Summary of Pressure Rise Workshop

S.Y. Zhang and T. Roser
Brookhaven National Laboratory

I. Background of Workshop

II. Electron and Ion Desorption

III. Chamber Coating and Treatment

IV. Electron Cloud Effect

V. Conclusion and Perspective

31st ICFA Advanced Beam Dynamics Workshop on
Electron-Cloud Effects
"ECLOUD'04"
Napa (California), April 19-23, 2004

The 13th ICFA Beam Dynamics Mini-Workshop
Beam Induced Pressure Rise in Rings
Brookhaven National Laboratory, Upton, NY
December 9 - 12, 2003

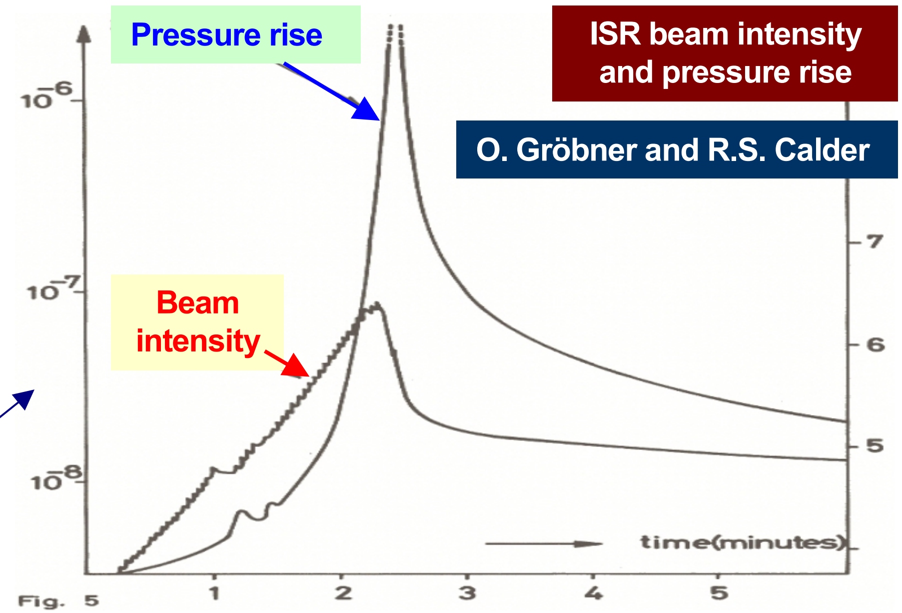
I. Background of Workshop

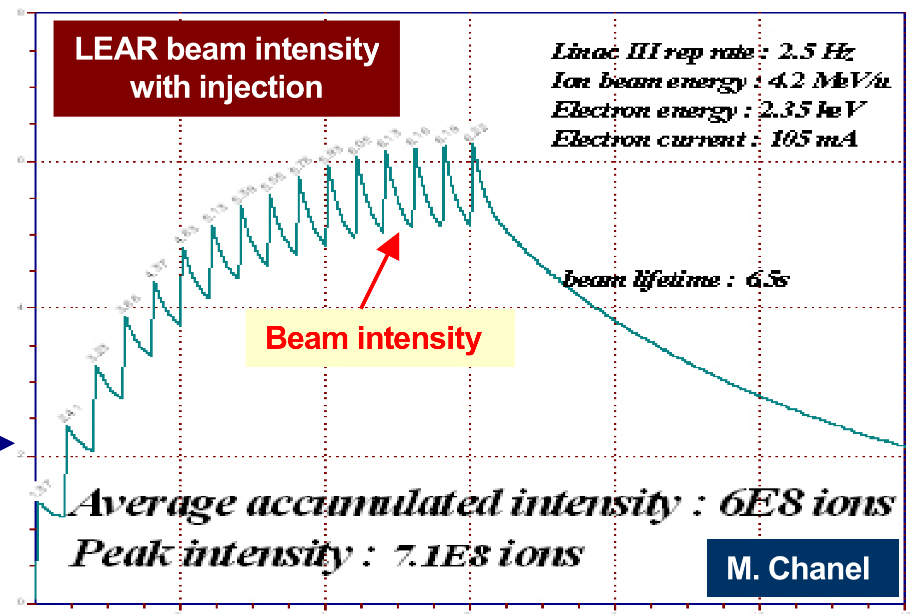
1. CERN ISR intensity was limited by pressure rise

- Beam gas ionization generated ions were pushed to the wall, causing pressure rise.
- Pressure rise caused more ionization - pressure run-away.
- Chamber baking and treatment, added lots of pumps.

2. Low energy heavy ion machine

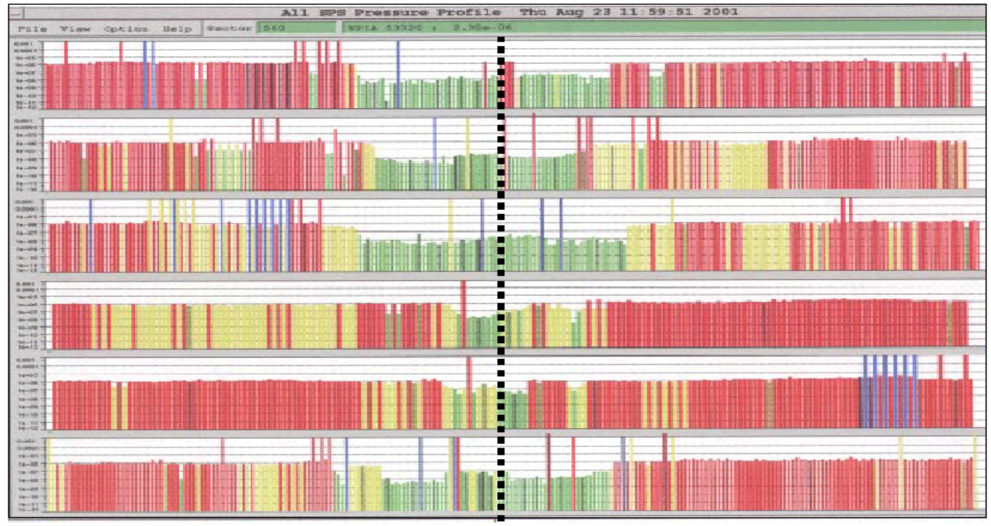
- High vacuum required due to large charge exchange cross section: AGS Booster, CERN LEAR, GSI SIS.
- Beam loss creates pressure rise by ion desorption.
- The stored beam intensity is limited.





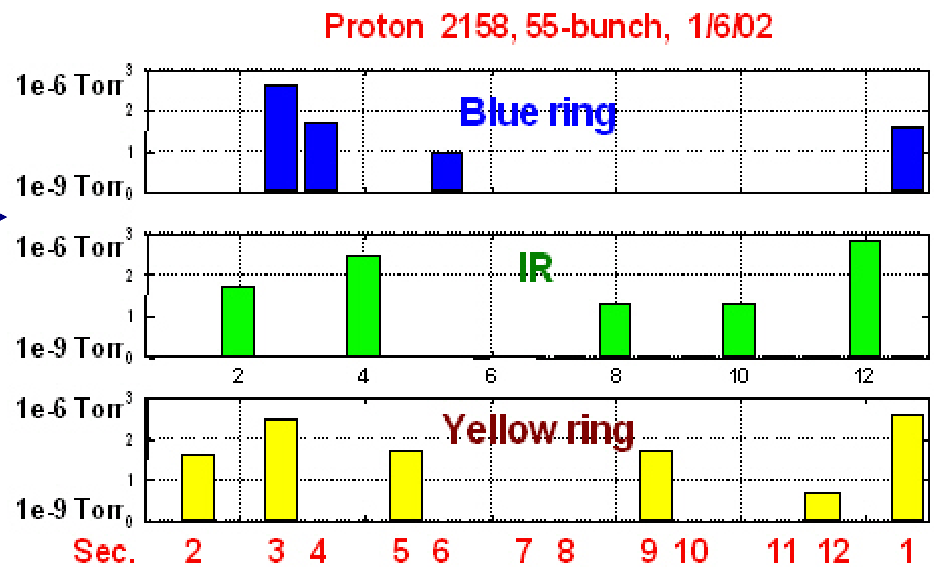
3. Electron cloud effect

- The electron cloud induced pressure rise is usually more or less uniformly distributed in the ring.
- The electron cloud related beam instability and emittance growth prevent further intensity increase, and the pressure rise is often a secondary problem.
- RHIC pressure rises occur only in part of warm sections, with non-uniform distribution.
- Without beam instability and emittance growth, beam intensity can be increased until the pressure rise impacts operation.



