Atomic Collision Experiments at Relativistic Energies

•**Motivations**

$E \approx 10^{20} V/cm$

$\gamma \approx 100$

$E_{crit} \approx 10^{16} V/cm$

$\gamma \approx 10$
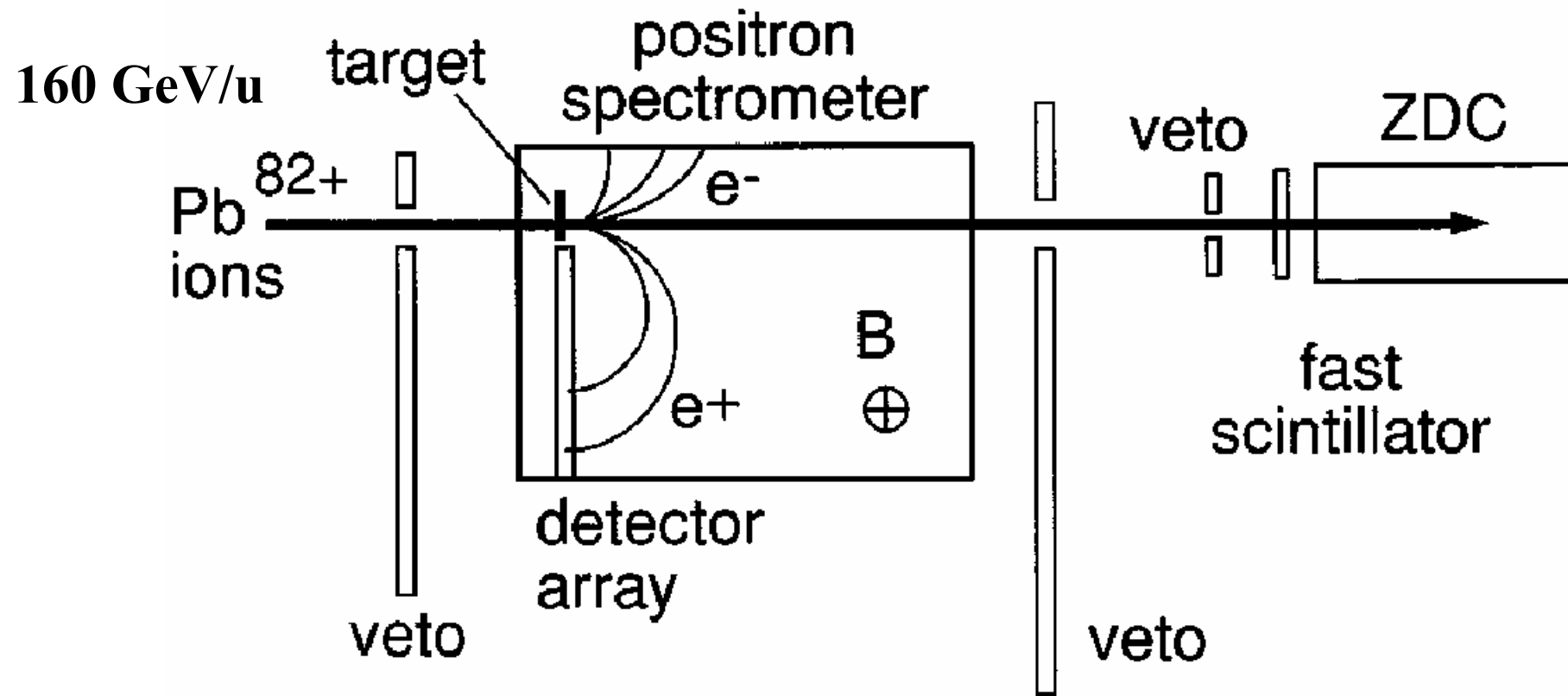
