US LARP Proposal for Electron Cloud Activities (FY04)

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US LARP Collaboration Mtg.

Danfords Inn (Port Jefferson), Sept. 16–18, 2003

BNL-FNAL-LBNL

Regular contacts/collaborators for LHC-related work

- CERN:
  - F. Zimmermann
  - G. Arduini
  - J. M. Jiménez
  - N. Hilleret
- SLAC:
  - M. Pivi
  - R. Kirby

- In addition, related work (PSR, APS, PEP-II, ...) in collaboration and/or consultation with:
  - R. Macek
  - M. Blaskiewicz
  - K. Harkay
  - Y. H. Cai
  - G. Rumolo
  - R. Cimino
  - I. Collins

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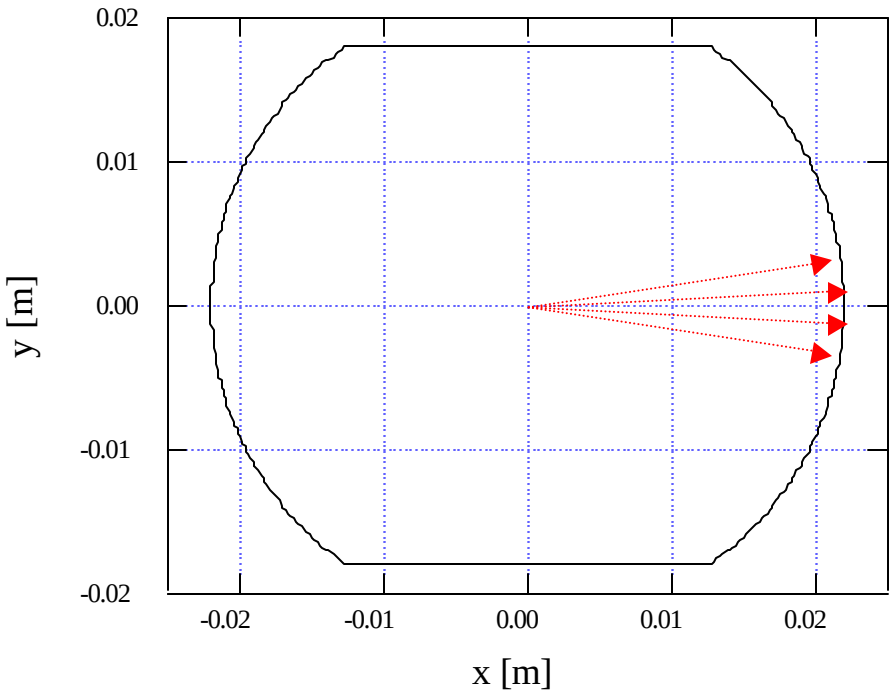
Electron clouds

- Main issue: power deposition *P/l* on the beam screen
  - max. load from all sources =1.17 W/m per ring
- In LHC, the EC is seeded by photoelectrons:
  - synchrotron radiation has: $E_{\mathrm{crit}} = \frac{3\hbar c}{2\rho}\gamma^3 = 44.1\ \mathrm{eV}$
  - leading to: $N_{\gamma/p,\mathrm{tot}} = \frac{5\alpha\gamma}{2\sqrt{3}}\Delta\theta = 0.4$ photons per proton per dipole
  - which leads, in turn, to ~6x10^{-4} electrons/proton/m (assuming QE=0.05)
  - key parameters: QE and photon reflectivity *R* (specular and diffused components)
- ...and amplified by secondary electron emission:
  - both the SEY $d(E_0)$ and the emitted-energy spectrum *dd/dE* are important
- In summary: key players are: QE, *R*, $d(E_0)$ and *dd/dE*
  - plus, of course, bunch population, bunch spacing and bunch train length