SPS pressure rise in the ring

J.M. Jimenez



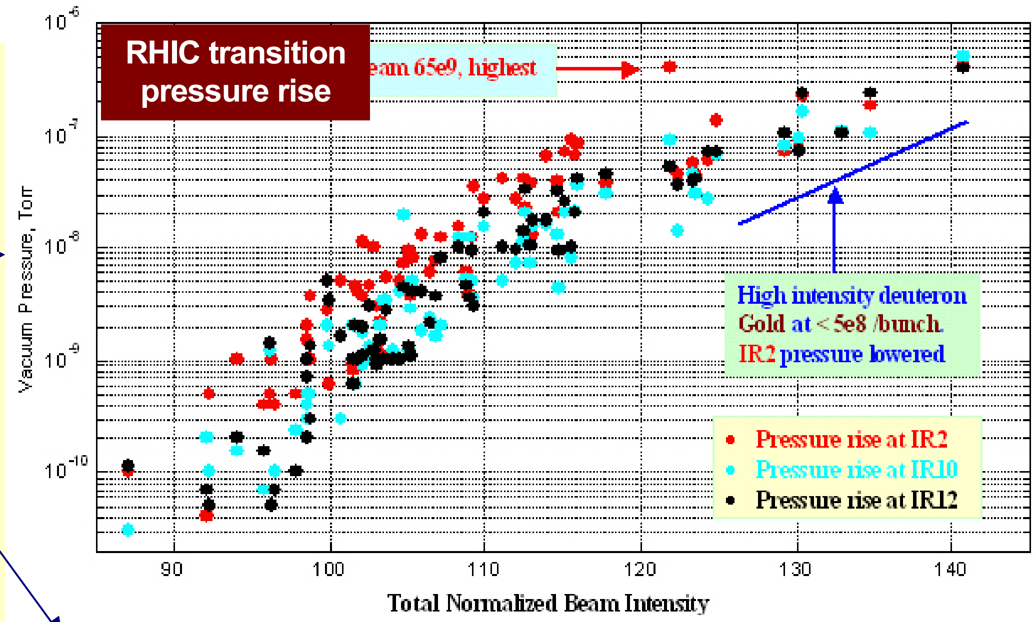
RHIC pressure rise in the ring

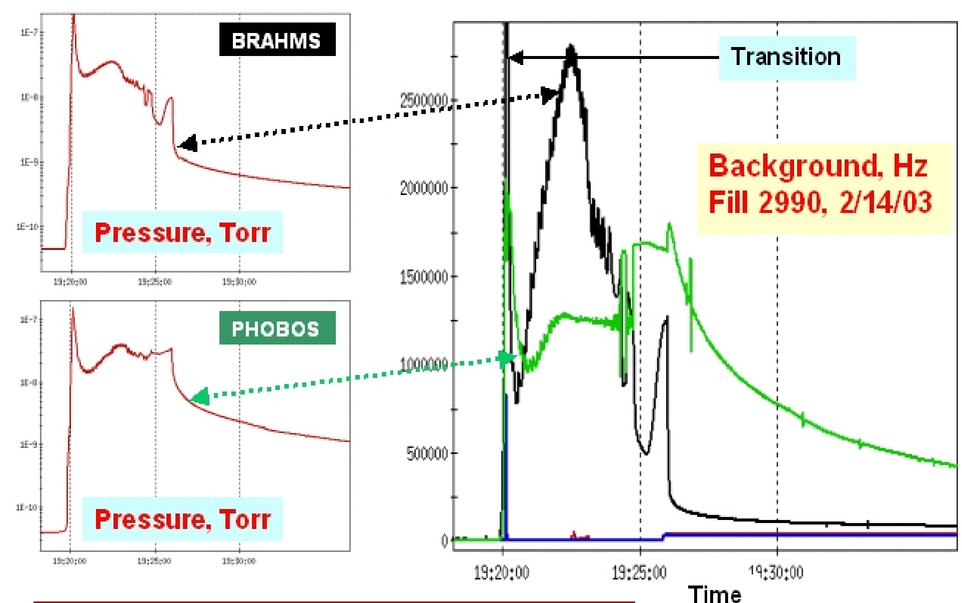
4. RHIC transition pressure rise

- RHIC transition pressure rise is related to the total beam intensity.
- This pressure rise causes experimental background problem.

5. Pressure rise workshop

- Concerns of several existing machines.
- Concerns of machines in construction and/or planning, such as LHC, SNS, LEIR, GSI upgrade, RHICII, eRHIC, and heavy ion fusion accelerators.
- Three working groups:
  1. Electron and ion desorption.
  2. Chamber coating and treatment.
  3. Electron cloud effect.