$\gamma \approx 1$

$$E \approx \frac{\gamma Z}{b^2}$$
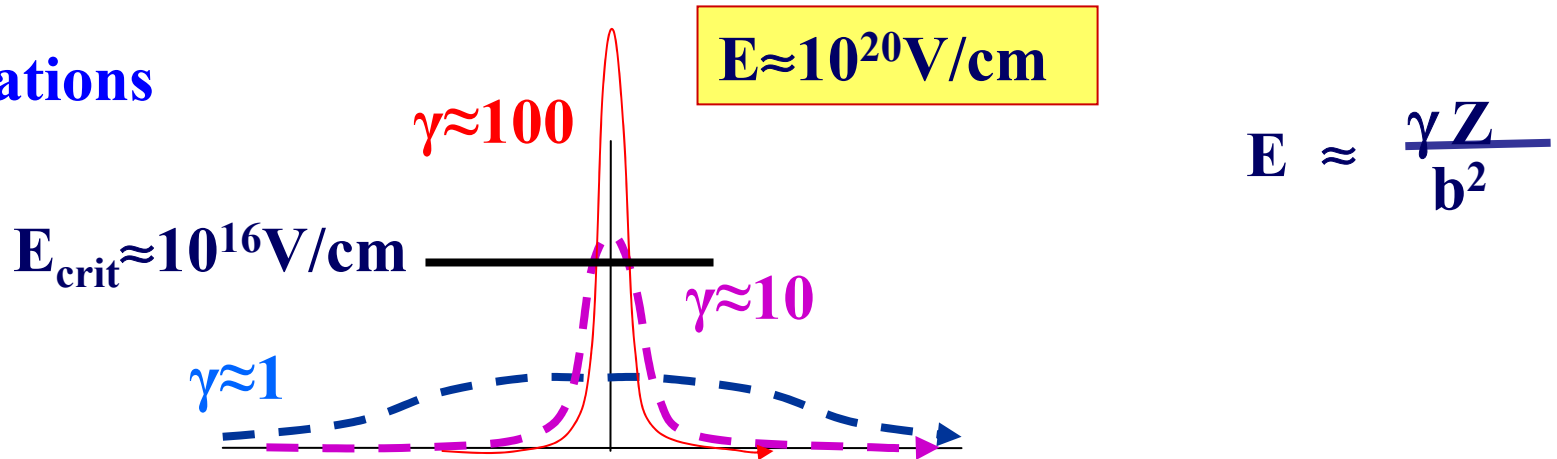
•**what has been done?** cross sections for electron-positron pair creation, capture, ionization with 10 GeV/u Au* and 