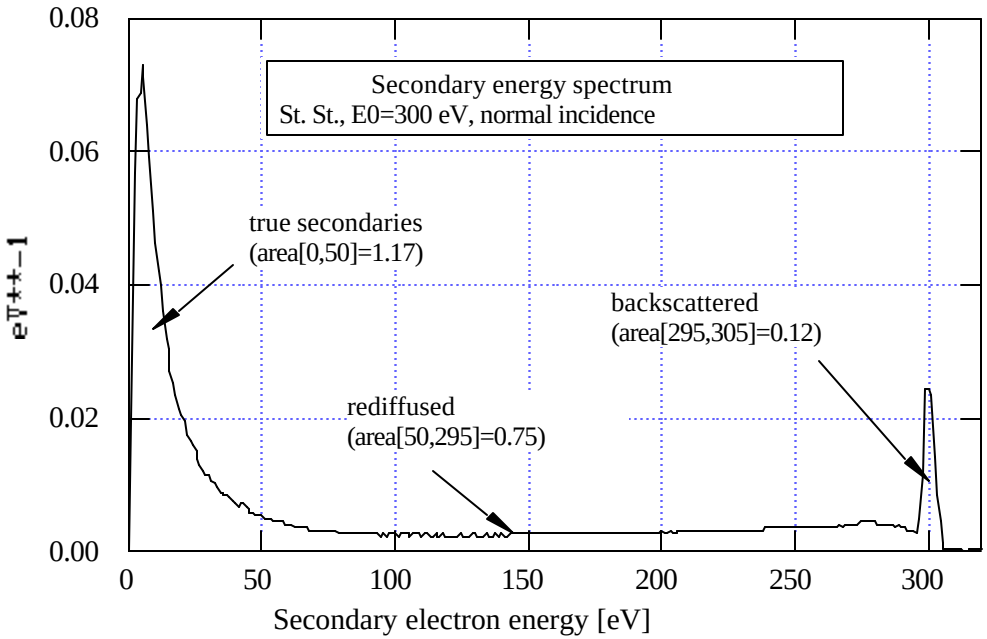
Effect of photon reflectivity *R*



- If *R*~0, electrons remain confined in outer edge (at least for a while)
- If *R*~1, electrons emitted ~uniformly ⇒ higher *P/l* than for *R*~0
  - estimate: factor of ~a few times larger for a 72-bunch train

St. St. spectrum (dd/dE) at E_0=300 eV (d_{max}=2.04):

- Depends on material and state of conditioning
  - St. St. sample, E_0=300 eV, normal incidence, (Kirby-King, NIMPR A469, 1 (2001))



st. steel sample
d = 2.04
d_e = 6%
d_r = 37%
d_{ts} =57%

d_e+d_r =43%

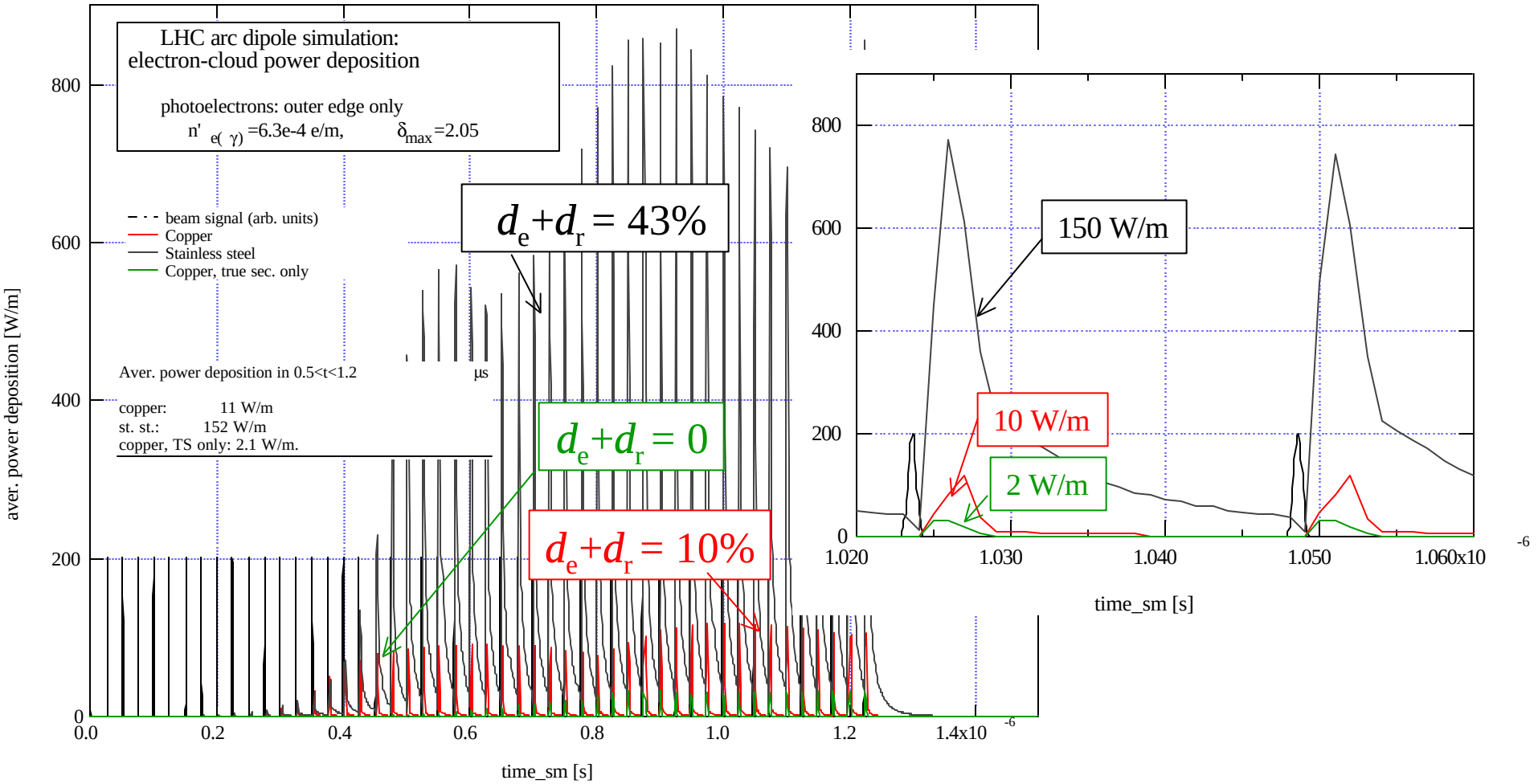
Cu sample
d = 2.05
d_e = 1%
d_r = 9%
d_{ts} =90%