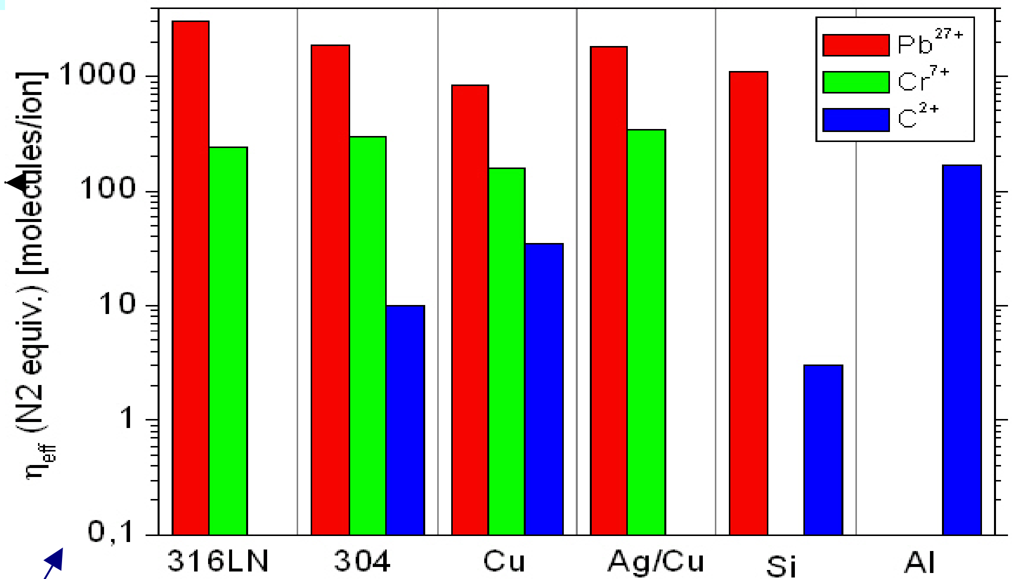


RHIC pressure rise and background

II. Electron and Ion Desorption

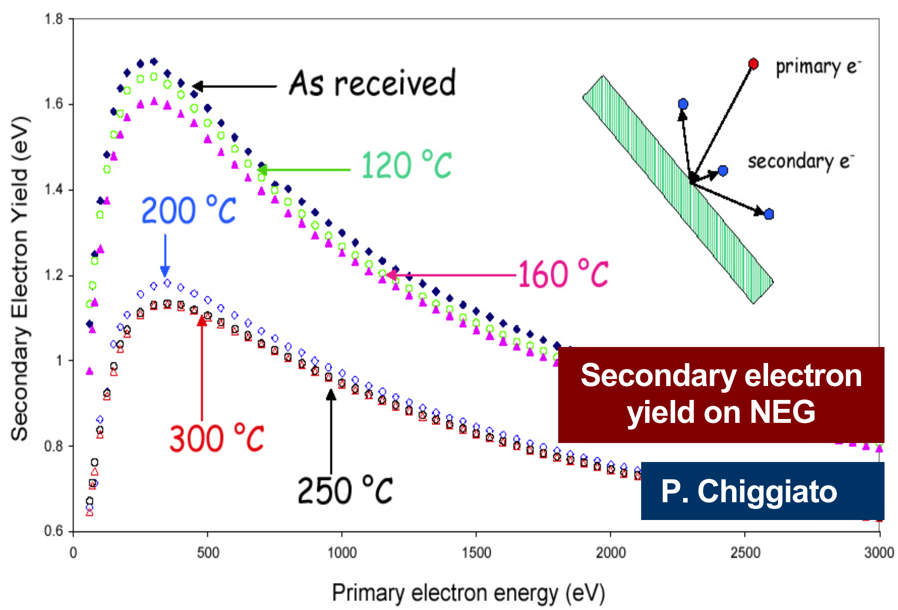
1. Perpendicular incident

- Electrons are kicked to the wall by passing bunch during the EC multipacting, the incident direction is perpendicular.
- In ISR type pressure rise, ions are pushed to the wall by circulating beam, it is also perpendicular incident.
- Progress on ion desorption measurement on various materials and surface treatment.
- Progress of measurement on secondary electron yield on NEG coated surface.
- Uncertainty is large for non - perpendicular incident.



Ion desorption yield, 1.4 MeV/u

A. Kraemer

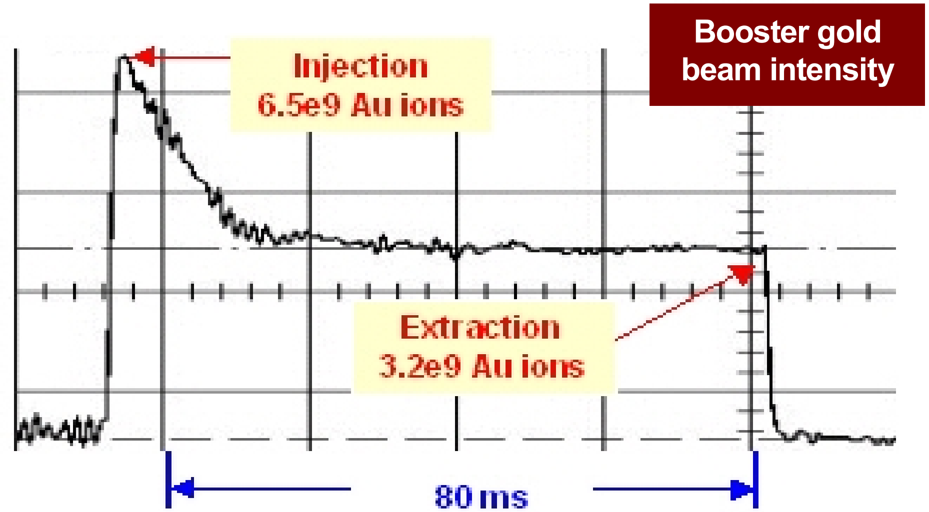


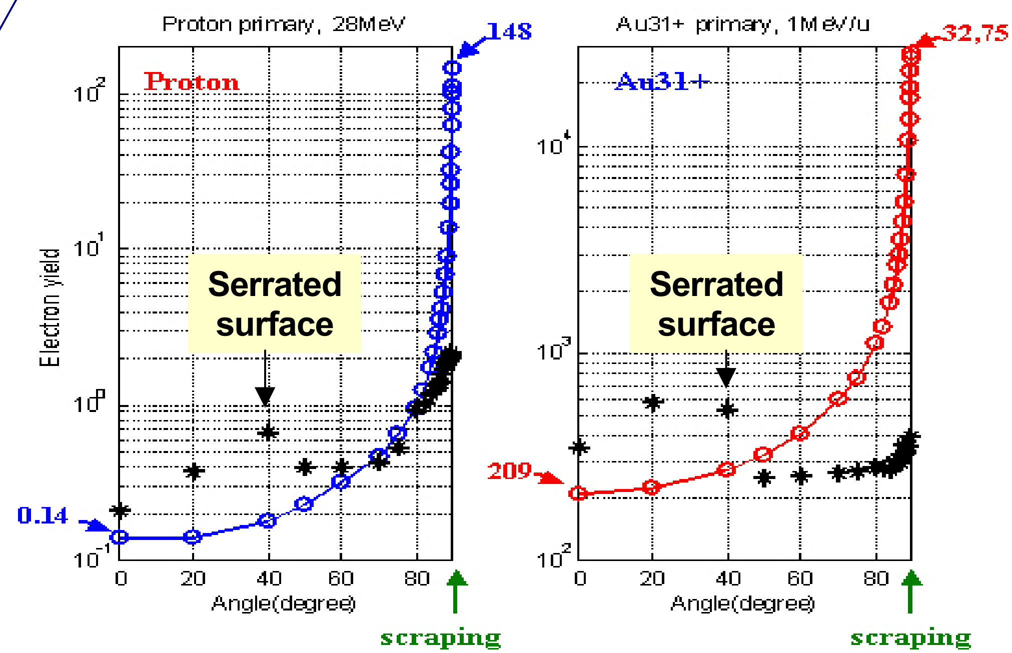
Secondary electron yield on NEG

P. Chiggiato

2. Non-perpendicular incident

- Beam injection and charge exchange caused beam loss are with the incident angles of mrad or less.
- At the time of AGS Booster was designed, ion desorption rate was believed to be 1 - 10.
- More than 1e5 molecules can be generated per lost Au ion. The gold beam injection loss induced pressure rise has caused > 40% loss during the acceleration at high beam intensity.
- Similarly, in early design of SNS, SEY was believed to be 0.1 - 1 per lost proton.
- SEY of proton impact is measured to be larger than 100 at grazing angles.



