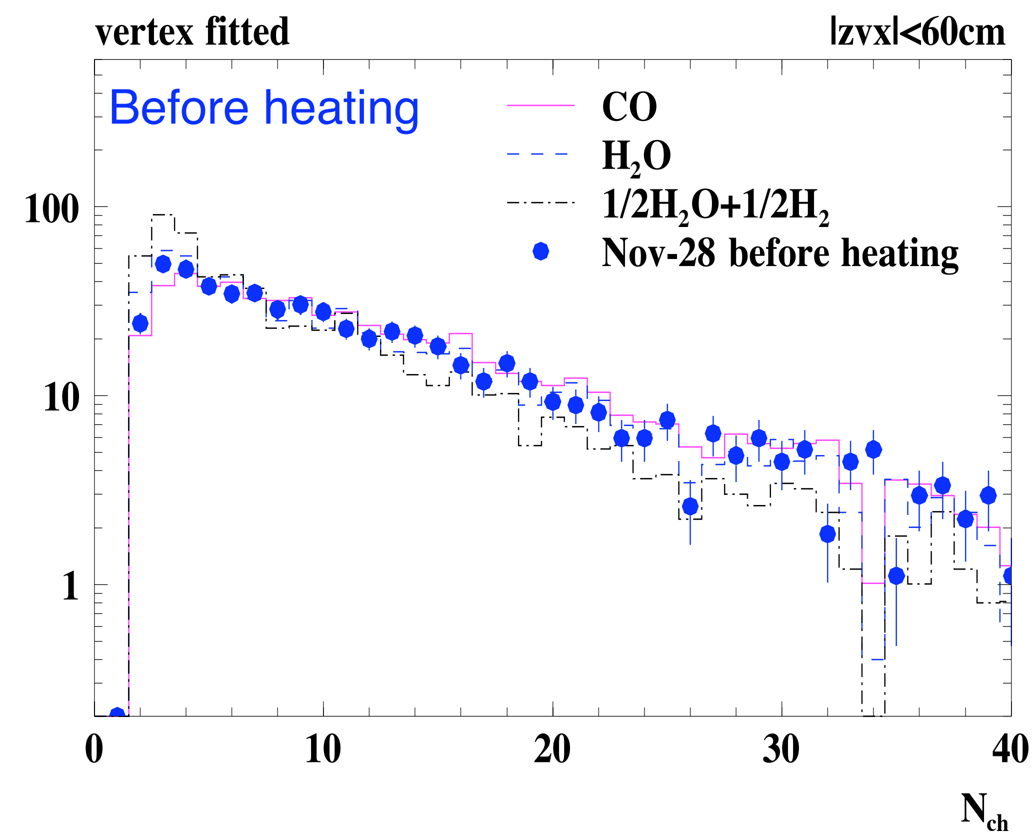
Full GEANT Simulation of Beamline up to 110m

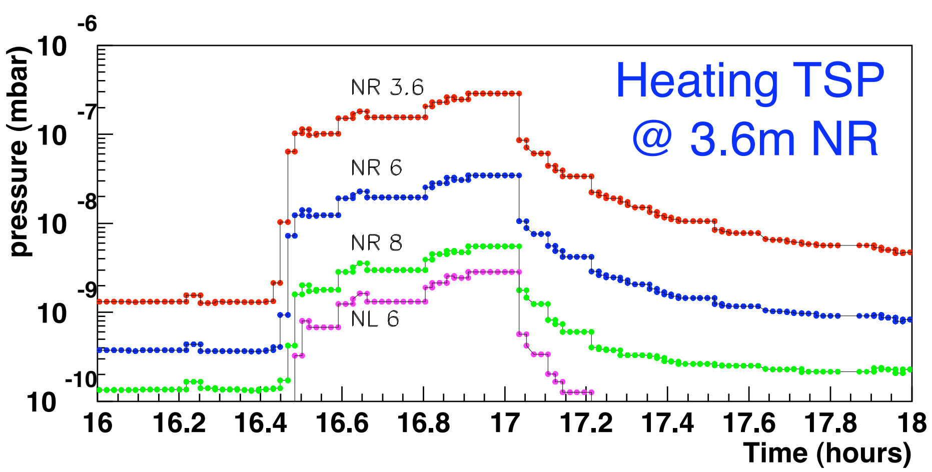


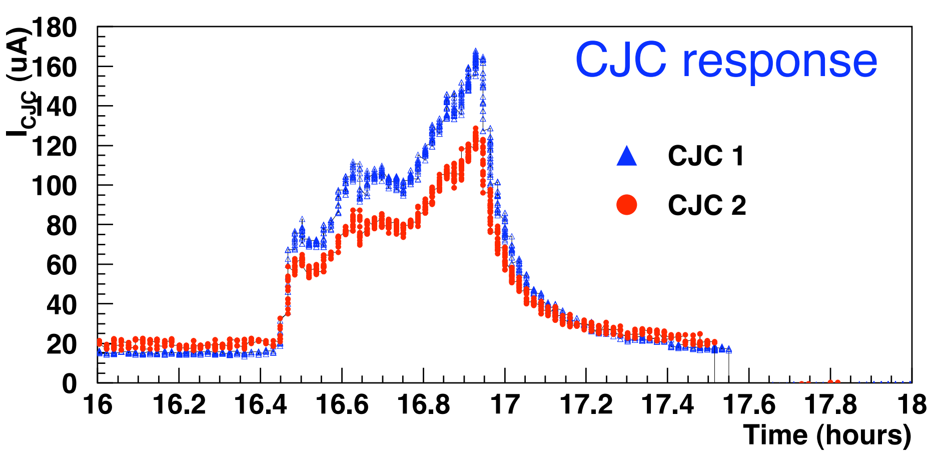
Trying to understand Origin of Proton Gas Background