160 GeV/u S and Pb# on fixed targets
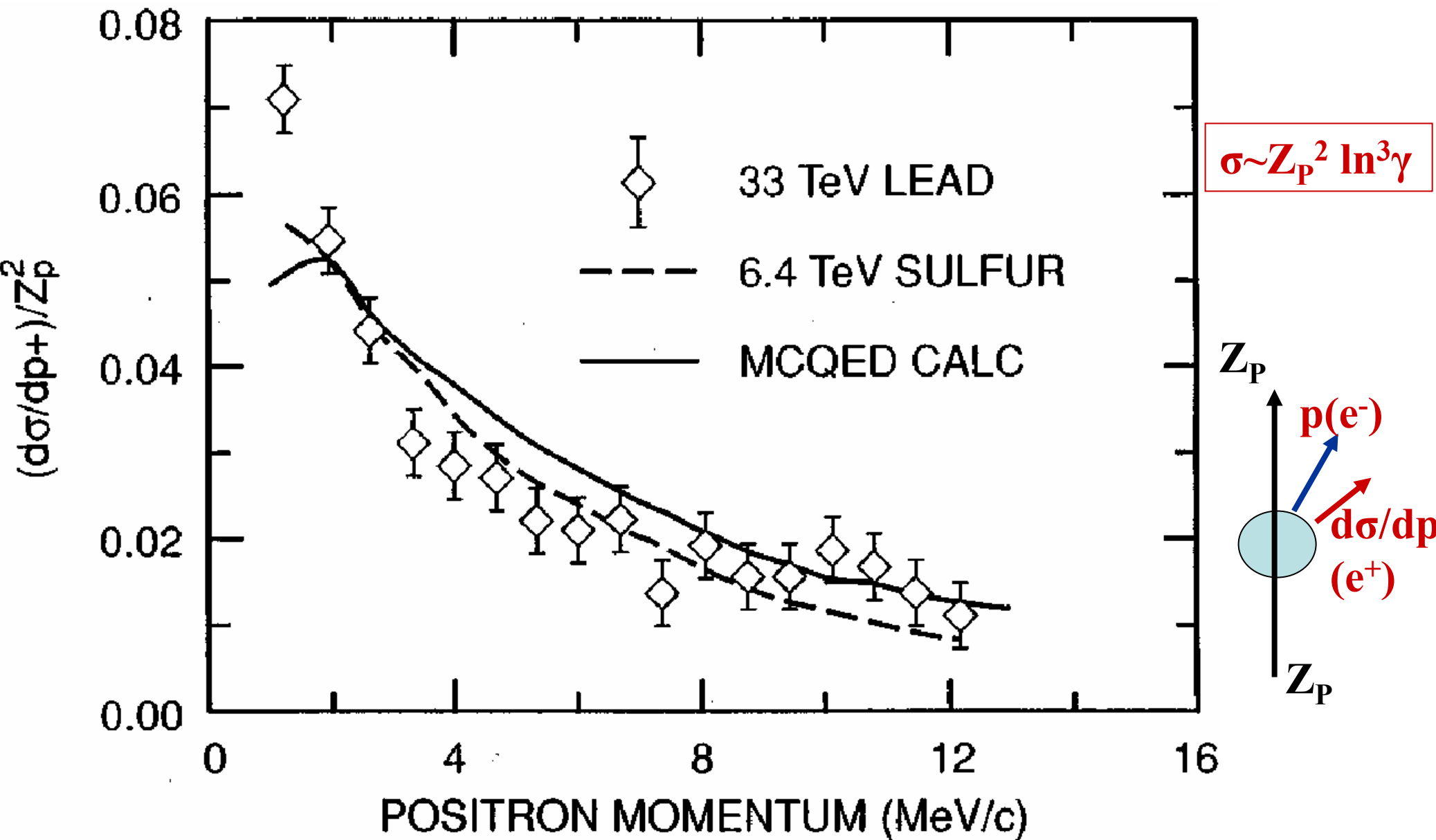
•**open questions?** multiple pairs, impact parameter dependence, higher order perturb. theory, density effects, cusp from electron loss,