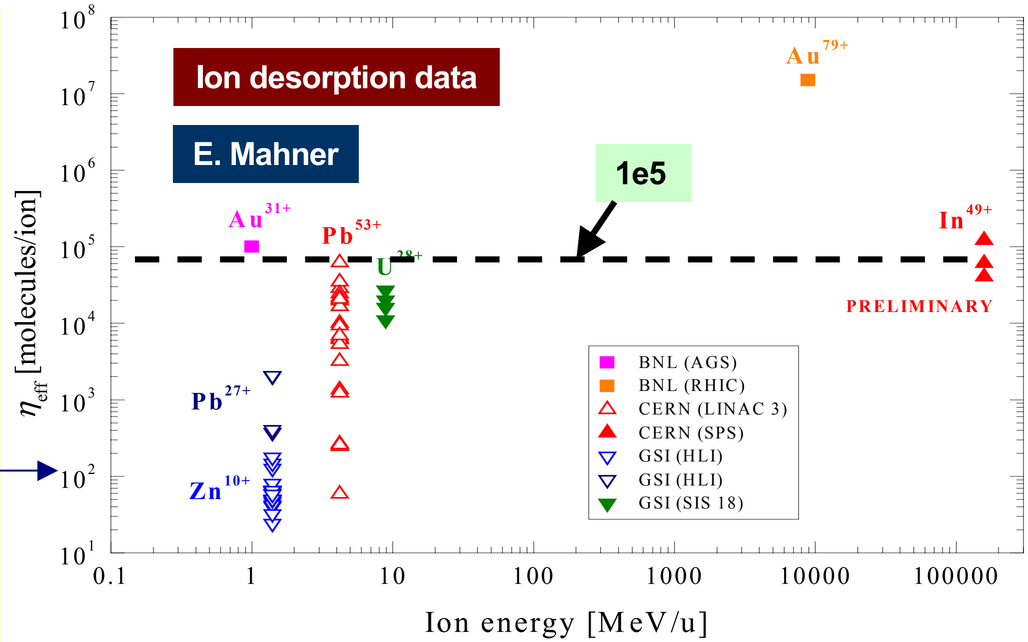


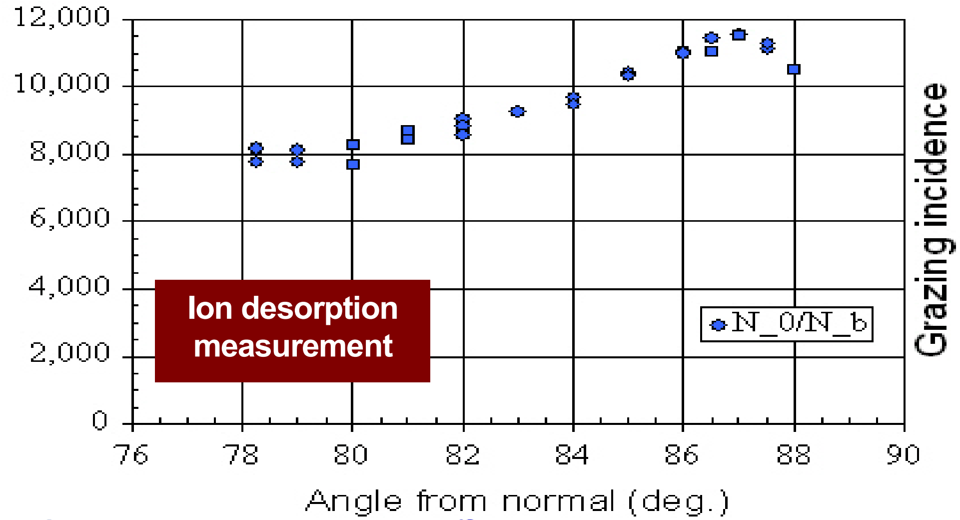
SEY of proton and Au impact

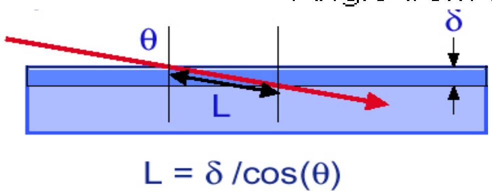
P. Thieberger et al

3. Progress in ion desorption measurement

- **Measurement at AGS Booster, RHIC, LEAR, SPS, LINAC3, SIS and GSI HLI shows ion desorption rate of 10 - 1e7, under different conditions.**
- **The ion desorption rate of around 1e5 was measured at several accelerators.**
- **For low energy machine, the relevant incident angle is in mrad or less. For high energy machine, it may go to μrad or less.**
- **A bunch measurement shows peak desorption rate at 87 deg.**
- **The adequate length of surface relevant to grazing angle measurement?**



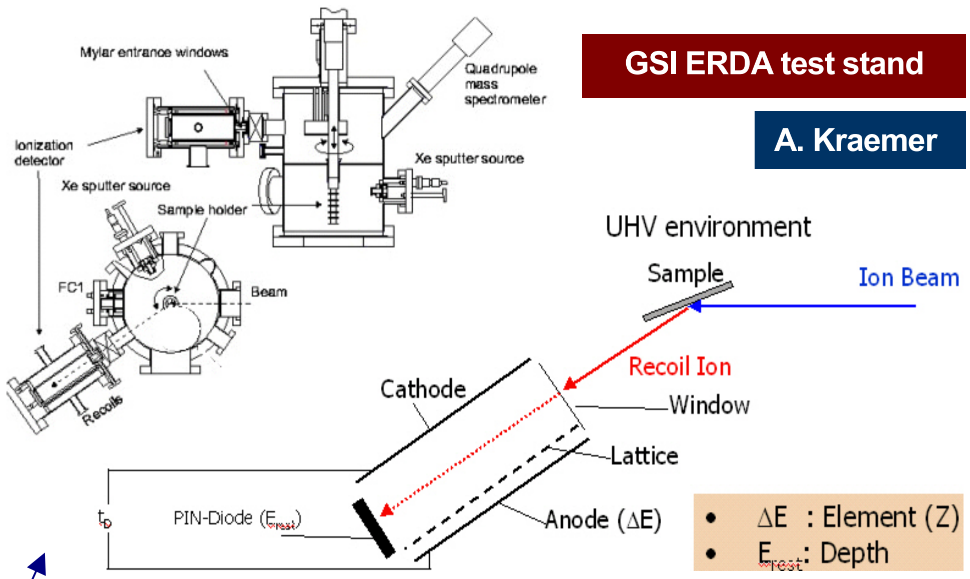


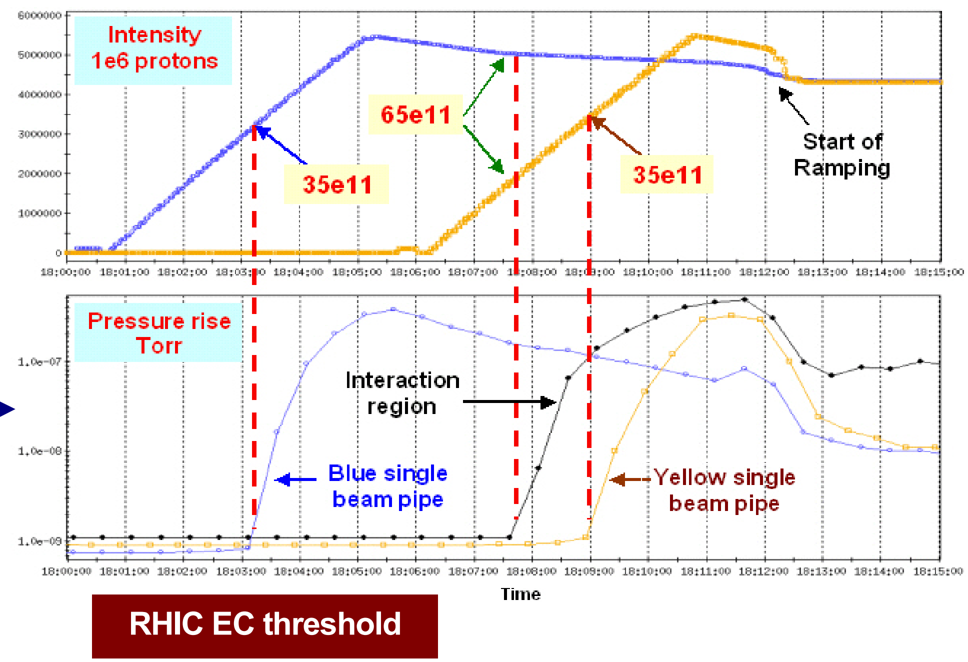


A. Molvik

4. Status and plan

- It is not unusual that the measured desorption rates differ in orders of magnitude with similar conditions.
- Surface chemistry/physics may help for better understanding.
- It is proposed for systematic measurements according to species, energy, charge state, and incident angle.
- More measurements based on test stands are planned at CERN, GSI, BNL, and others.
- Beam measurement in the accelerators is also important. For example, EC intensity threshold of 34 m long straight section in RHIC is < 60% of 17 m long chambers.