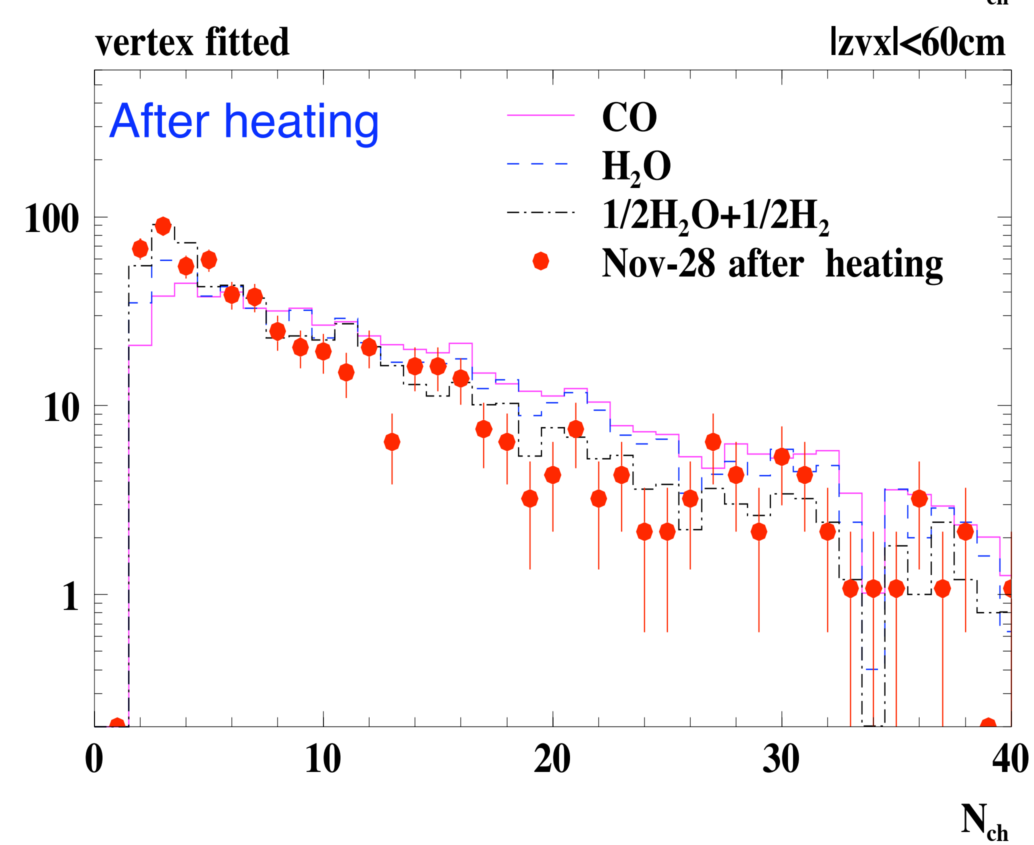


Charged multiplicity





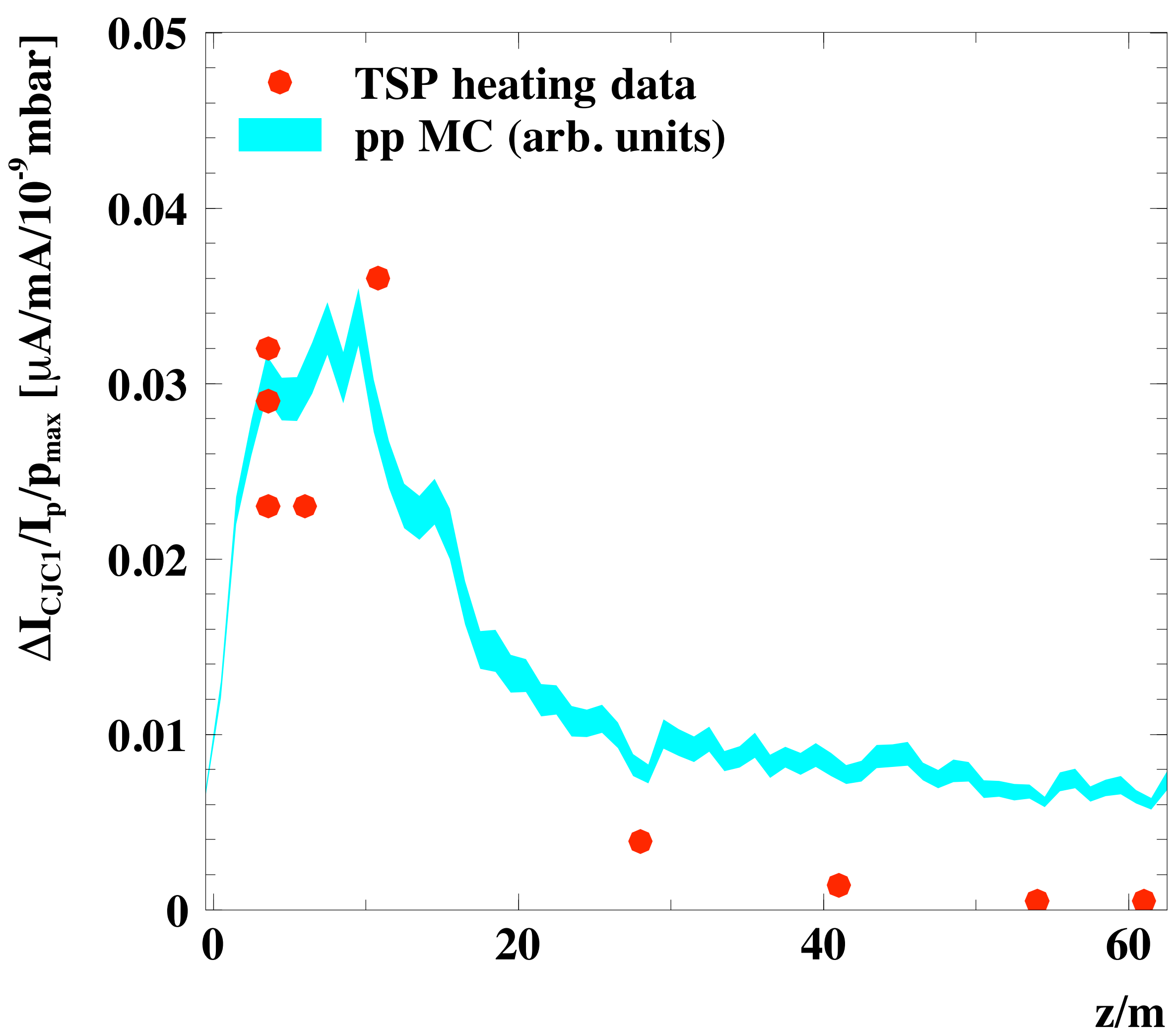


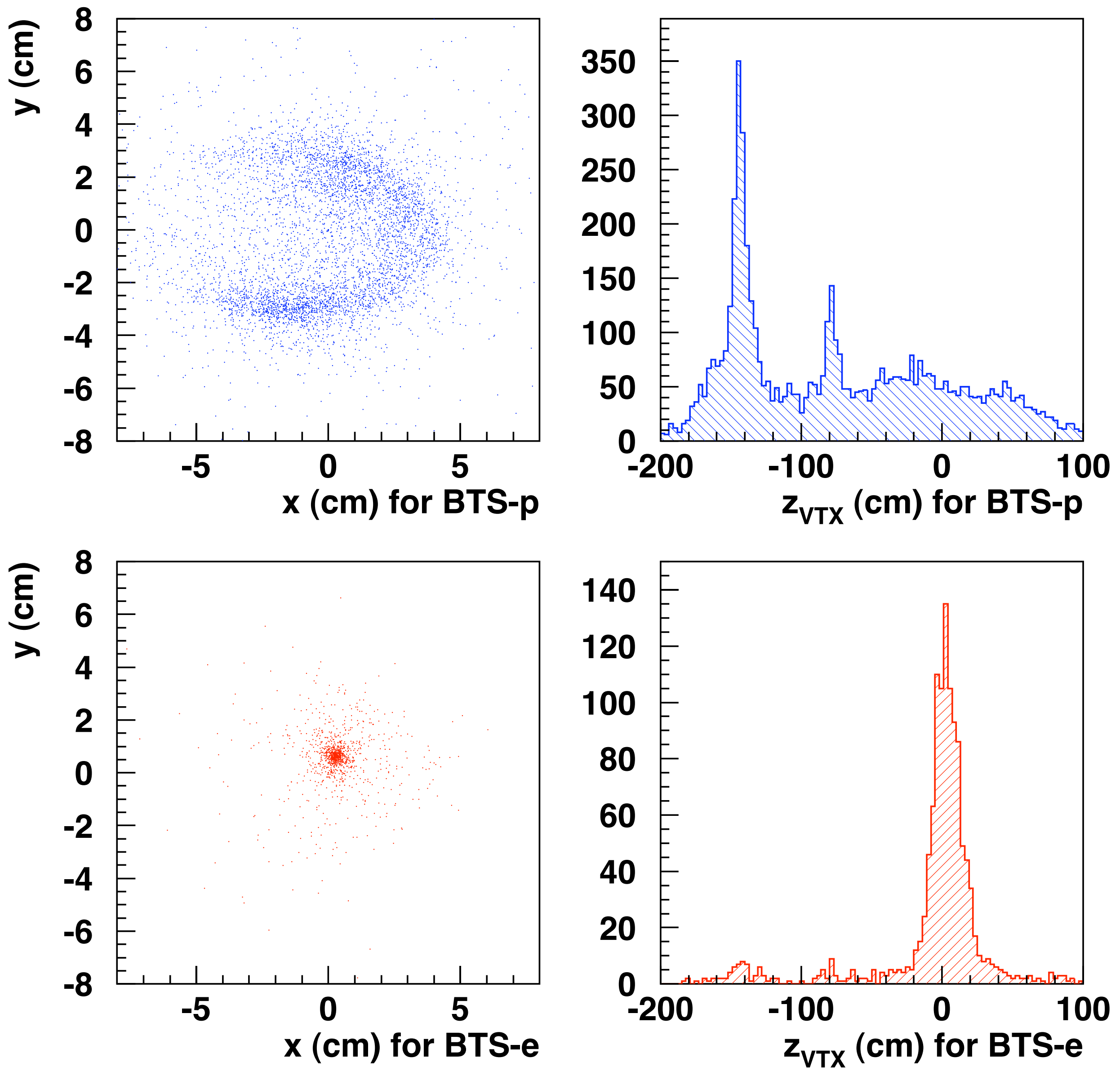


TSP heating mainly releases H2

Heating TSP

More TSP Heating to calibrate Sensitivity in z





- Some discrepancy observed between pressure simulations and measurements
- Conclusion
  - large sensitivity to vacuum conditions in the region 2 to 12 m proton upstream

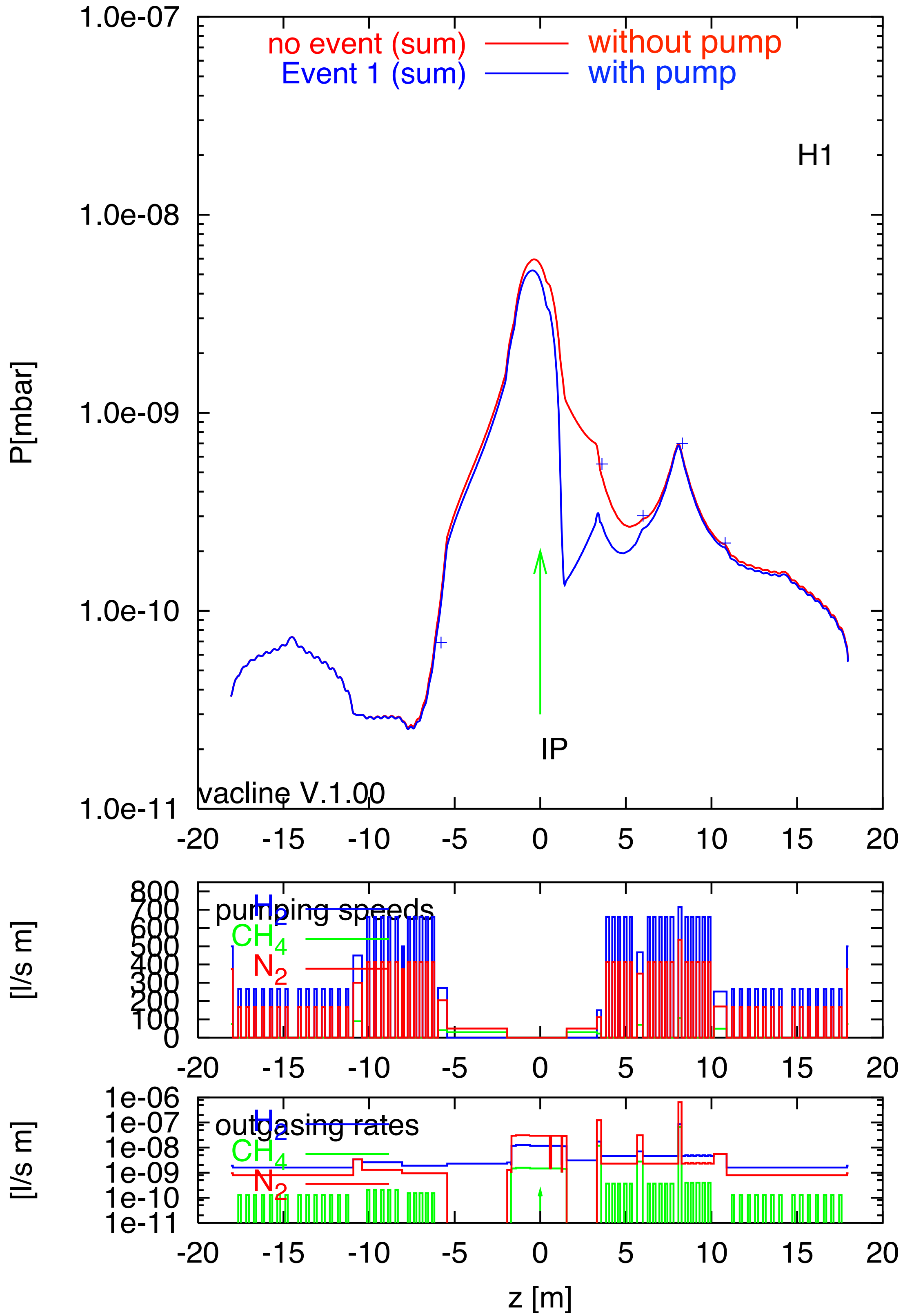
Improvements implemented in Shutdown 2003

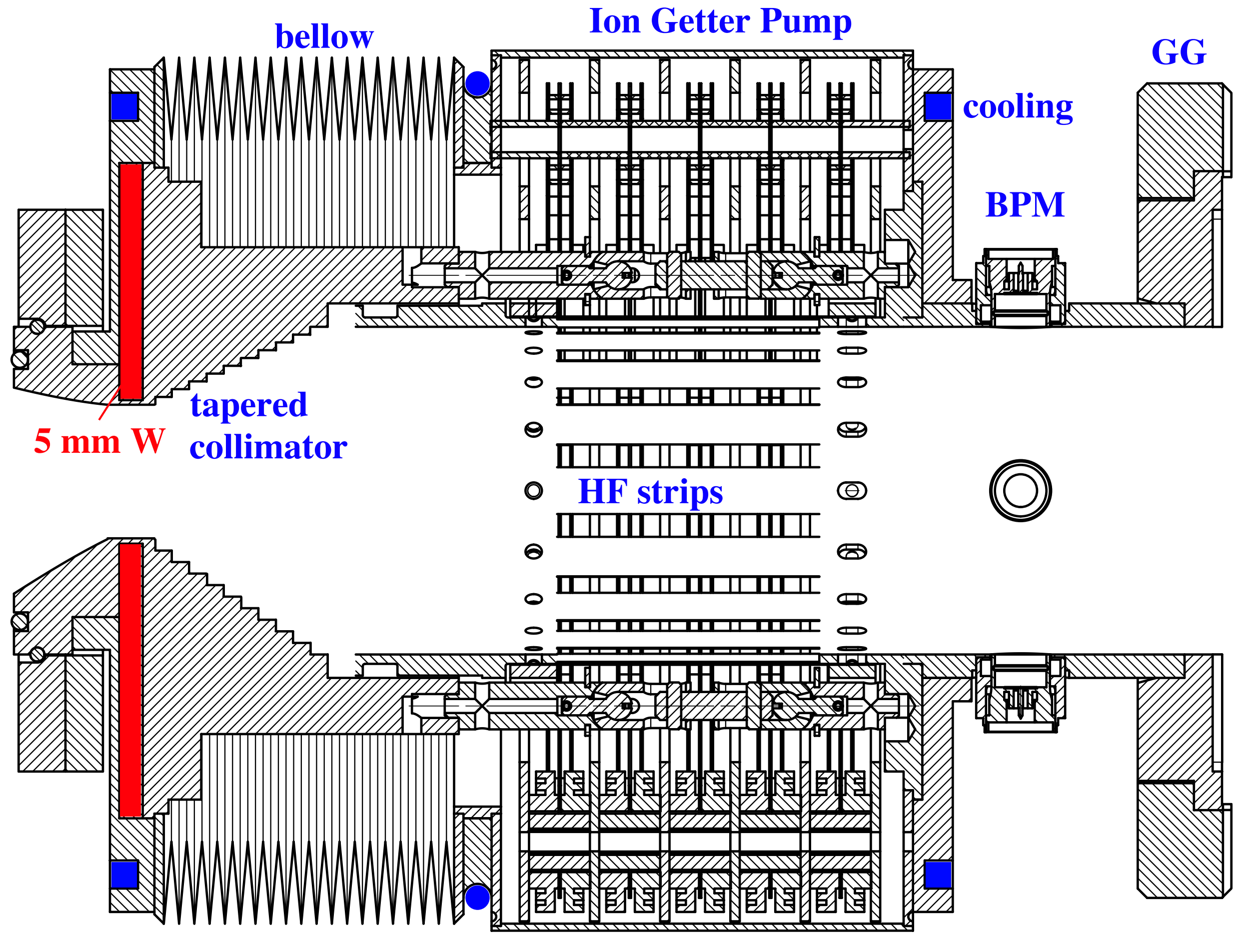
- Synchrotron radiation
  - movable collimator 64m left against radiation from BI magnet
  - [coating of absorber 4 with Cu-Mo]
  - ZEUS: improved design of masks C5A-C to avoid sneak through
  - H1: additional lead shield underneath BST electronics
  - HERA: careful beam steering and beam based alignment
- Electron gas
  - additional NEG pump in GA magnet left of IP to improve vacuum
- Proton gas
  - double pumping speed of ion getter pumps 3.6 - 11 m
  - improve conductance by increasing width of pumping slits
  - H1: tapered C5B to reduce HOM loss

    add integrated ion getter pump
  - H1 & ZEUS: reduce thickness of C5B collimator (factor 4)
- Other
  - reduce sensitivity of experiments
    - ZEUS: reduce gas gain, increase electronic amplification
    - H1: increase current threshold