•**di-electronic capture from the pair-** new higher order effect

CERNWA98 set-up

160 GeV/u

Figure legend:
- ◇ 33 TeV LEAD
- - - - 6.4 TeV SULFUR
- —— MCQED CALC

$\sigma \sim Z_P^2 \ln^3\gamma$

Axes:
- y-axis: $(d\sigma/dp+)/Z_p^2$
- x-axis: POSITRON MOMENTUM (MeV/c)

Diagram labels: Z_P, $p(e^-)$, $d\sigma/dp$ (e^+), Z_P

160 GeV/u Pb → Z_T

single pairs~ Z_T^2

$Z_2\alpha$

e^+

e^-

$Z_1\alpha$

Yield = Const x Z_T^p

M. P. Theory x 4

M. P. Theory

Fit to Experiment

p = 2.03 ± 0.03

POSITRON YIELD

TARGET ATOMIC NUMBER

double pairs ~ Z_T^4
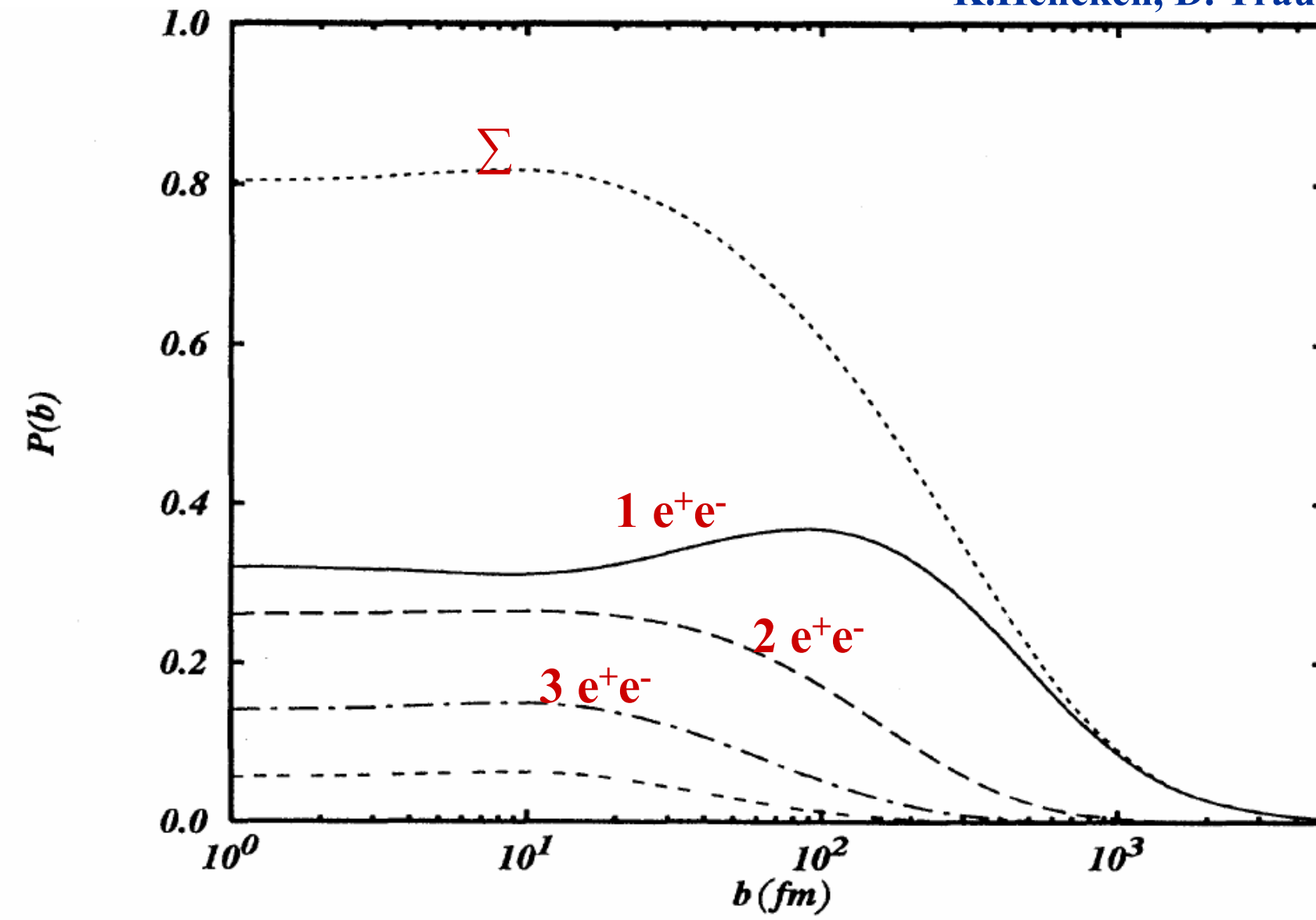
$(Z_2\alpha)^2$

e^+

e^-

$(Z_1\alpha)^2$
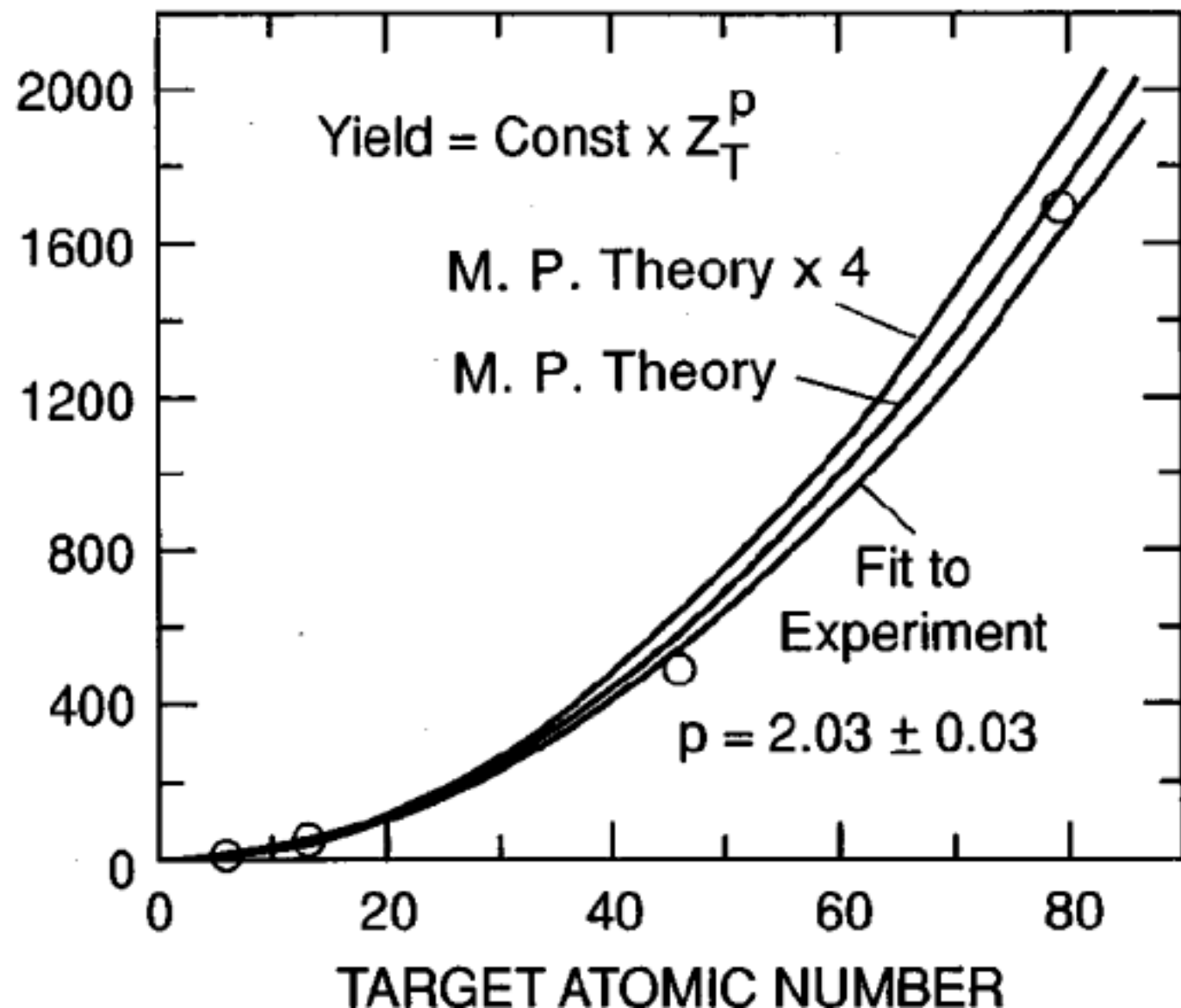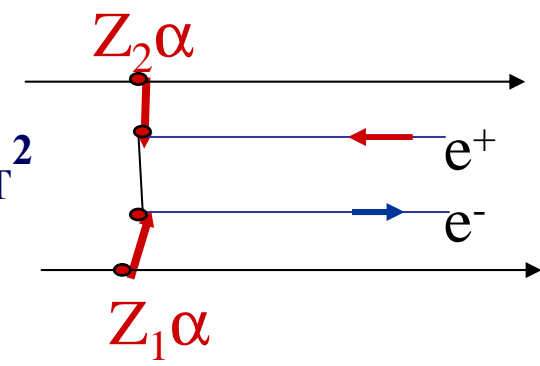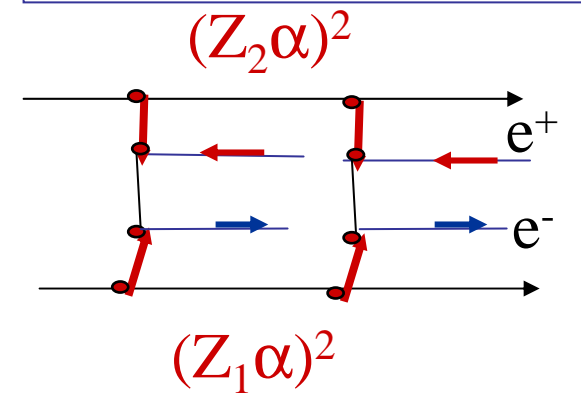
$\sigma_{DP} \approx 2.5\%$ of σ_{SP}