d_e+d_r =10%

- Hilleret's group CERN: Baglin et al, CERN-LHC-PR 472.
- Other measurements: Cimino and Collins, 2003 -- see later)

Sensitivity to relative ratios of d_e, d_r and d_{ts} at fixed d_{max}=2.05

Simulated power deposition vs. time (LHC arc dipole)



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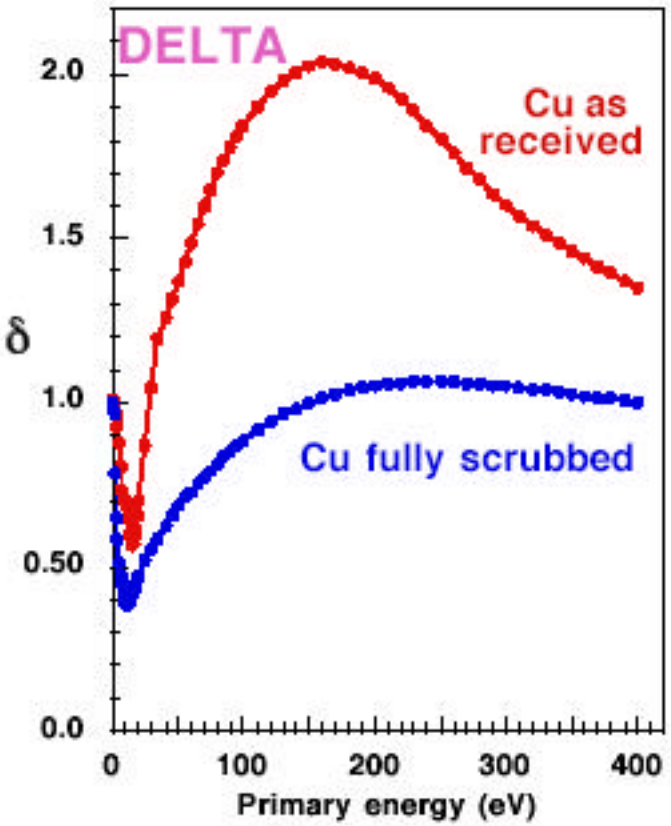
Activities at CERN (mostly SPS)

- 3+ years of EC studies with dedicated instrumentation at SPS
  - in-situ measurements: measure $d(E_0)$ of Cu samples in the vacuum chamber
  - calorimeters, RT and cold: measure P/l
  - strip detectors: measure EC distribution at the wall, including B-dependence
  - RFAs: measure intensity and energy spectrum of EC at the wall
  - photon R and QE off Cu samples: measured at EPA, ELETTRA and BINP
  - simulations (code ECLOUD)