Improvements in H1

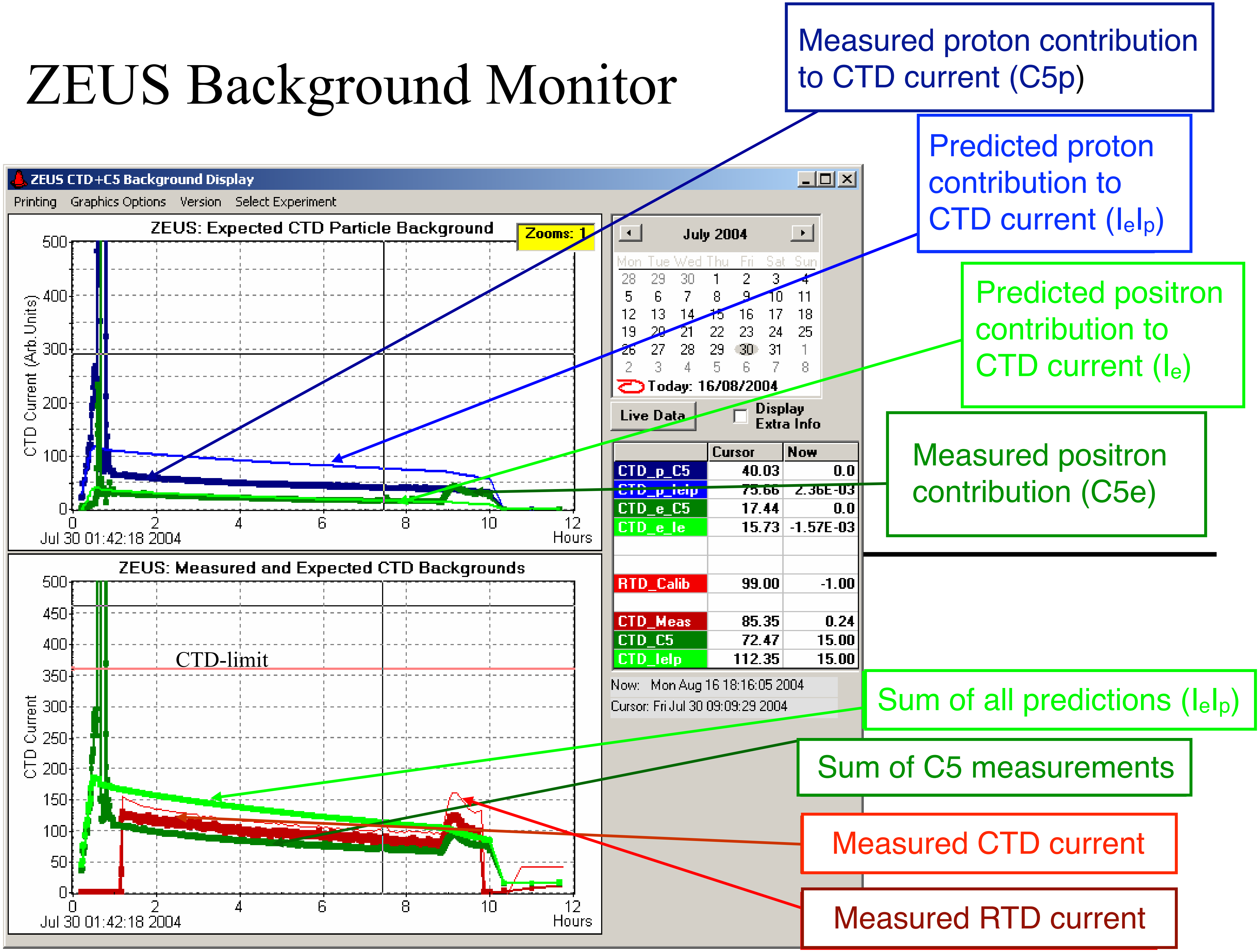
Simulated pressure profile



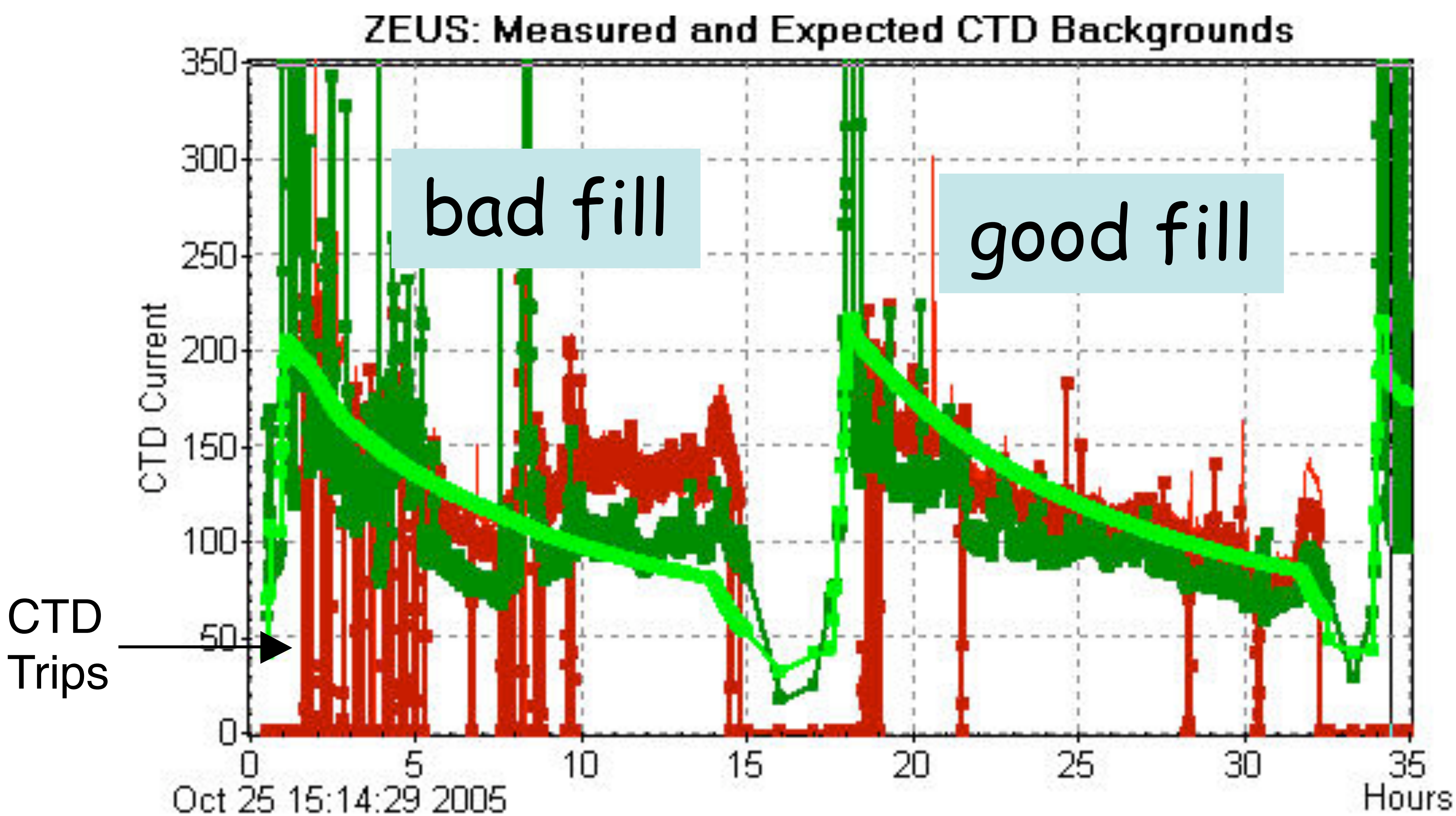


- Simulated effect of adding 400 l/s IGP inside the H1 detector
- Tapered shape of C5B reduces HOM losses and vacuum degradation at injection energy
- Reduced thickness of W-collimator increases transparency for protons