At small impact param
$P_{DP} \approx 80\%$ of P_{SP}
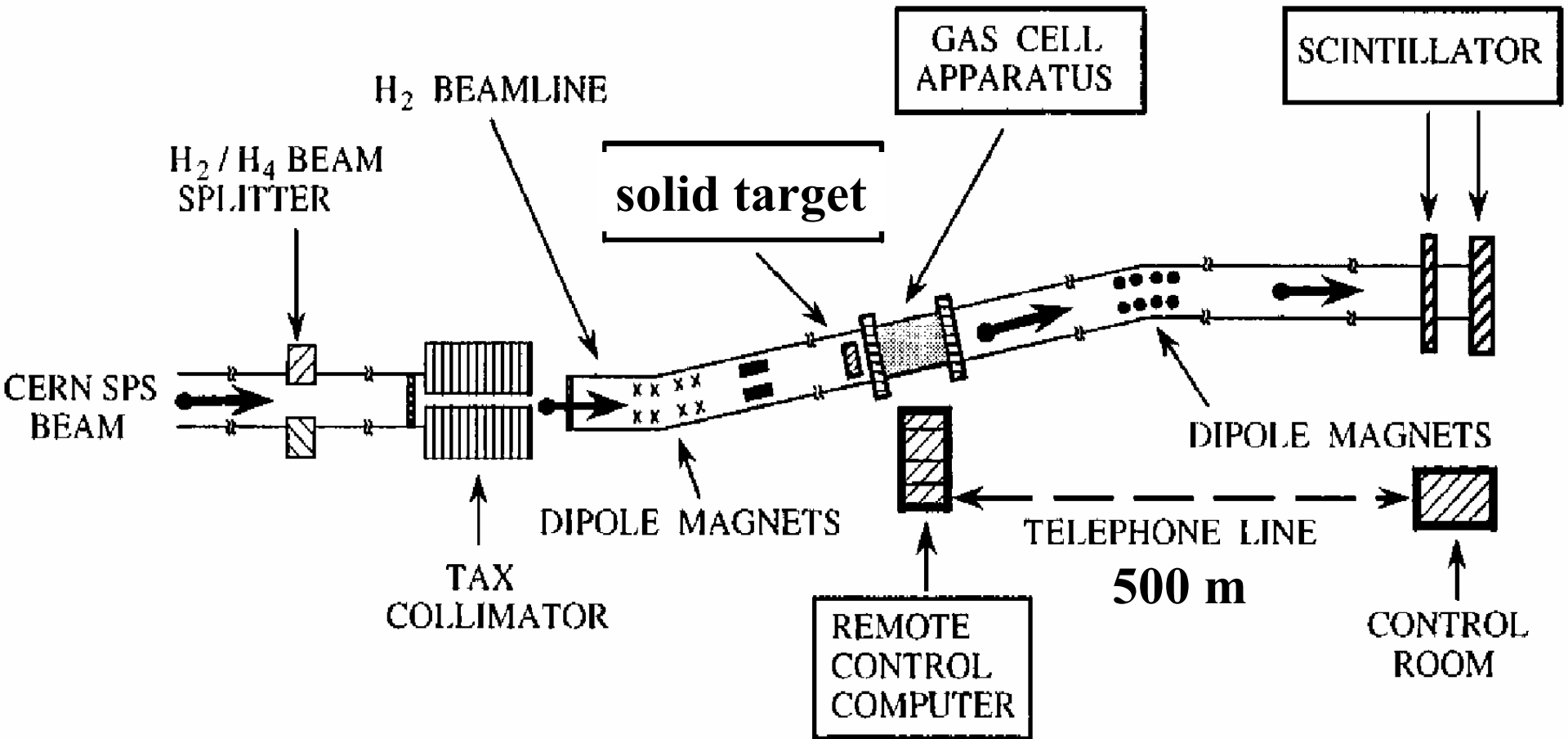