Some observations (e.g., APC mtg. 8/1/03)

- Beam scrubbing works well; favorable effects seen in:
  - vacuum pressure
  - electron flux at wall (strip monitors)
    - conditioning is faster by ~x3-5 at RT than at 30K
    - electron distribution at wall not fully understood (dependence on *B* field and chamber height)
    - heat load higher by ~x3 at RT than at 30K
  - in-situ SEY measurements
    - Cu sample: d_{max} decreases from ~2.3 to ~1.6 in ~2 days' run
  - calorimeters COL DEX and WAMPAC
    - heat load ~same at RT and at 30K
  - TiZrV coating suppresses ions and electrons after activation at 200C
    - not appropriate solution for the arcs, unfortunately
- Various measurements of QE and *R* not perfectly consistent

Other SEY measurements



- Bench measurements in mu-metal chamber
  - R. Cimino and I. Collins (ASTEC2003, Daresbury Jan. 03)
  - conditioning of d_{max} but not of $d(0)$ is consistent with PSR experience for stainless steel
  - the result $d(0)$˜ 1 seems unconventional
  - if validated, it could have a significant unfavorable effect on the EC power deposition in the LHC
    - because electrons survive longer in between bunches

Suggestions from F. Zimmermann

e-cloud contributions suggested to LBNL (&SLAC?) in the US LARP

(1) SPS benchmarking with POSINST

- e- energy spectrum with field & w/o field during conditioning
- spatial distributions of electrons - structure in the field-free case?
- differences between room & cryogenic temperature
- POSINST vs .ECLOUD comparisons

(2) interaction of microwaves with e- cloud & residual gas

- e.g., experiments by F. Caspers and T. Kroyer

(3) develop a common understanding of low-energy reflection

- possibly as LBNL-SLAC collaboration
- might include measurements at SLAC (E. Garwin, R. Kirby)

(4) photon diffuse & back scattering from sawtooth surface

- measurements at the ALS
- resolve apparent discrepancy between Novosibirsk & ELETTRA

(5) long-term emittance growth & instability issues

5 September 2003 AB/ABP LCE Meeting F. Zimmermann

Electron-cloud LARP goals: FY04 and beyond

- Simulations for the SPS
  - reproduce measured electron energy spectrum and spatial distribution
    - dependence on B field and chamber geometry
  - reproduce calorimeter results
  - POSINST vs. ECLOUD: understand and iron out differences
- Better data for $d(E_0)$ and dd/dE for actual Cu samples
  - region $E_0 < 20$ eV important (and hard to measure)
  - possibly at SLAC
- Better data for QE and R for actual Cu samples, both RT and cold
  - at ALS (J. Byrd)
  - attempt to resolve existing discrepancies
- Electron-cloud interaction with microwaves (novel diagnostics)
- Assess effects of EC on beam (emittance growth, instabilities)