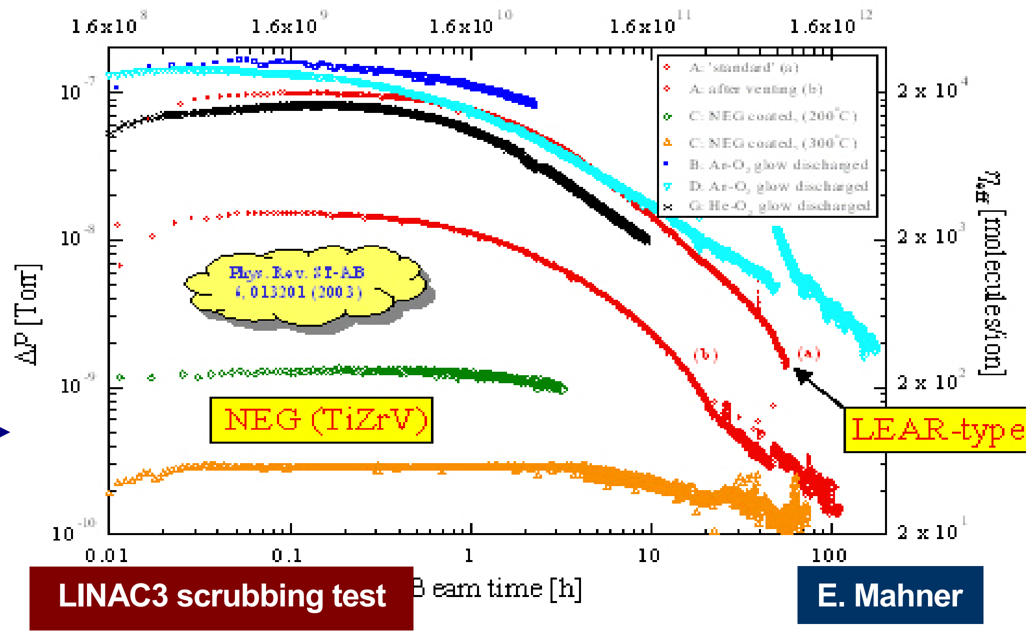


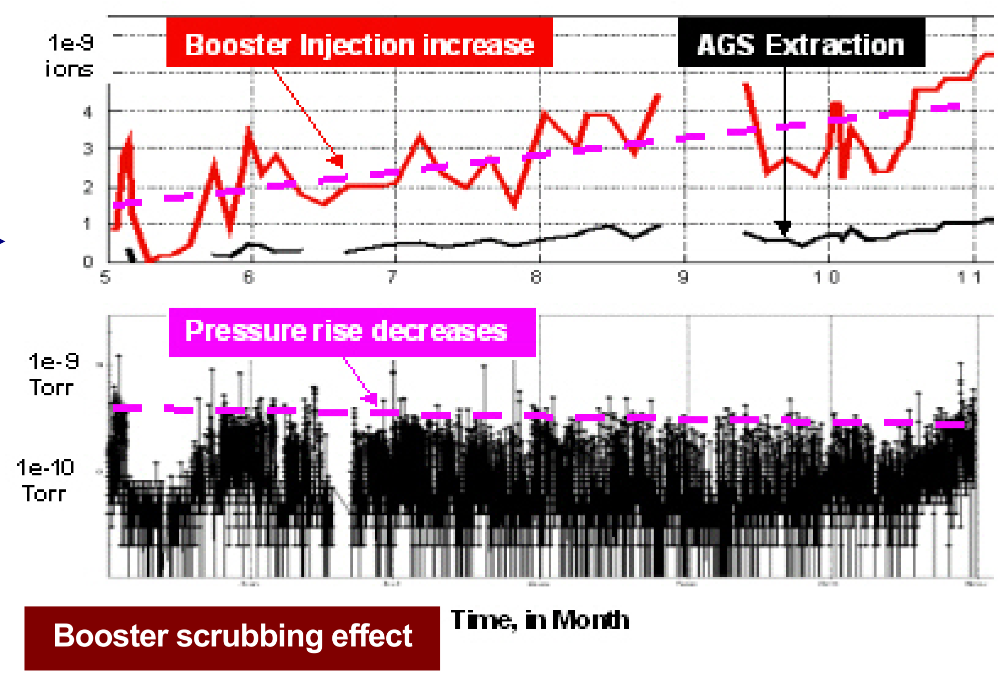


BROOKHAVEN NATIONAL LABORATORY

5. Beam scrubbing by ion sputtering

- Beam scrubbing by ion sputtering has been proved beneficial in reducing ion desorption induced pressure rise at LINAC3.
- Beam scrubbing is planned in the commissioning of LEIR as LHC ion injector.
- Similar effect has been observed at the AGS Booster for the Au injection in longer time period. The dose requirement agreeable with the LINAC3 data.
- One problem in sputtering scrubbing is the control of dose deposition in the relevant surface area. This is comparable with the EC scrubbing in dipole field.

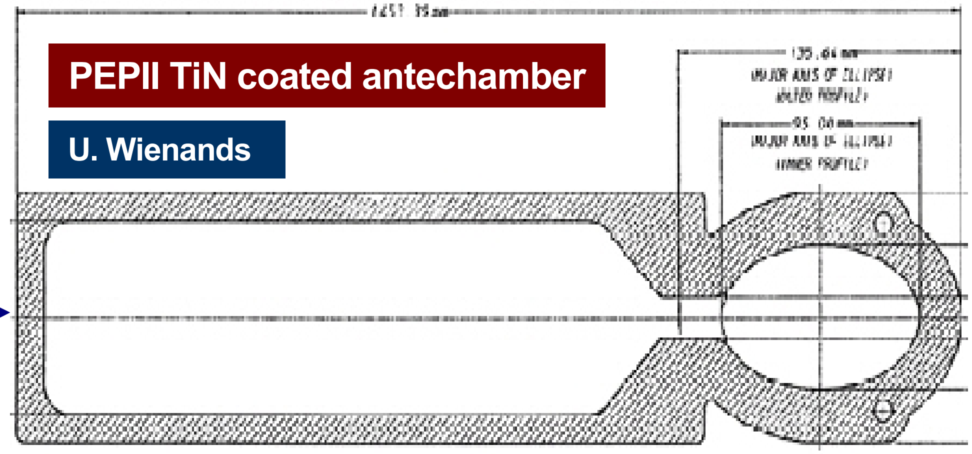




III. Chamber Coating and Treatment

1. TiN coating

- TiN coating is aimed at SEY reduction.
- TiN coating has been applied to many machines, such as the PEPII antechamber. It is applying to entire vacuum chamber at SNS.
- General reduction of SEY is observed, but not all times. PSR three installations of TiN coated pipe have yet to reach a conclusion.
- Improvement of coating under high pressure of 5 mTorr at BNL for SNS pipe coating. SEY was improved from 2 ~ 2.5 to 1.5 ~ 1.9.
- The better coating has rougher surface.



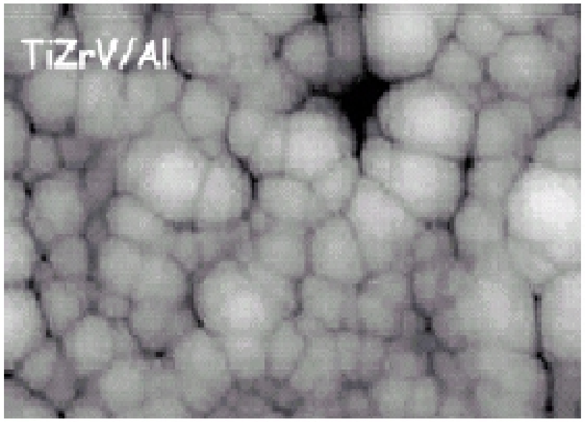
5 mTorr	1.5 mTorr
λ ~1 cm	~3.3 cm

TiN surface comparison

H.C. Hseuh

2. NEG coating

- **Multi - benefit of NEG coating**
  1. **It turns outgassing chamber surface to the getter pump.**
  2. **Reduction of SEY and electron desorption rate.**
  3. **Possible ion desorption reduction.**
- **Positive measurement results on SEY and electron desorption.**
- **Limited measurement on ion desorption, consistent results yet to be reached.**
- **Rough NEG film is needed for better pumping (surface ~ bulk), it also helps for SEY reduction. Is it also beneficial for electron and ion desorption?**
- **It is found at CERN that coating is rougher if the chamber surface is rougher. Coating condition may also be important.**