Display in HERA Control Room

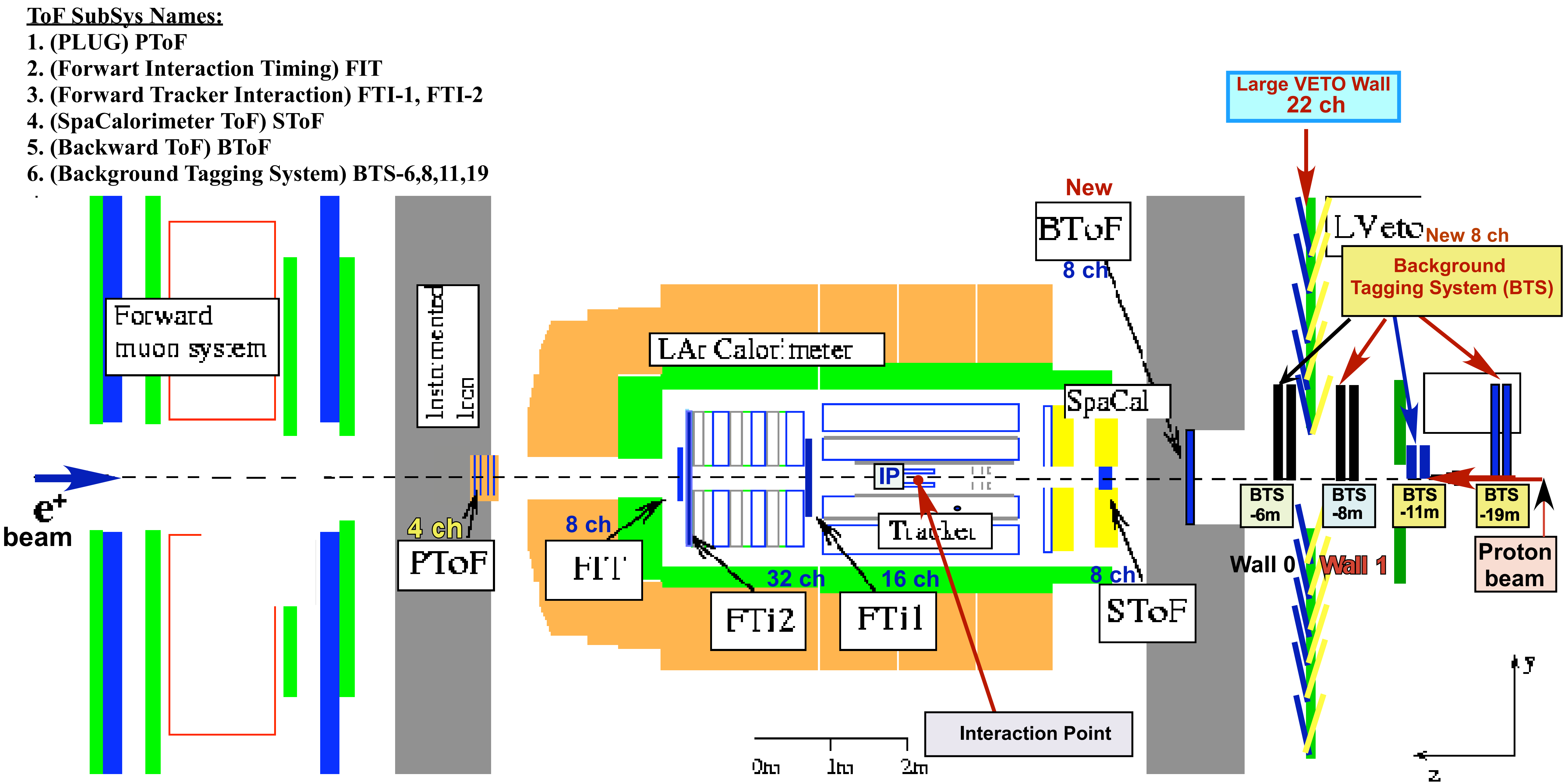


Example Fills



Important tool for HERA shift crew and for other experiments

H1 Monitors



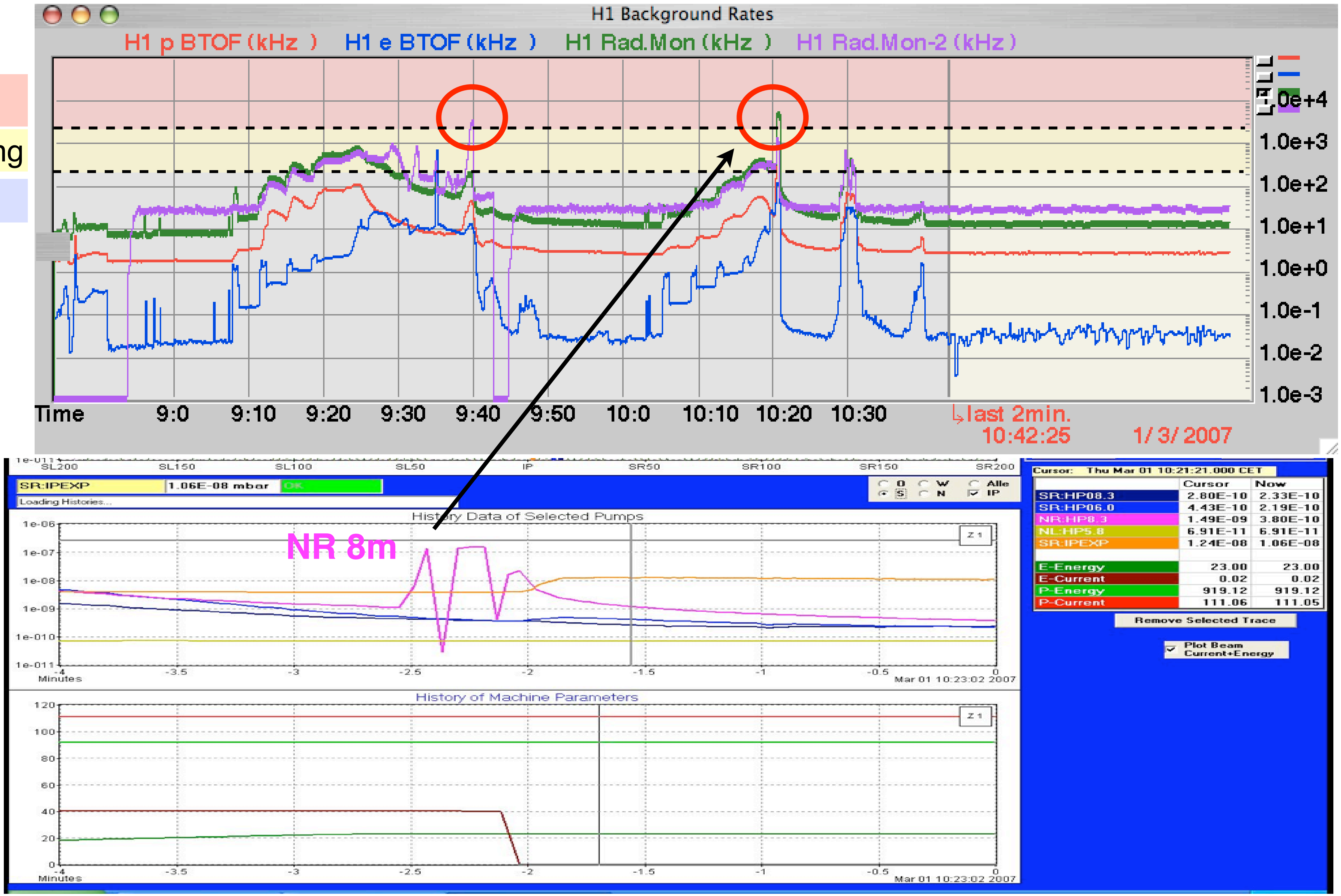
ToF SubSys Names:
1. (PLUG) PToF
2. (Forwart Interaction Timing) FIT
3. (Forward Tracker Interaction) FTI-1, FTI-2
4. (SpaCalorimeter ToF) SToF
5. (Backward ToF) BToF
6. (Background Tagging System) BTS-6,8,11,19
Large VETO Wall
22 ch
New
BToF
8 ch
LVeto
New 8 ch
Background
Tagging System (BTS)
Forward
muon system
LAr Calorimeter
SpaCal
IP
Tracker
e+
beam
4 ch
PToF
8 ch
FIT
32 ch
16 ch
FTi2
FTi1
8 ch
SToF
BTS -6m
BTS -8m
BTS -11m
BTS -19m
Wall 0
Wall 1
Proton
beam
Interaction Point
0m
1m
2m
y
z

Dump of e-Beam triggered by H1 Radiation Monitor

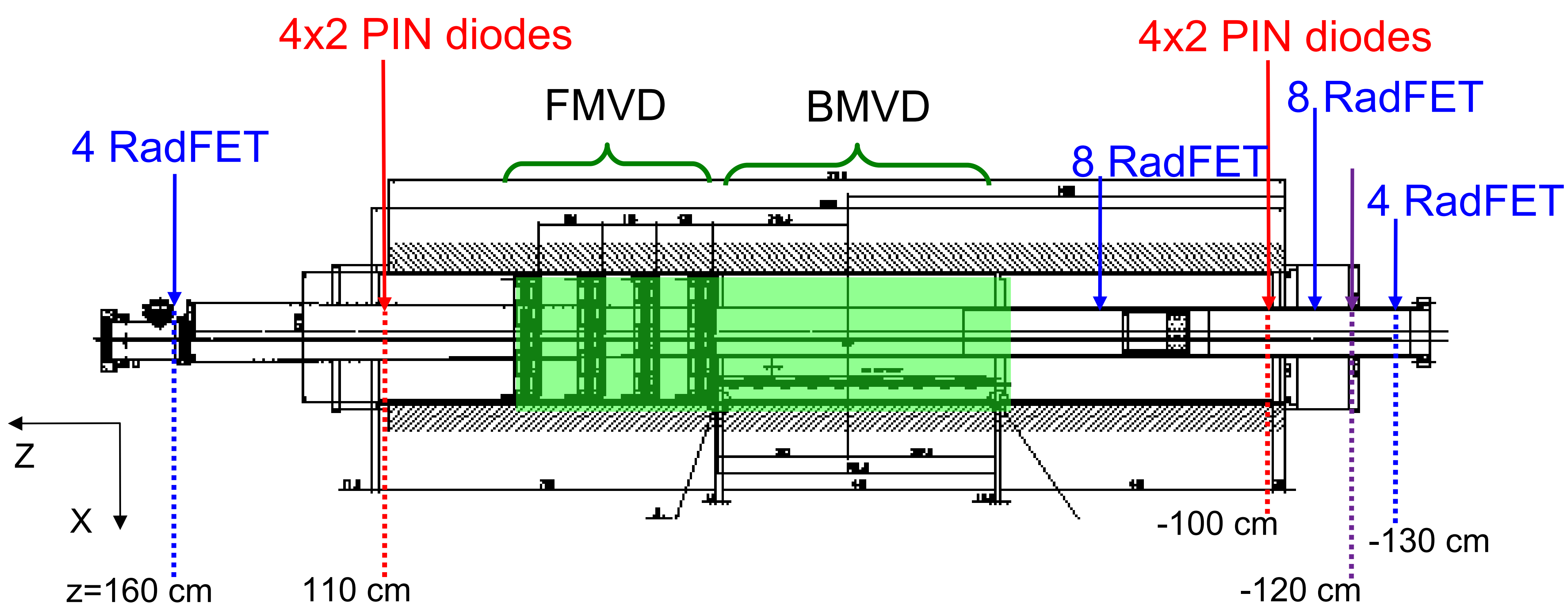
Alarm

Warning

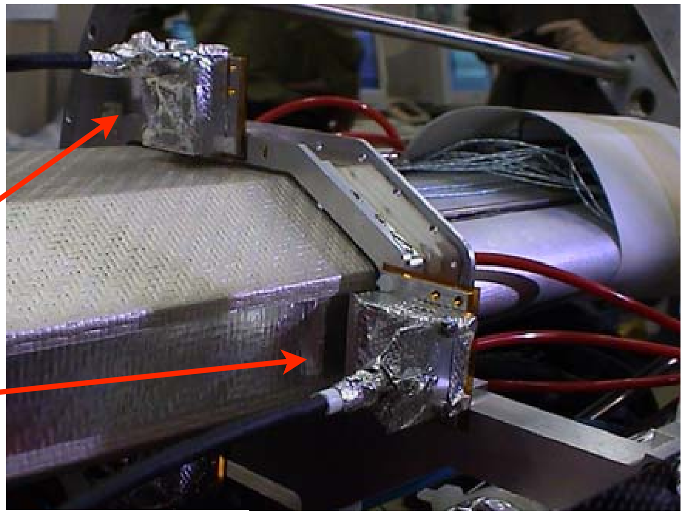
HV on

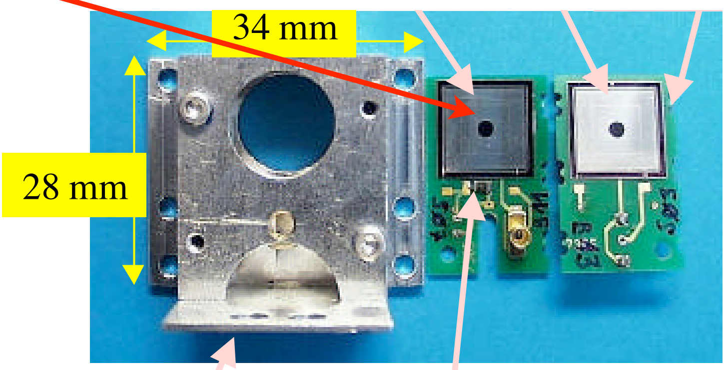


ZEUS Radiation Monitor

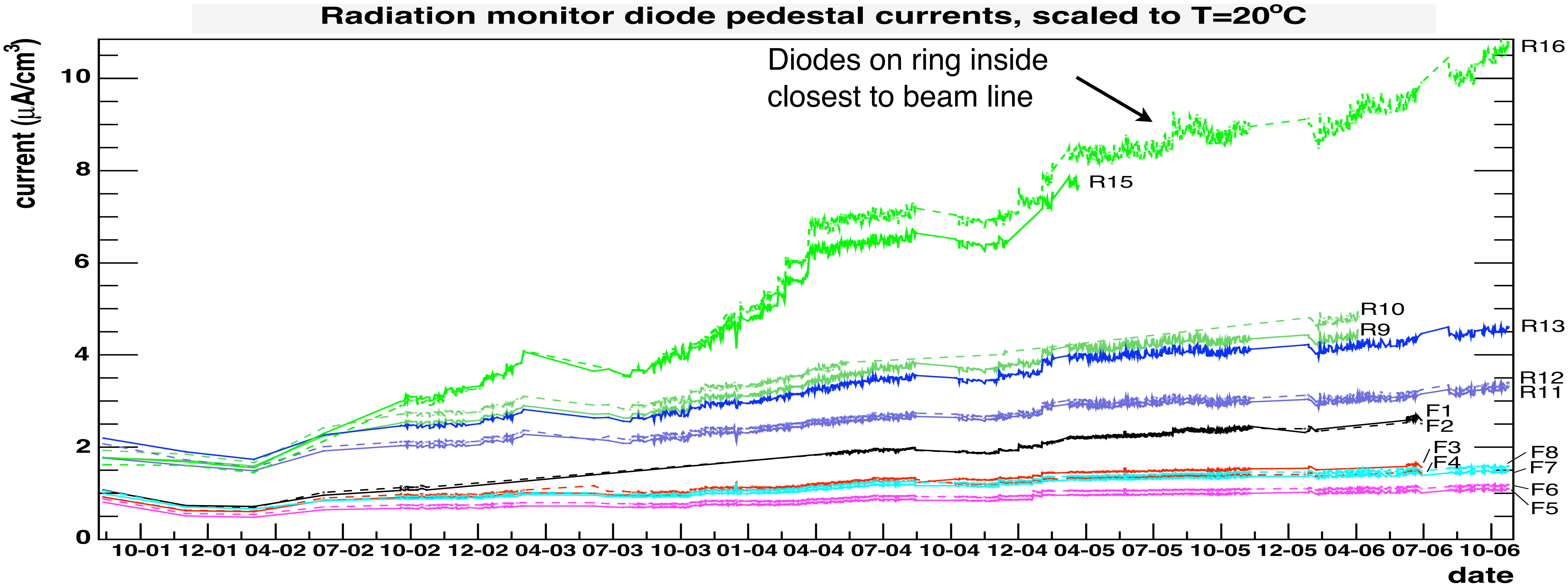


- Radiation Field Effect Transistors (RadFETs)
  - monitor surface damage from shift in threshold voltage
- Silicon PIN diodes
  - instantaneous dose rate from signal current
  - connected to automatic dump system (e-beam)
  - bulk damage from offset leakage current