Multiple pairs in b-dependence
γ=100 Au-Au
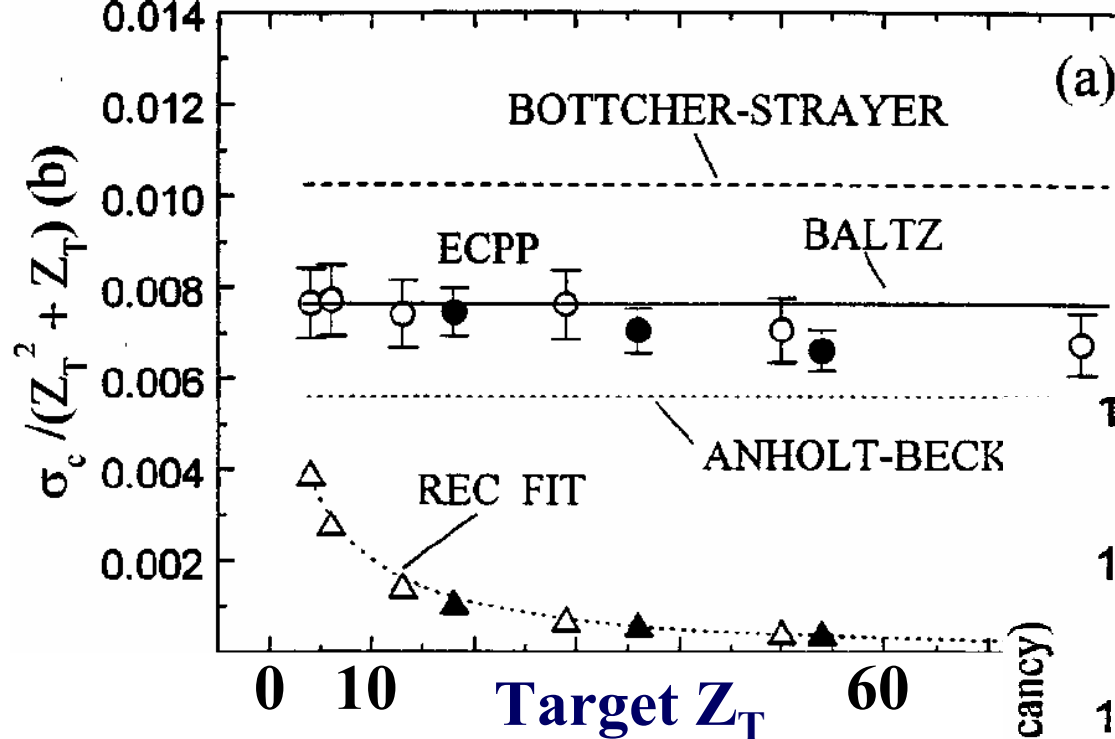
K.Hencken, D. Trautmann, G. Baur