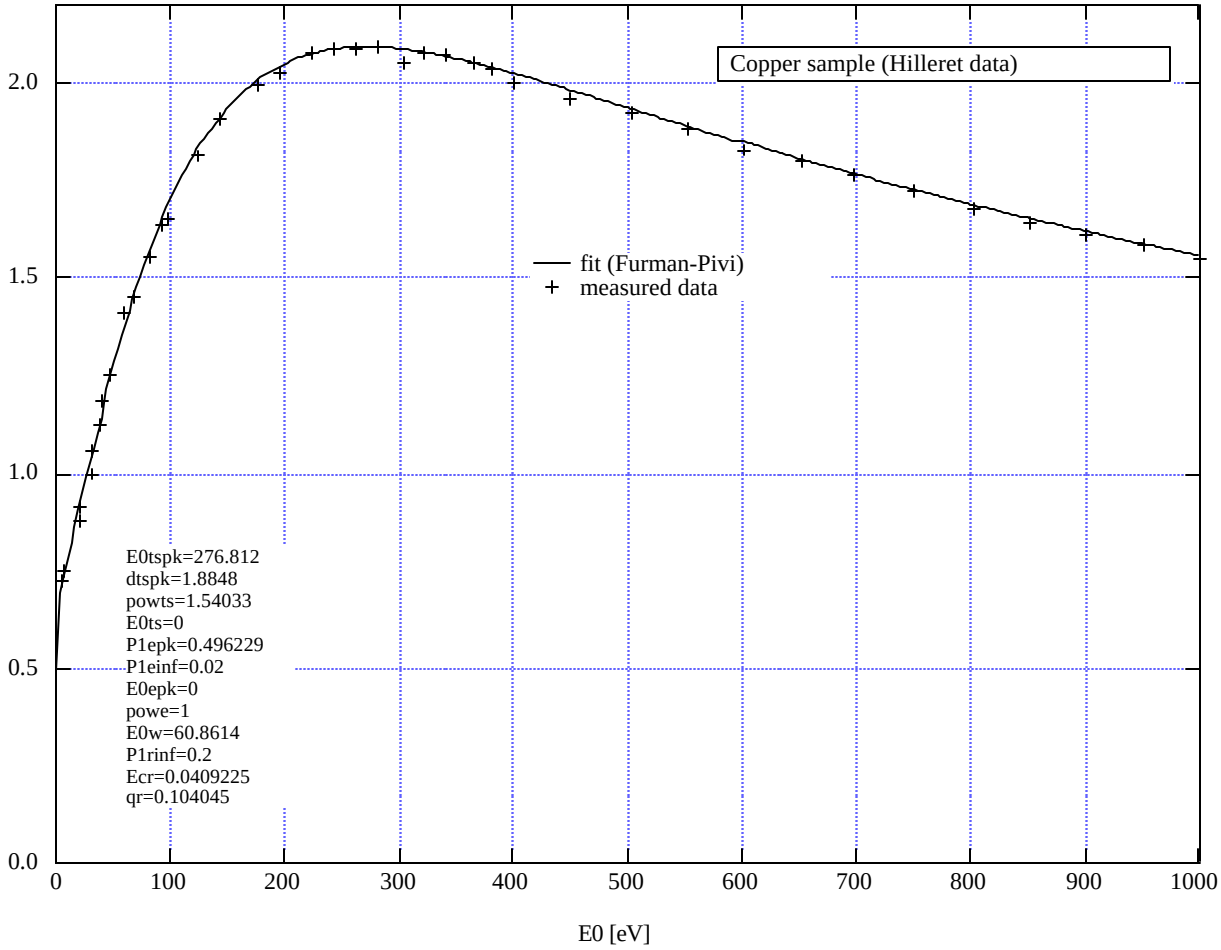
Electron-cloud LARP goals: FY04 and beyond (contd.)

- Improve simulation codes
  - parallelize for speed
  - self-consistent calculation of single-bunch effects
  - this work is leveraged by other efforts/labs/programs:
    - SciDAC program (particularly beam-beam work at LBNL)
    - NERSC (LBNL) (supercomputer support)
    - PSR (LANL) (electron-cloud measurements)
    - SNS (ORNL) (electron-cloud simulations)
    - HIF-VNL (electron-cloud measurements and simulations)
- Ongoing benchmarking at other machines (PSR, PEP-II, …)