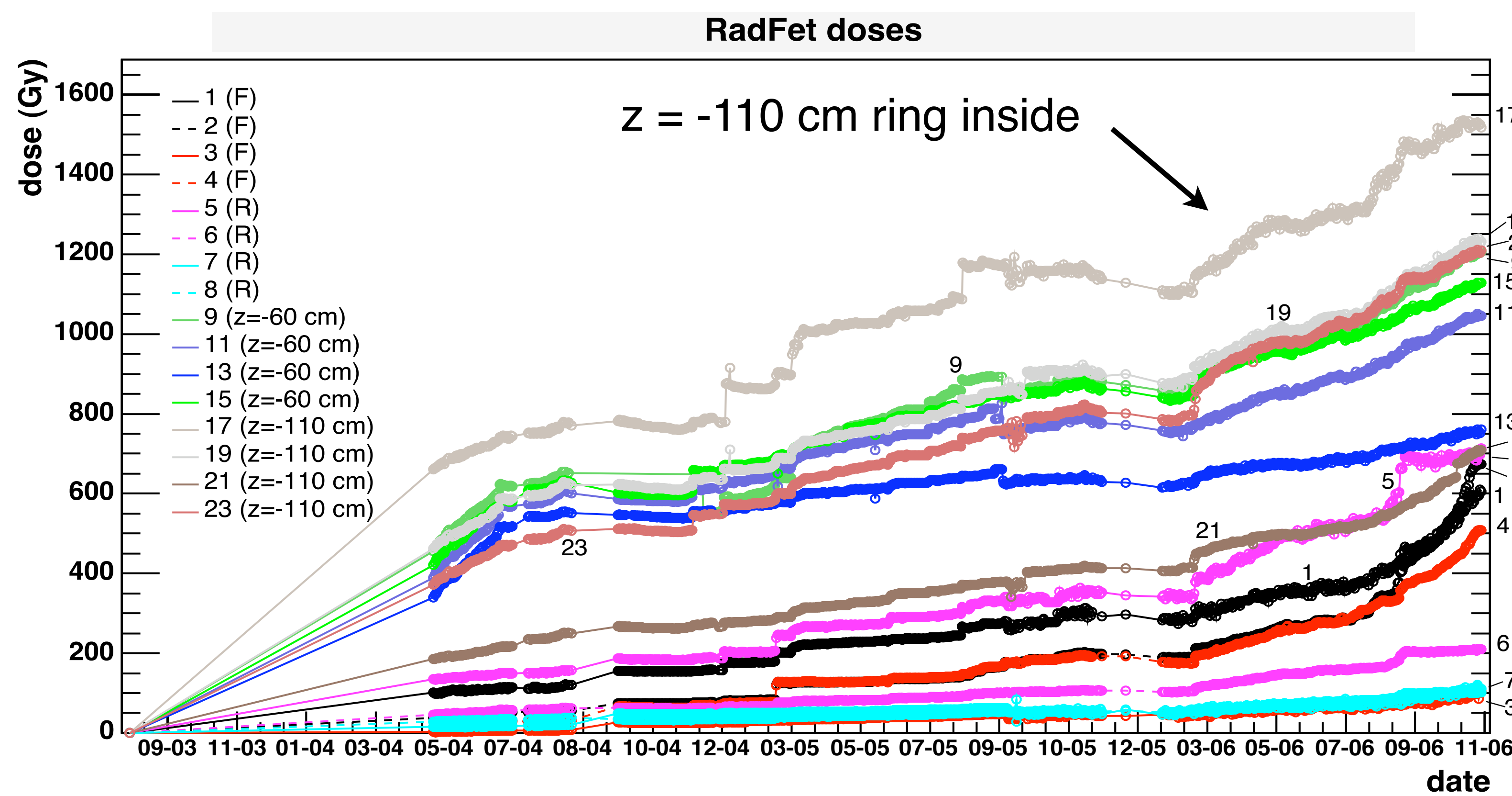




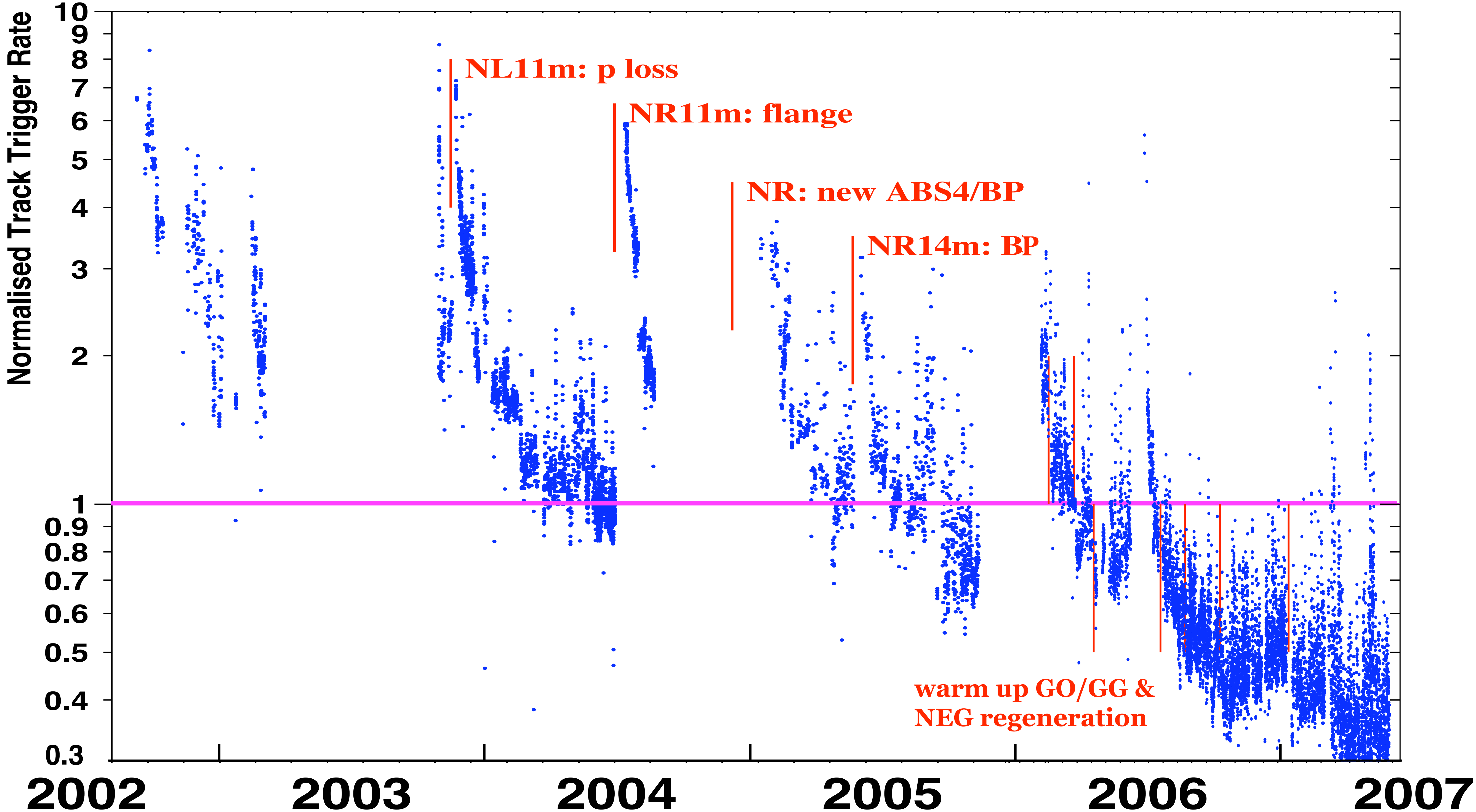
Accumulated Doses in ZEUS MVD in 2001-2006



- Observe non-uniform distribution of doses inside MVD
  - increase roughly $\propto \int L dt$
- Dose of ~ 2 kGy measured ring inside in backward direction
  - consistent with significant contribution from off-momentum $e^{-/+}$
  - correlated with observed S/N degradation of ~10%



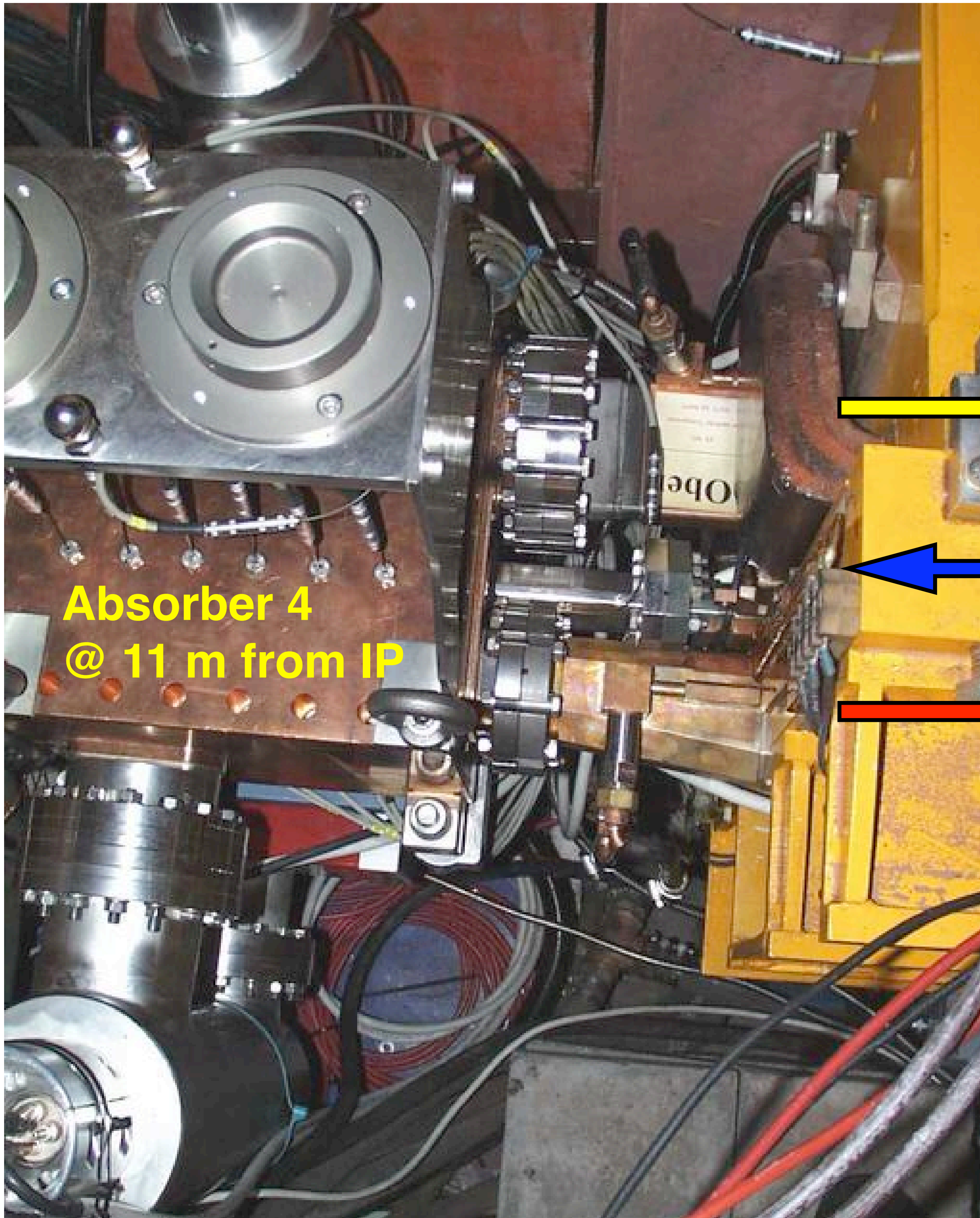
H1 Proton-Gas Background in HERA II



Time constants for vacuum conditioning:

- short term after leak: $\tau \approx$ 20-30 days
- long term base level: $\tau \approx$ 600 days

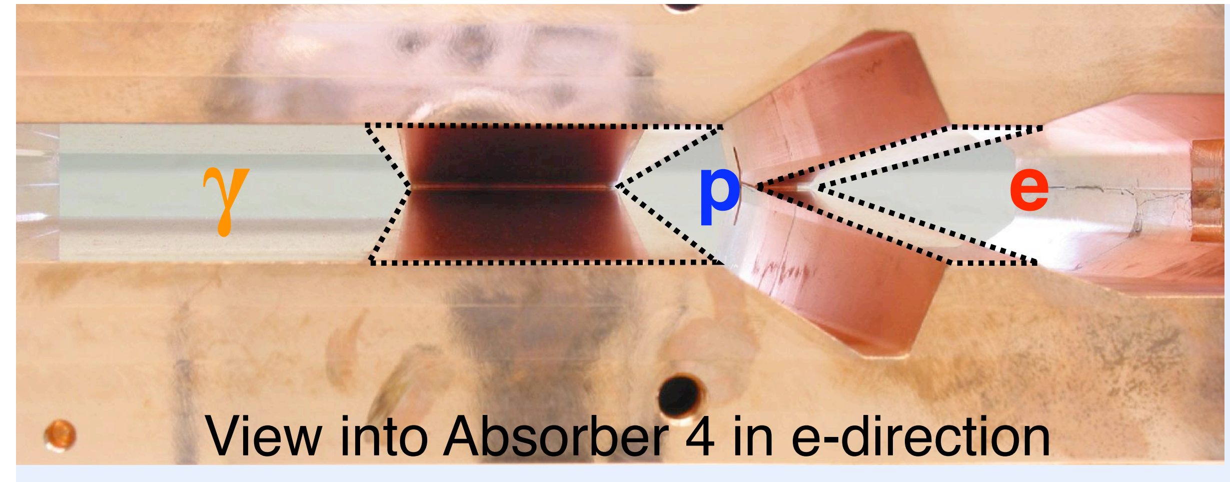
Most Critical Region: Abs4 @ 11m Proton Upstream

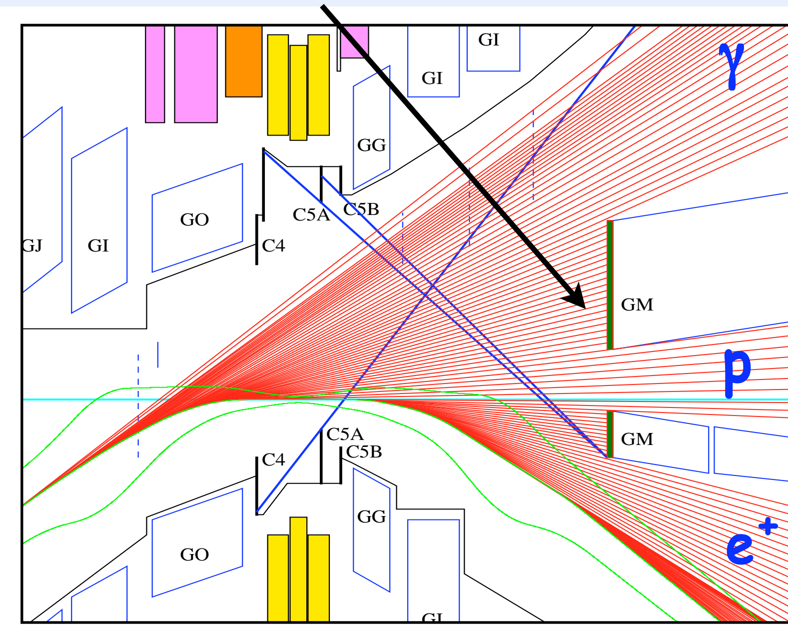


synchrotron radiation

protons

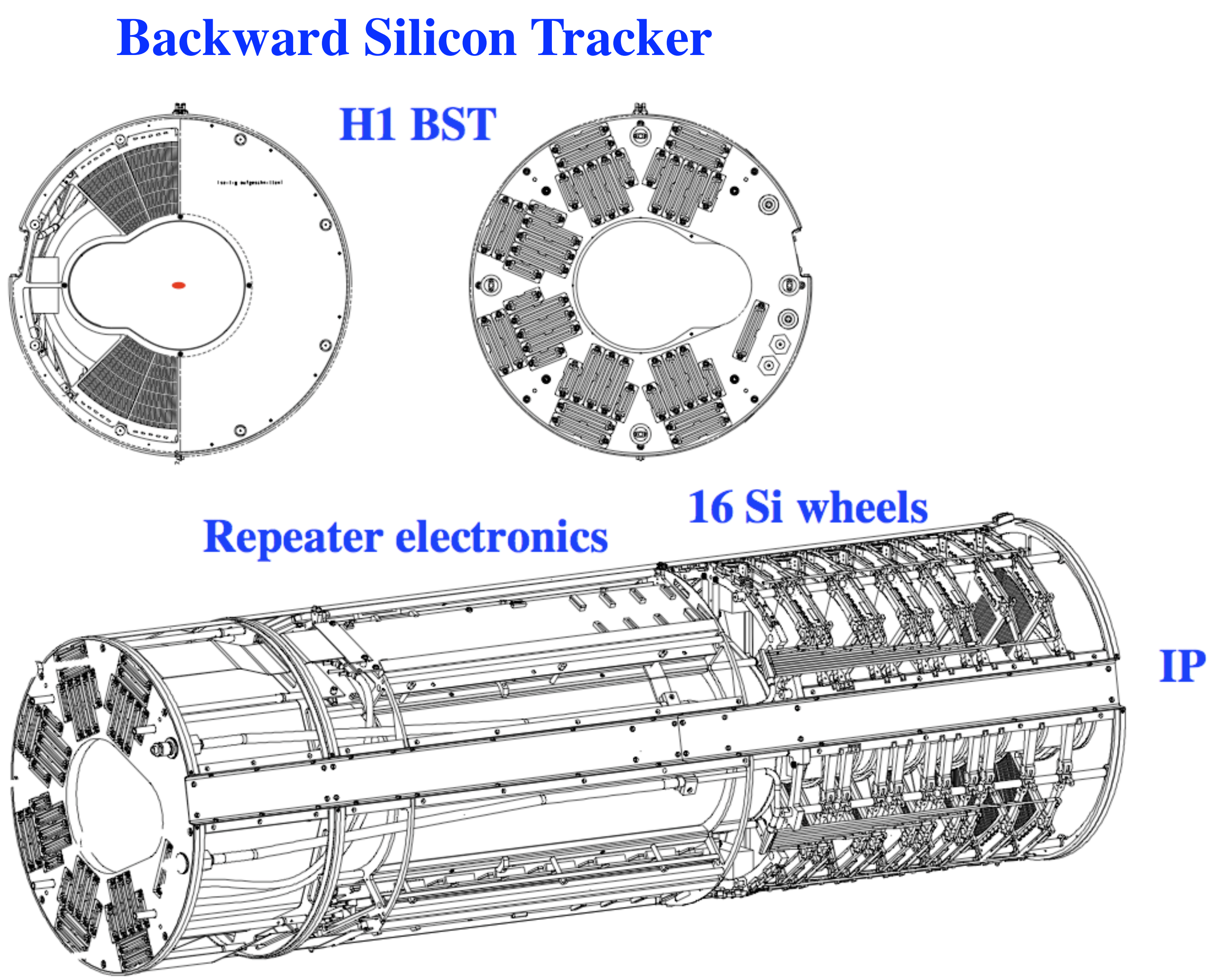
electrons

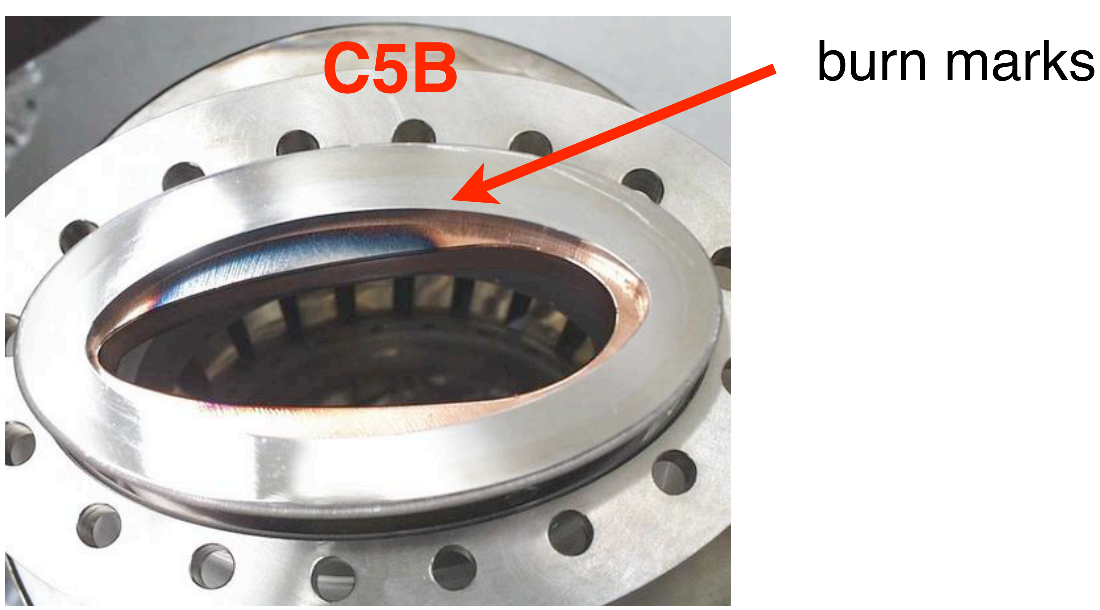




- Three flanges in a very dense area
- Large stress on flanges due to
  - direct synchrotron light: thermal
  - misalignment: mechanical
- Fast temperatures changes in case of e-beam loss