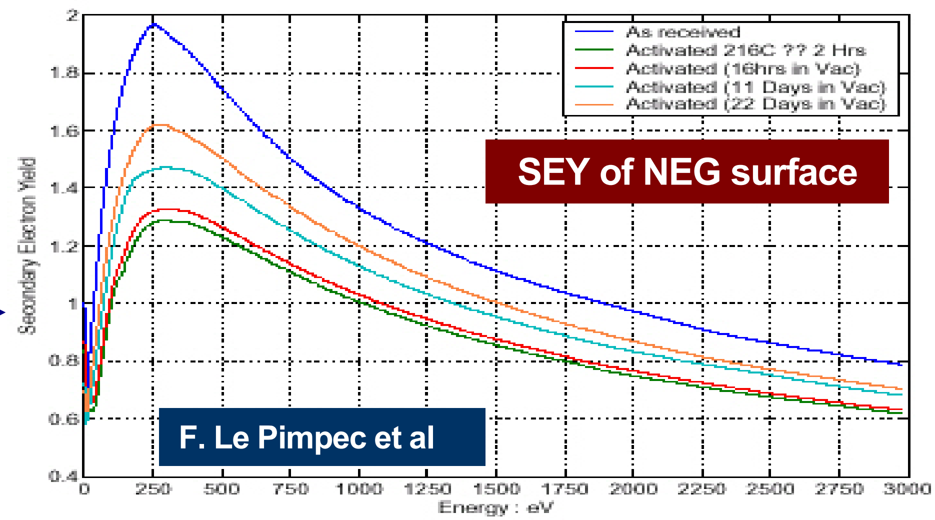


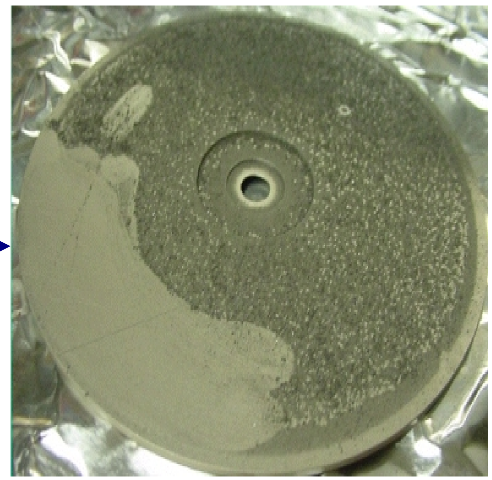
NEG surfaces on St. St . & Al

V. Ruzinov

3. More about NEG coating

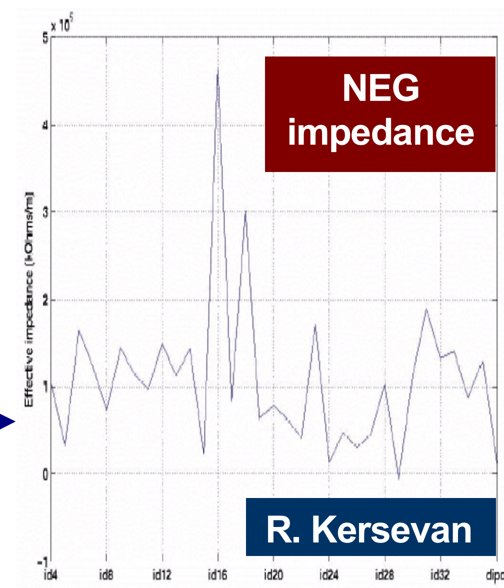
- For activated NEG surface, SEY is 1.1 ~ 1.3. For saturated surface it remains below 1.4, measured at CERN.
- SLAC measurement shows SEY of 1.3 ~ 1.6 after 22 days in vacuum, still comparable with steel surface after beam scrubbing, SEY = 1.5, and the well conditioned TiN with SEY = 1.6.
- Cornell observed the powder substance on NEG surface, from excessive H_2 sorption.
- NEG surface impedance is better than steel, but not as good as Al, measured at ESRF.
- Activation condition needs to be optimized for pumping, reduction of SEY, electron and ion desorption.





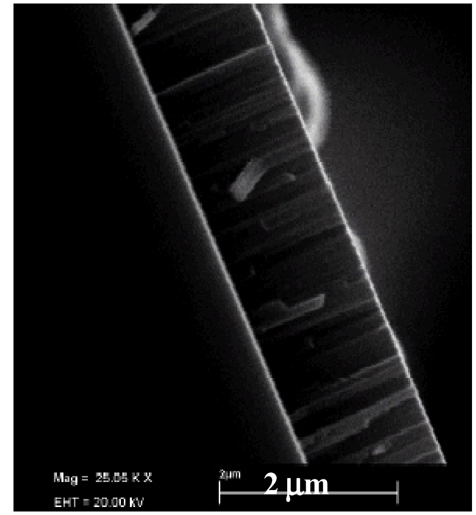
NEG powder

Yulin Li



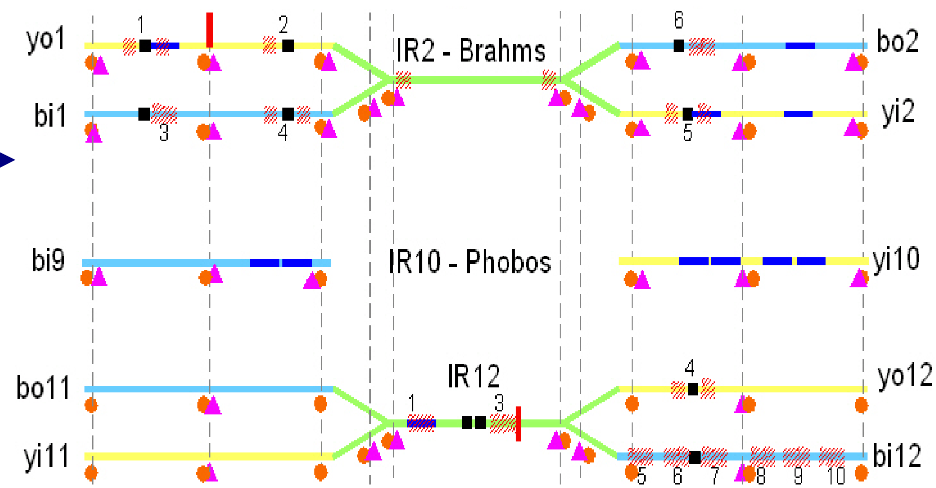
4. Collaboration and plan

- **More issues for NEG coating**
  1. **Coating condition.**
  2. **Aging effect and lifetime.**
  3. **Venting effect.**
  4. **Pumping capacity.**
  5. **Activation condition.**
- **Collaborations include Cornell, ESRF, GSI, KEKB, LHC & LEIR, PEP II, and BNL.**
- **Total 11 NEG coated pipes, each 5.2 m long, have been installed in the RHIC. Beam study is undergoing for ion desorption, suppression of electron multipacting, and linear pumping.**
- **Test stand at the BNL Tandem for ion desorption and activation condition.**