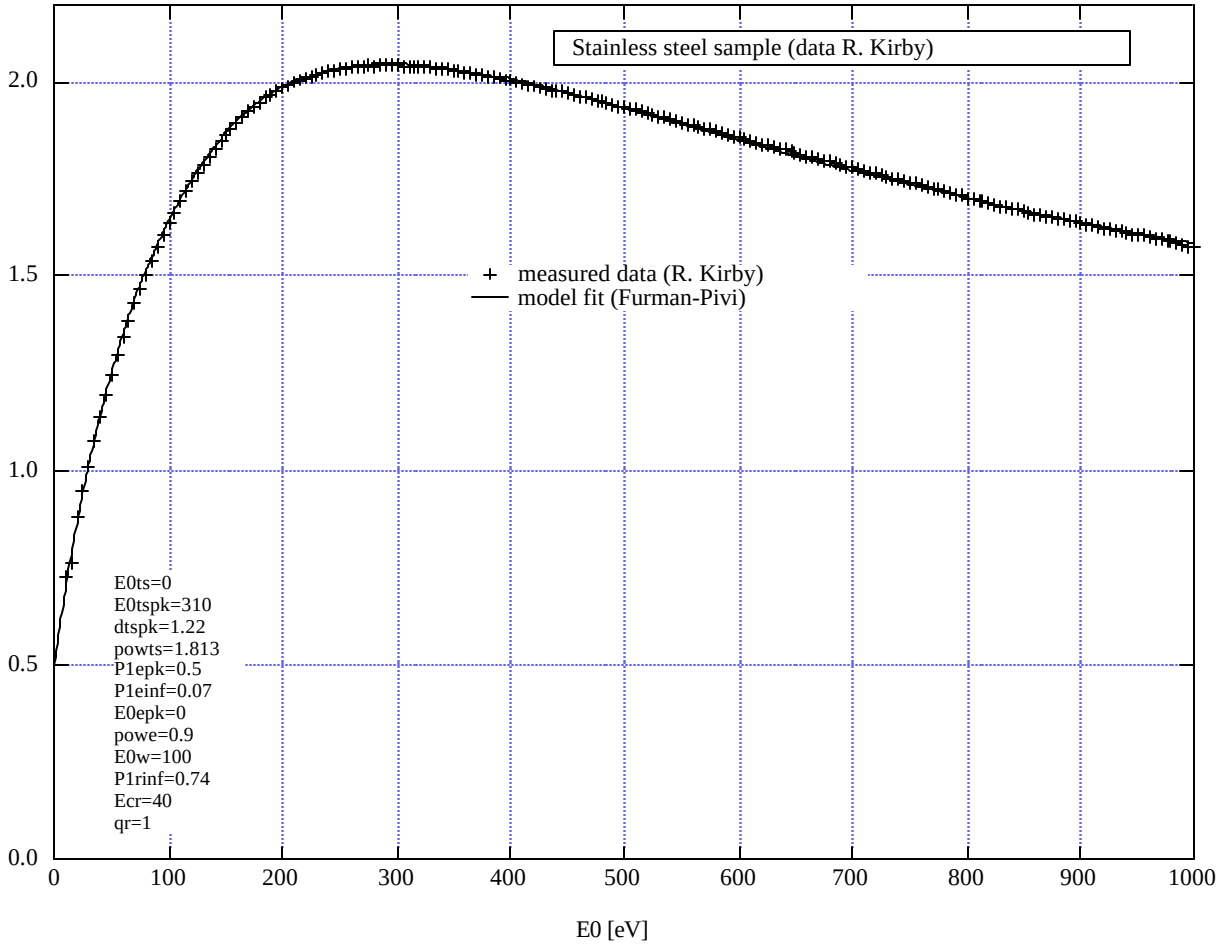
Additional information

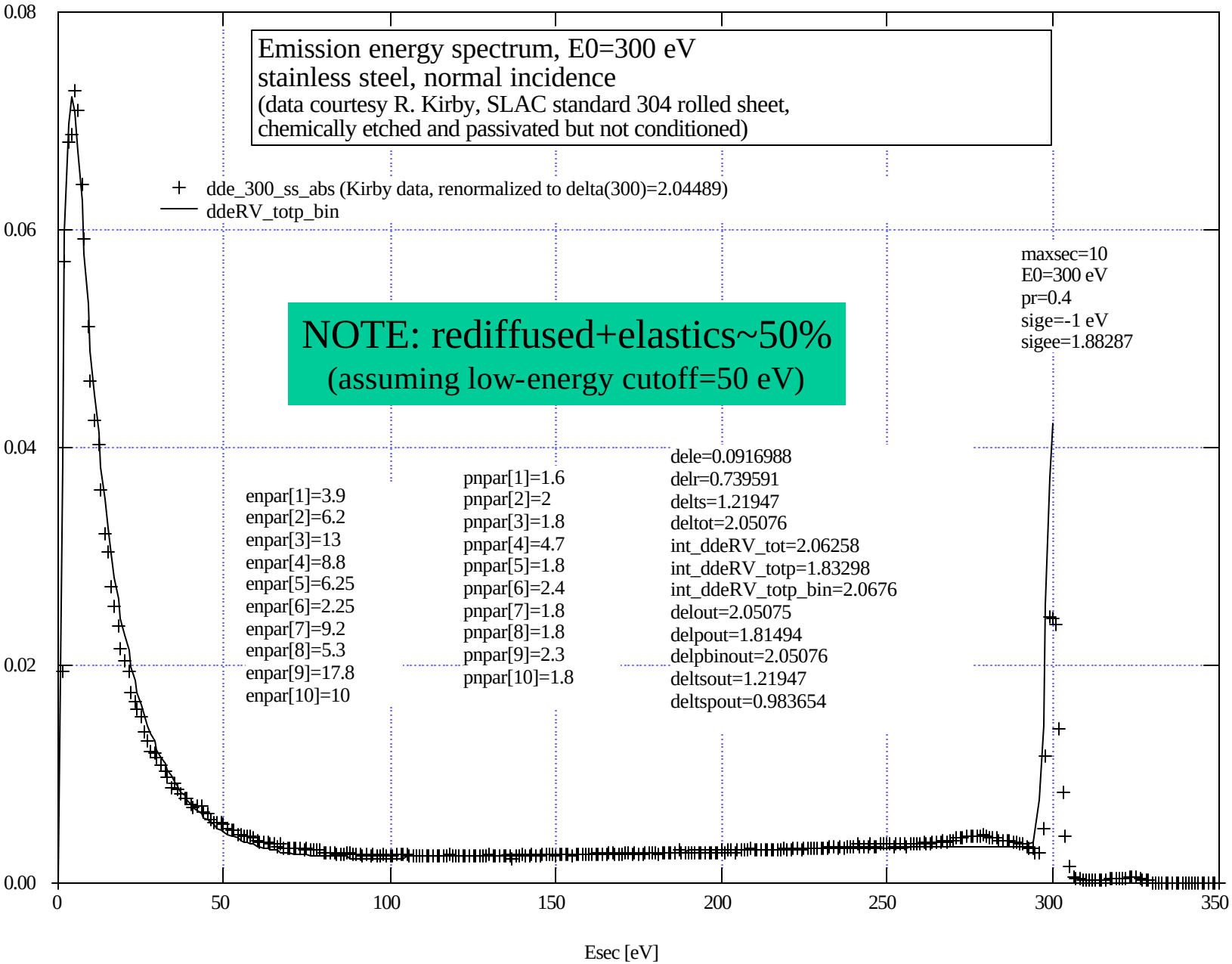
- Important websites:
  - http://lhc-beam-beam.web.cern.ch/lhc-beam-beam/
  - http://wwwslap.cern.ch/collective/electron-cloud/electron-cloud.html
  - http://www.aps.anl.gov/asd/physics/ecloud/ecloud.html
  - http://ab-div.web.cern.ch/ab-div/Meetings/APC/Welcome.html