Radiation Damage in H1 BST in 2002

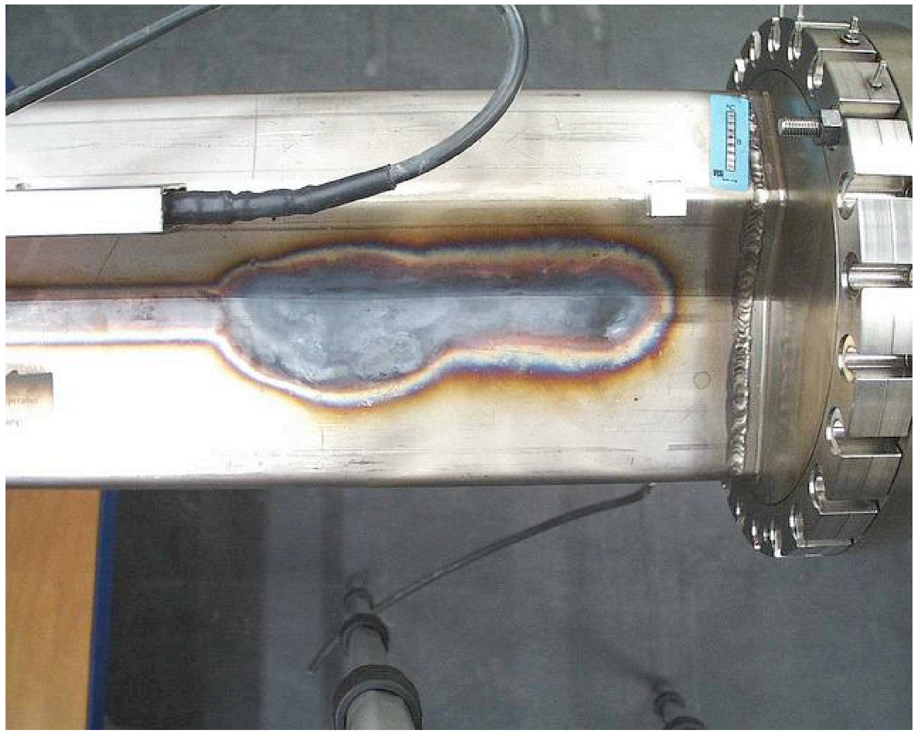




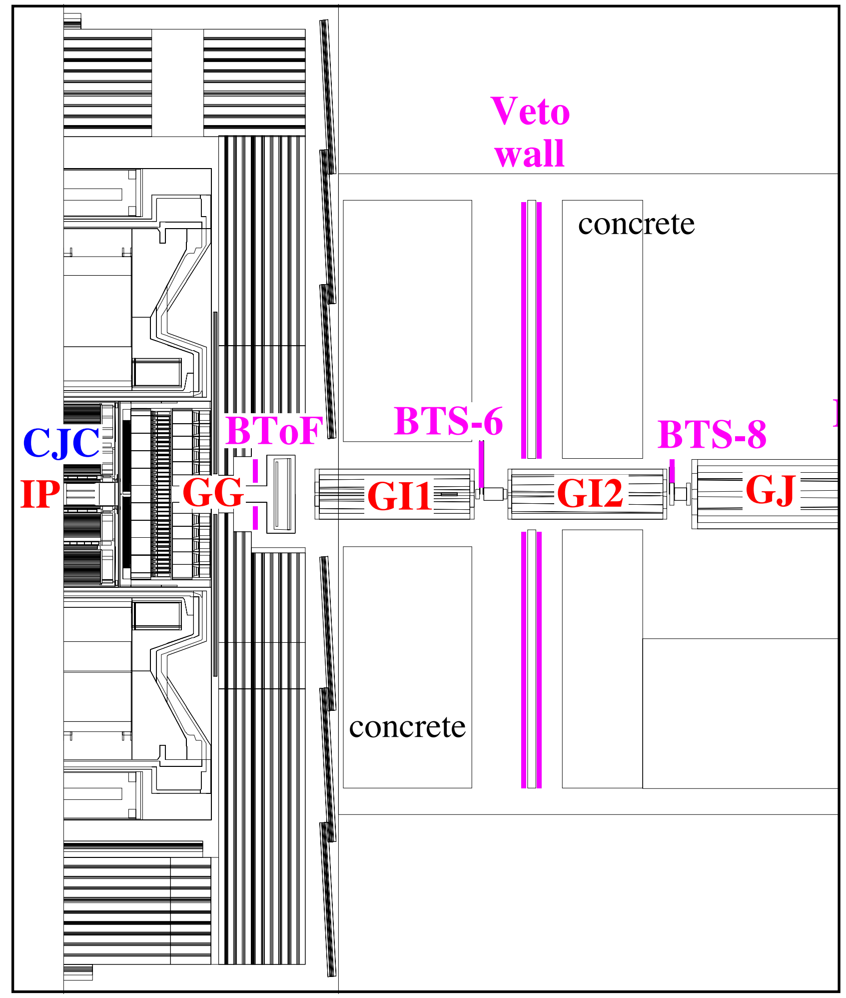
- Silicon readout chips damaged
- Repeater electronics damaged
  - replaced with radiation hard versions
- For 2002 RPL glass dosimeters showed **10-30 kGy** in backward part close to the beam
  - electronics can only tolerate ~0.15 kGy
- Possible sources
  - beam losses
  - direct synrad hitting C5B, perhaps at injection
- Remedies
  - install lead shield underneath repeater in 2003

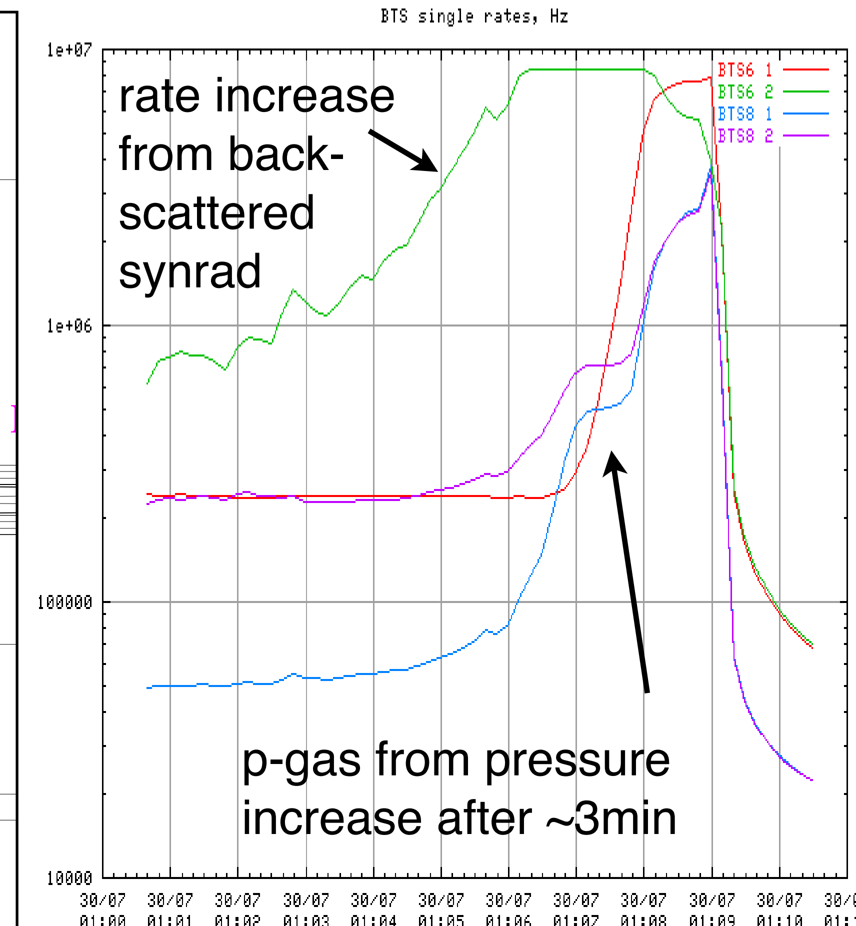
Direct SynRad hitting Beampipe @ 6-8m NR

June 2004



June 2006





- Gas bursts correlated with high BTS6 rates
- Beam pipe shows 2-5 mm deformation inward
- Probably due to misdirected e-beam
- Installed active safety system
  - temperature sensors
  - vacuum pressure monitors

Conclusions

- Severe background problems in the year 2002 delayed significantly startup of HERA after luminosity upgrade

- Sources of the problem were identified and solutions implemented in shutdown 2003
  - very fruitful collaboration between all experiments and the machine group
  - main problem was proton gas interactions
    - remaining weak point around absorber 4 caused further problems in the following years

- Indispensable for a detailed understanding of the background sources are:
  - sufficient time for special runs
  - detailed simulation of machine and detectors
  - diversified monitoring tools (not just rates)
  - complete and accessible archive of all relevant data to study correlations

- Good vacuum needs patience and takes time !!

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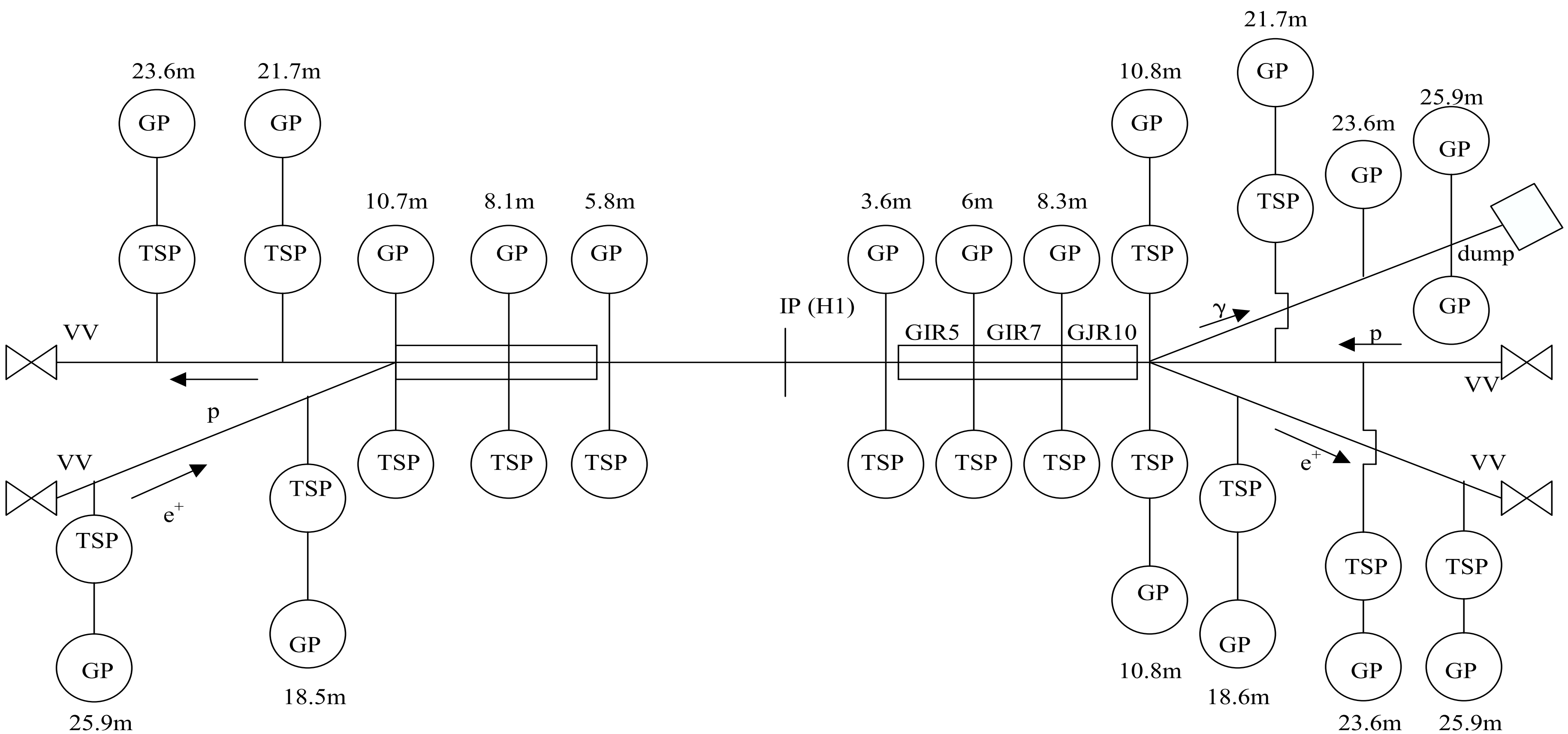
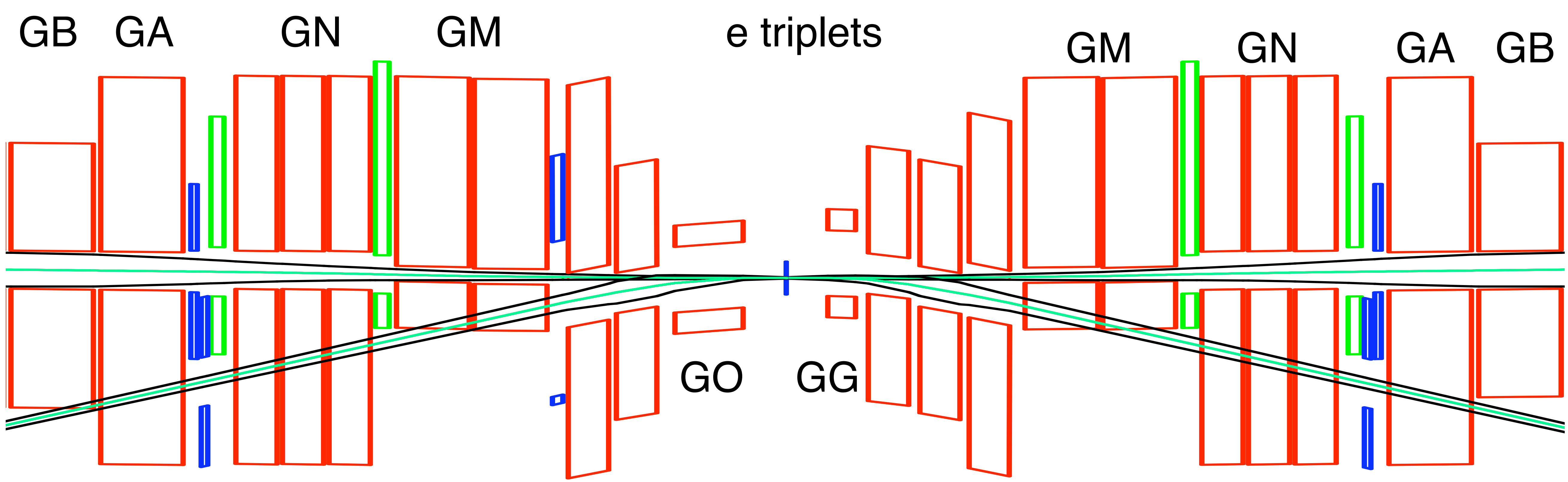
Extras