NEG coating and surface

R. Kersevan



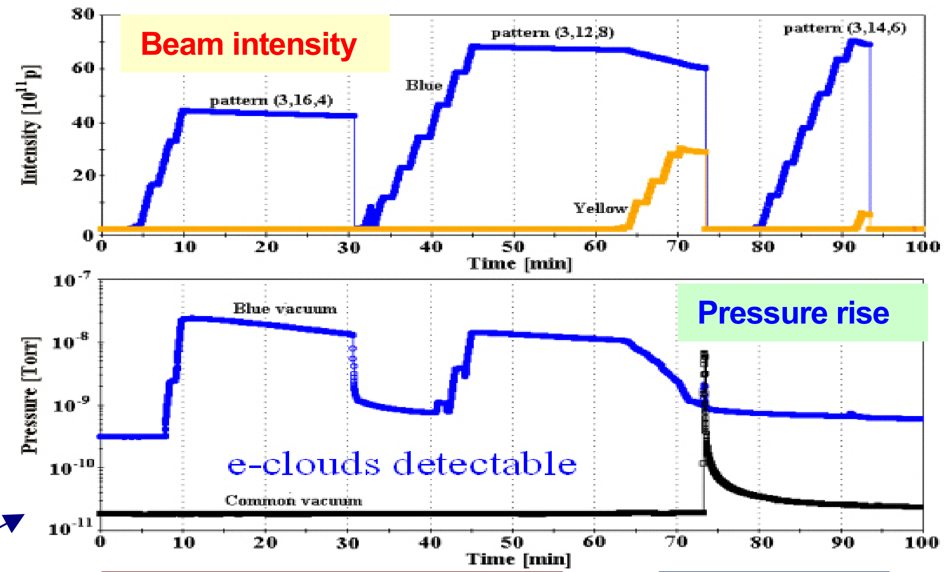
NEG pipes in RHIC

H.C. Hseuh

IV. Electron Cloud Effect

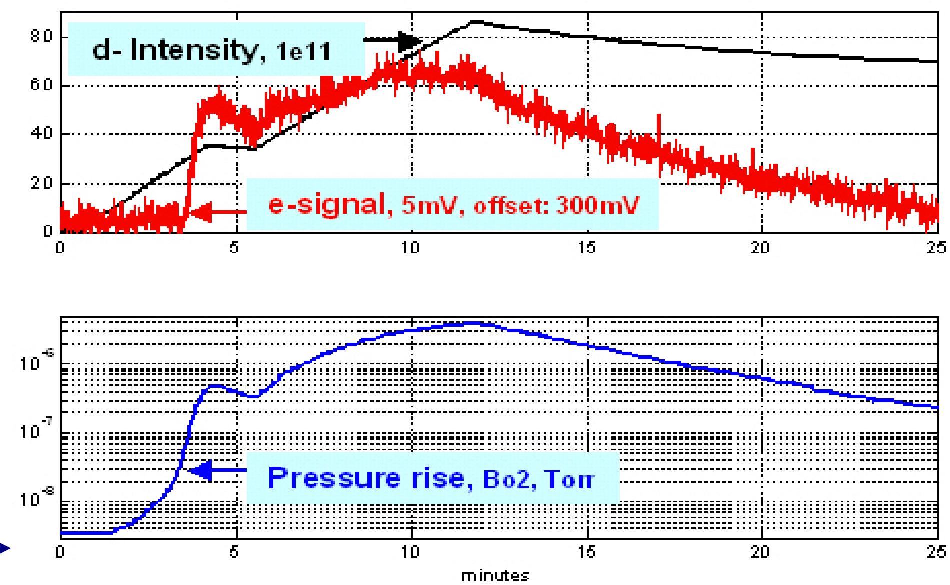
1. Mechanism of electron cloud

- Thanks to theoretical and experimental studies in past several years, when electron clouds occur in RHIC, it wasn't much of a surprise to observe 'classical' features of it.
  1. Bunch intensity effect.
  2. Bunch spacing effect.
  3. Bunch gap effect.
  4. Solenoid effect.
  5. Scrubbing effect.
  6. Associated pressure rise and its saturation.
- Not quite quantitatively
  1. Electron density and distribution.
  2. Solenoid effect.
  3. Effect of beam size.
  4. Relation between e-signal and pressure rise.



RHIC bunch gap effect

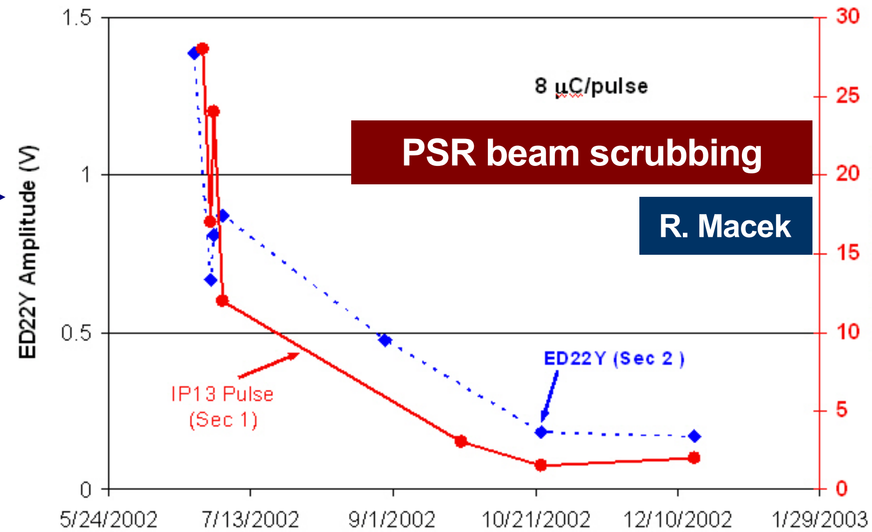
W. Fischer

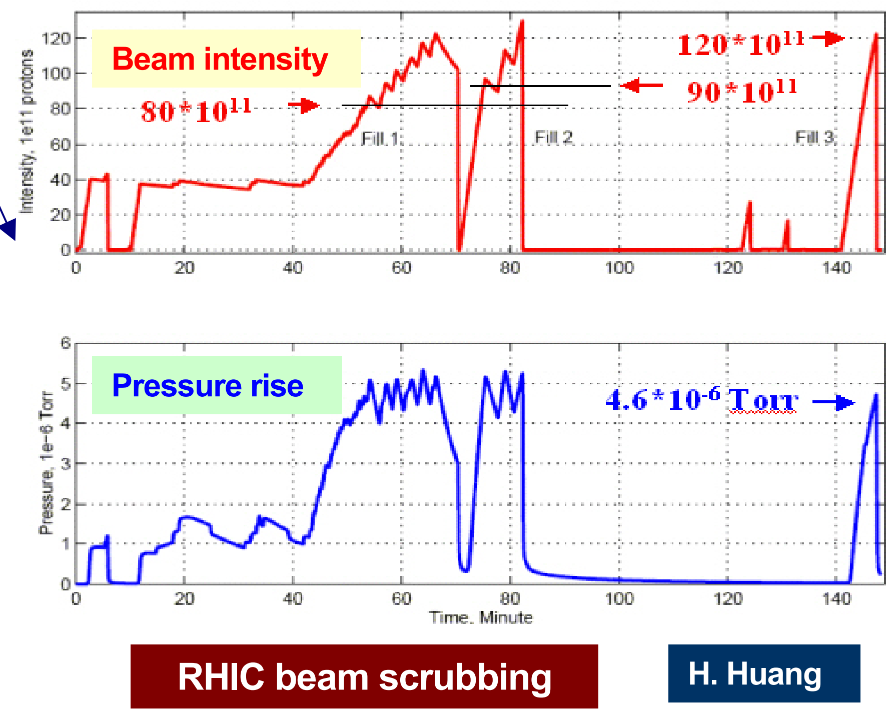


RHIC e-signal and pressure rise

2. Beam scrubbing

- A long term beam scrubbing effect was observed at PSR.
- CERN SPS achieved the LHC beam requirement by applying beam scrubbing for several days.
- In RHIC scrubbing, the pressure rise was kept at 5e-6 Torr, with control of beam injections. Beam scrubbing effect was observed at all locations with non- trivial pressure rise.
- In was found in both SPS and RHIC that the pressure rise can be used as a measure for the effectiveness of the beam scrubbing.
- In SPS, it was found that SEY may recover after only 4 hours without running LHC beam.