SEY for a copper sample



SEY for a St. St. sample



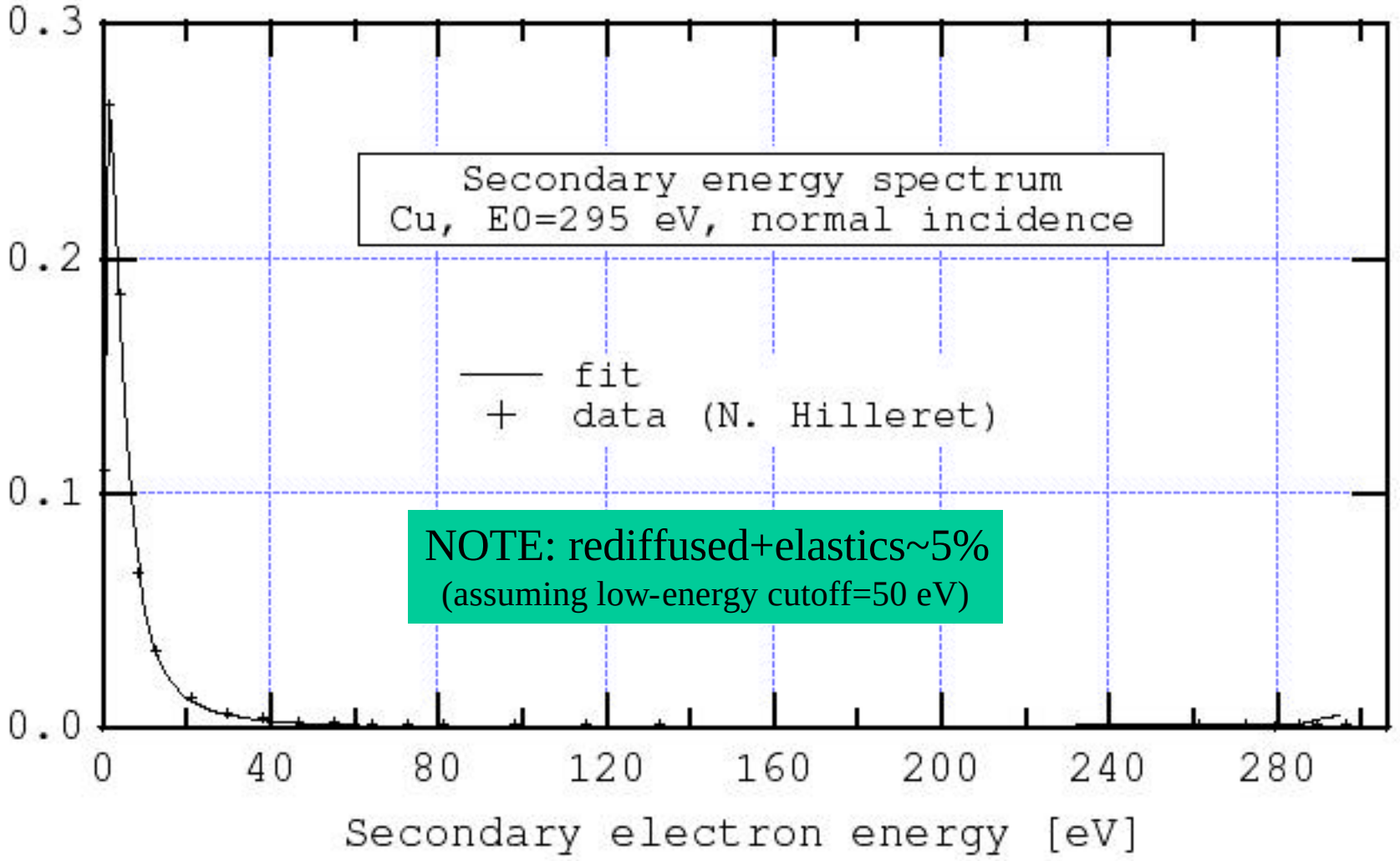

Emission energy spectrum, E0=300 eV
stainless steel, normal incidence
(data courtesy R. Kirby, SLAC standard 304 rolled sheet,
chemically etched and passivated but not conditioned)
dde_300_ss_abs (Kirby data, renormalized to delta(300)=2.04489)
ddeRV_totp_bin
NOTE: rediffused+elastics~50%
(assuming low-energy cutoff=50 eV)
maxsec=10
E0=300 eV
pr=0.4
sige=-1 eV
sigee=1.88287
enpar[1]=3.9
enpar[2]=6.2
enpar[3]=13
enpar[4]=8.8
enpar[5]=6.25
enpar[6]=2.25
enpar[7]=9.2
enpar[8]=5.3
enpar[9]=17.8
enpar[10]=10
pnpar[1]=1.6
pnpar[2]=2
pnpar[3]=1.8
pnpar[4]=4.7
pnpar[5]=1.8
pnpar[6]=2.4
pnpar[7]=1.8
pnpar[8]=1.8
pnpar[9]=2.3
pnpar[10]=1.8
dele=0.0916988
delr=0.739591
delts=1.21947
deltot=2.05076
int_ddeRV_tot=2.06258
int_ddeRV_totp=1.83298
int_ddeRV_totp_bin=2.0676
delout=2.05075
delpout=1.81494
delpbinout=2.05076
deltsout=1.21947
deltspout=0.983654
0.08
0.06
0.04
0.02
0.00
0
50
100
150
200
250
300
350
Esec [eV]

Electron-cloud interaction with microwaves

- electron cyclotron motion in dipoles:

$$eB/2\pi m_e c = 2.4 \times 10^{11} \text{ Hz} \quad \text{(for } B = 8.4 \text{ T)}$$

  - would resonate with a THz-range signal
  - from reflection and transmission, infer EC intensity
  - experiments at CERN (F. Caspers)


Secondary energy spectrum
Cu, E0=295 eV, normal incidence
fit
data (N. Hilleret)
NOTE: rediffused+elastics~5%
(assuming low-energy cutoff=50 eV)
0.3
0.2
0.1
0.0
0
40
80
120
160
200
240
280
Secondary electron energy [eV]