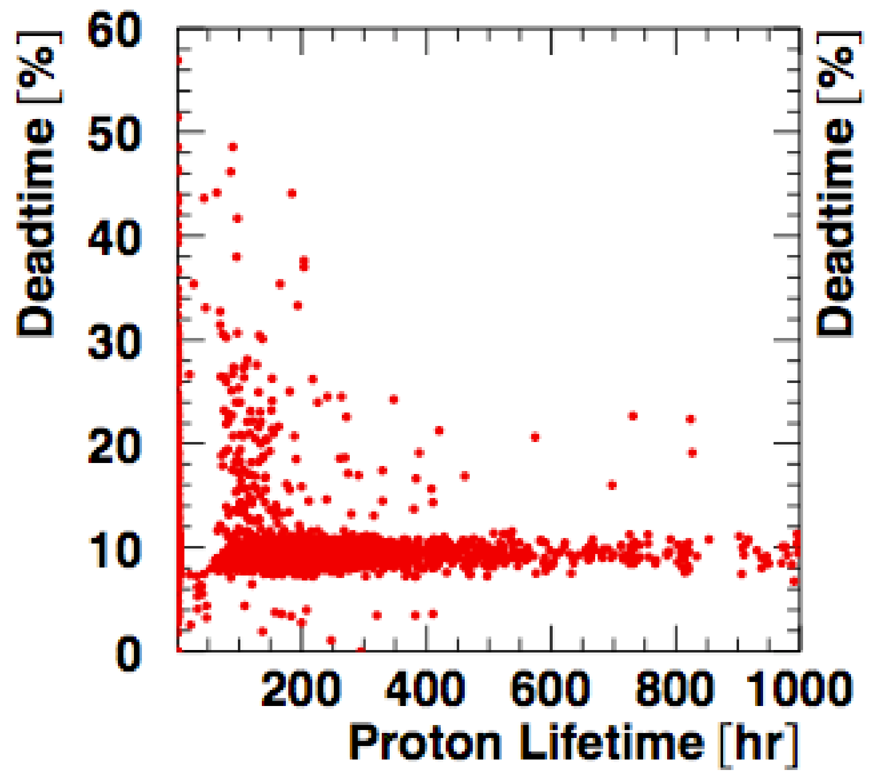
Vacuum System ±26m around the IP

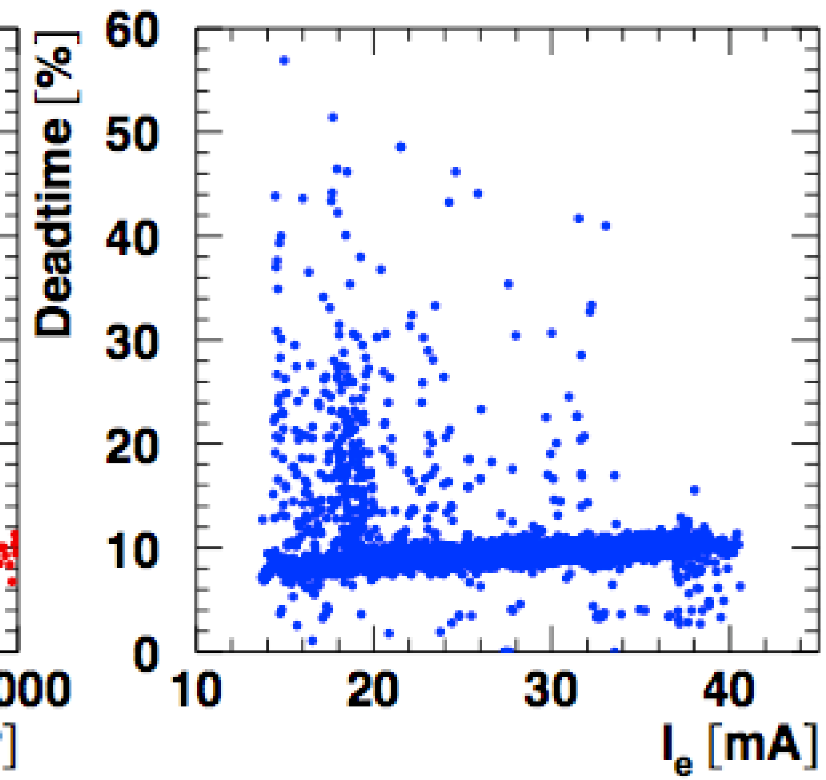




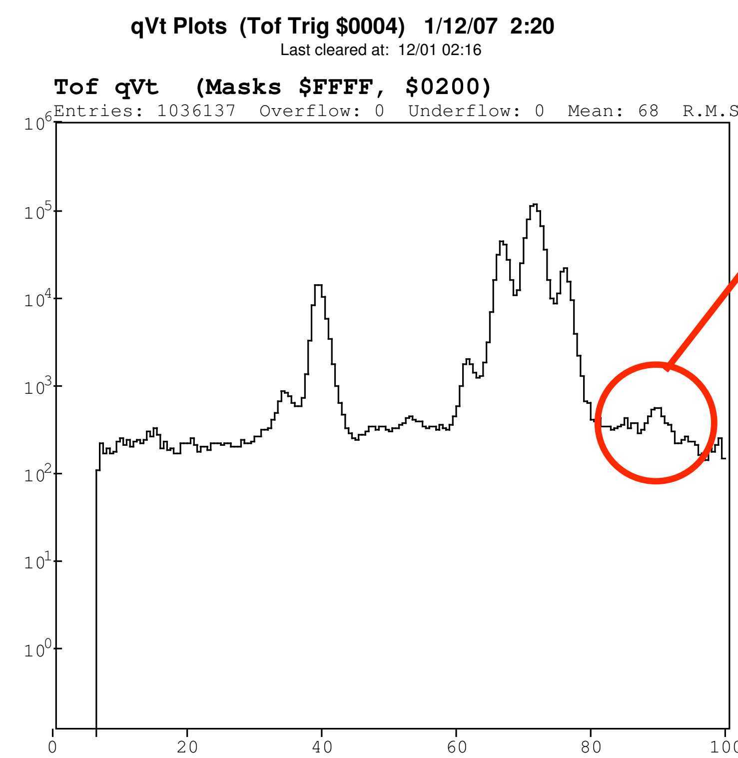
Increasing Deadtime

- Deadtime increases for proton lifetimes < 150 hr
- Typically happens towards end of the fill: I_e < 20 mA
- Protons „age“ during fill
  - most problematic for H1: late 20ns satellites
- Sometimes adjustment of p-collimators helps



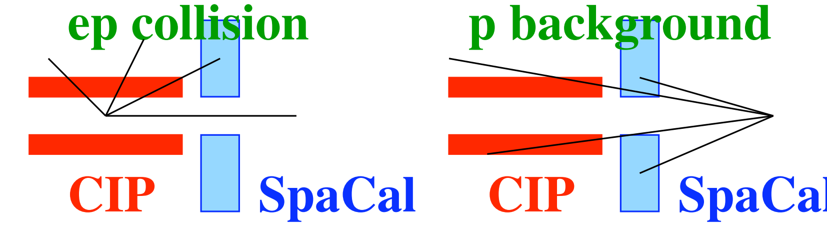


SpaCal backgroud can be understood from the QVT shift histogram



+20 ns satellite

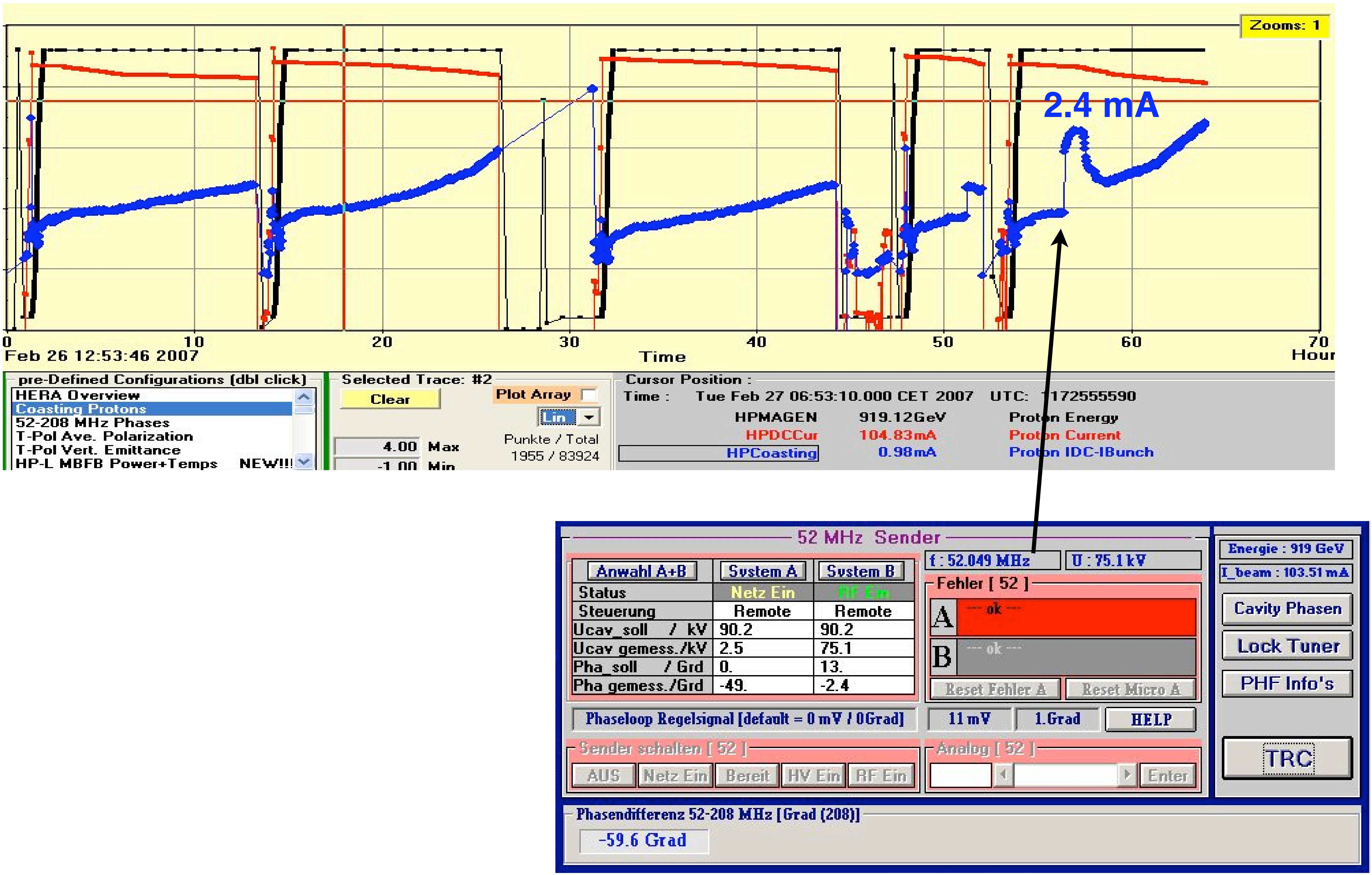
p background from this satellite arrives in the detector within the SpaCal ep time window



proton travels to IP, tracks from IP to Spacal

background tracks directly hit the SpaCal

Coasting Beam



Sudden Drop of Electron Lifetime

- Usually lead to trips and/or higher background
  - some are only very short
  - some are unrecoverable

- Most likely due to trapped dust particles