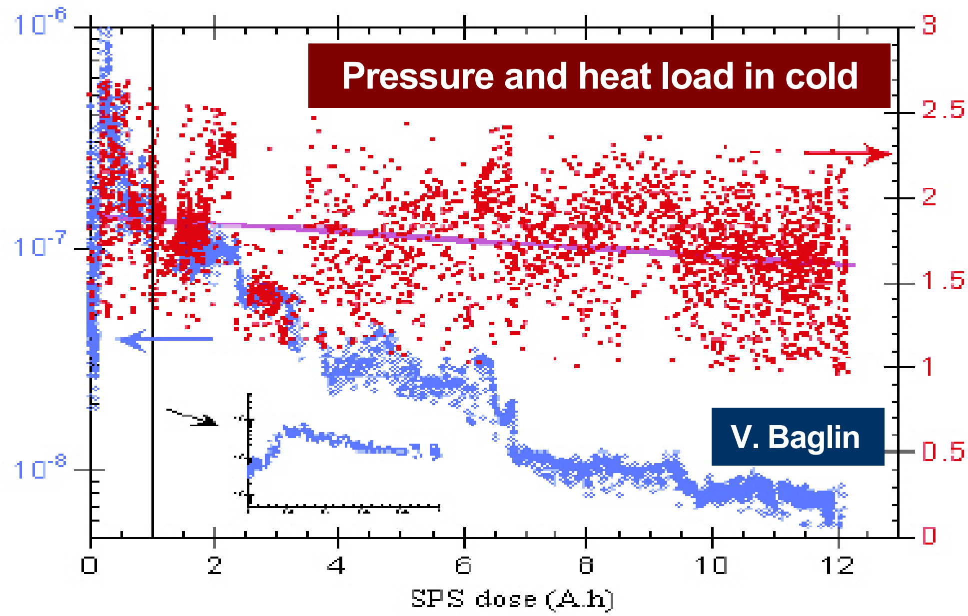


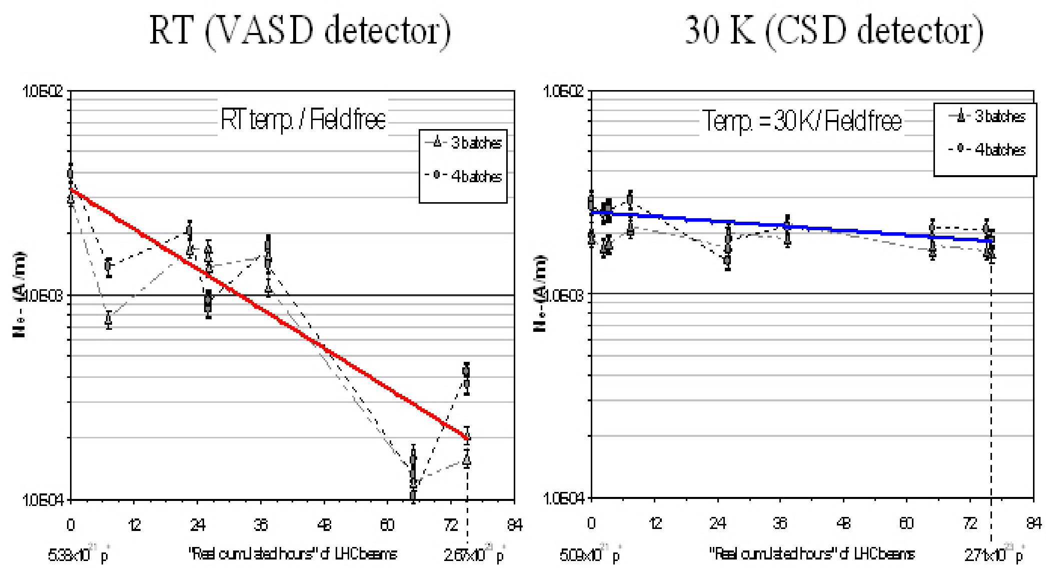


BROOKHAVEN NATIONAL LABORATORY

3. Challenges

- **SPS COLDEX scrubbing experiment showed**
  1. **Pressure rise reduction is similar for warm and cold sections.**
  2. **Heat load reduction at cold section is much less effective.**
  3. **Initial electron activity is similar at warm and cold, but the electron activity reduction at cold section is much less effective.**
- **Other problems of beam scrubbing**
  1. **Tolerable heat load.**
  2. **Possible beam instability.**
  3. **Possible beam emittance growth.**





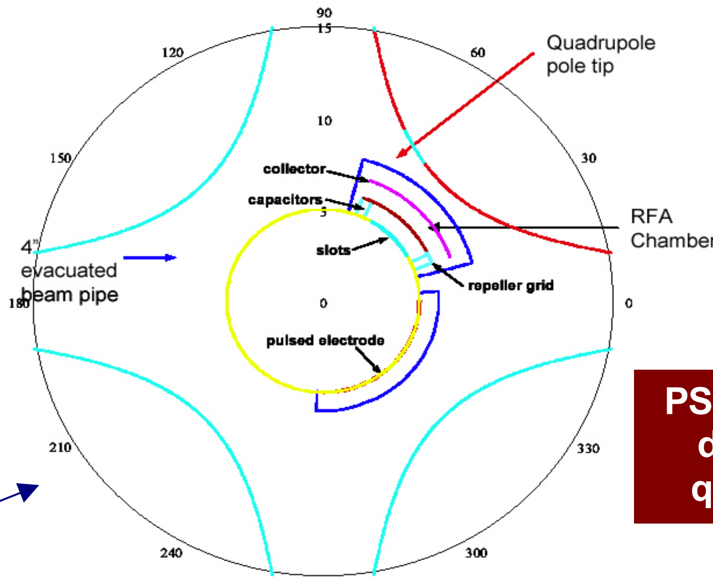
Electron activity, warm and cold

J.M. Jimenez

4. Problems and questions

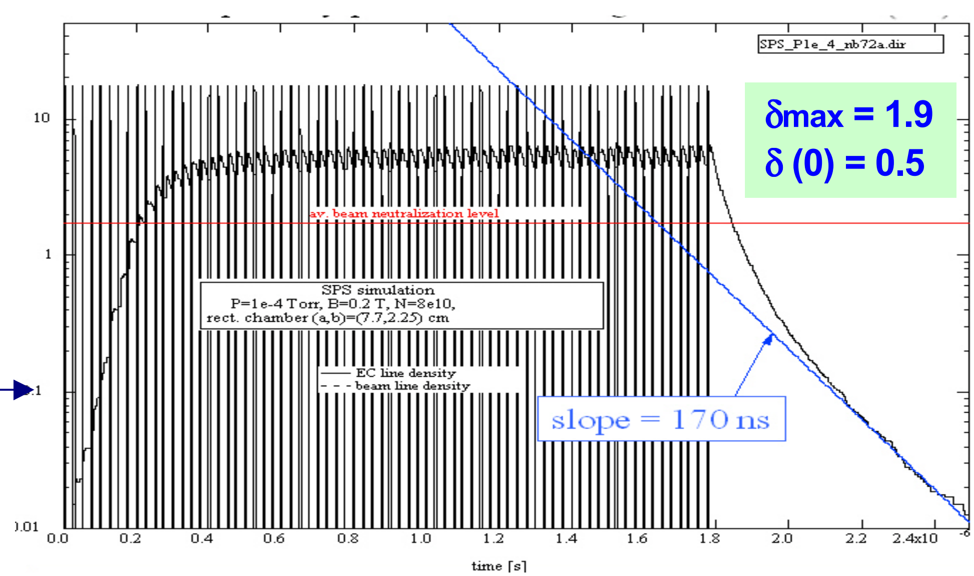
- **Stripes in dipole field affected by the beam/bunch intensity, bunch size, dipole field, and chamber size. The third stripe?**
- **Simulation shown that electrons may be trapped in quadrupole for a long time. PSR plan to use electron sweeping detector in a quadrupole for measurement.**
- **Low energy electron reflectivity**

1. **Both PSR and SPS observed secondary electron lifetime of $\tau \approx$ 170ns in the long bunch gap.**
2. **Same result was obtained by simulation using $\delta(0) = 0.5$ for 2 - 4 eV secondary electrons.**
3. **Recent observation of $\delta(0) \approx 1$ for electrons below 10 eV.**
4. **Consequences of using the new curve of e- reflectivity.**



PSR sweeping detector in quadrupole

R. Macek



EC dissipation in long gap for SPS

M. Furman

V. Conclusion and Perspective

1. Many results reported in the workshop were obtained during recent months, not years, indicating the need of existing and planned machines.
2. With the improvement in accelerator technology and pursuit of high intensity and luminosity, many machines are facing limits caused by particles other than the beam. Electron cloud is an example, but ions may also have direct and/or indirect effects, at least for hadron machines. Ions involved in RHIC pressure rise include: beam gas ionization generated ions, beam loss generated ions, secondary ions due to these two kinds of ions, and secondary ions generated from electron multipacting.
3. It is very important to identify and understand the dominant mechanism in each type of pressure rise. This goal is served by the several fronts pushed forward during the workshop, i.e., the electron and ion desorption, the chamber coating and treatment, and the comprehensive strategy to prevent electron clouds during the accelerator and collider operations.
4. For EC countermeasure, solenoids play a key role in raising luminosity at the B- factories. Colliders can adopt flexible bunch injection pattern to maximize the luminosity. In general, it is better to extend the bunch spacing and to raise bunch intensity. For example, at RHIC, the 56 bunch pattern yielded less background and higher luminosity than the 112 bunch pattern. SPS shows that for 25 ns, 50 ns, and 75 ns bunch spacing, the bunch intensity thresholds are 3e10, 6e10, and 1.2e11. The corresponding luminosity ratio would be 1, 2, and 5.3.