For measuring charge changing cross sections at γ≈200

Capture

(a)

BOTTCHER-STRAYER

ECPP   BALTZ

REC FIT

ANHOLT-BECK

$\sigma_c / (Z_T^2 + Z_T)$ (b)

Target Z_T

○ solid traget
● gas target

$\eta_{rel} = (\gamma - 1) m_e c^2 / E_{B,P}$

● this experiment

rel. theory

non-rel. theory

$\sigma_{K\text{-REC}}$ (b/electron K-vacancy)

ADIABATICITY PARAMETER η_{rel}

$\sigma_{capt} \sim Z_T^2 + Z_T$

'anti-screening'

$\sigma_{bare} \sim Z^2$

$\sigma_{theor} = \sigma_{paircapt}(1s)$

Radiative capture~electr. nr.

$\sigma_{REC} \sim Z_T$

Proj. Ioniz. 160 GeV/u Pb$^{81+,82+} \rightarrow Z_T$

(b) ANHOLT-BECKER

$\sigma_I/(Z_T^2 + Z_T)$(kb)

SORENSEN

TARGET ATOMIC NUMBER Z_T

Ionization from Pb^{81+}

□ ■

Ionization from Capture Pb^{82+}

○ ●

solid target

gas target

2

$\tau_r \approx 10^{-17}$s

1

$\gamma \approx 200 \rightarrow$

e$^+$

τ_r(lab) $\approx 10^{-15}$s

Δt(solid) $\approx 10^{-16}$s
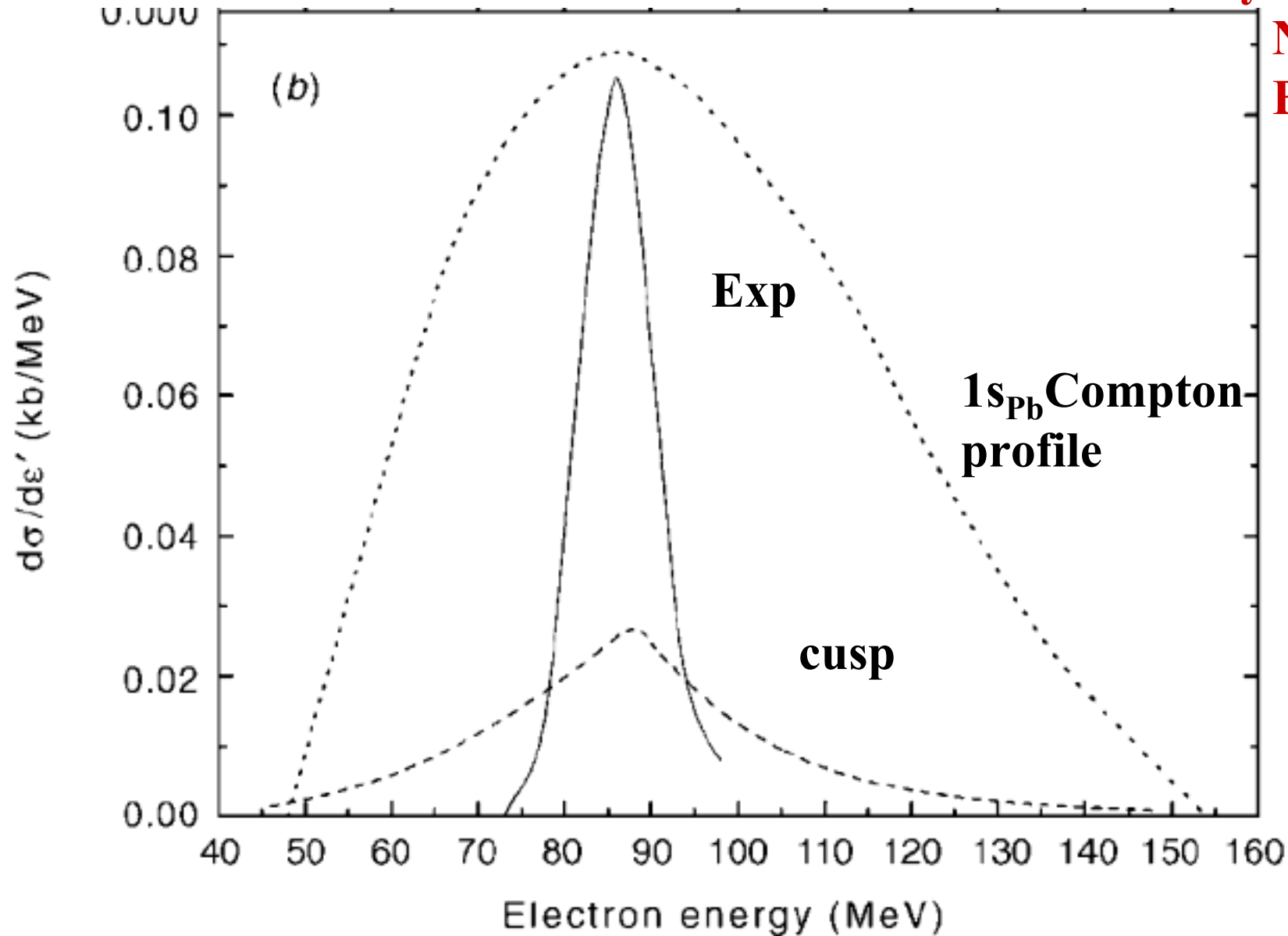
Δt(gas) $\approx 10^{-14} - 10^{-12}$ s
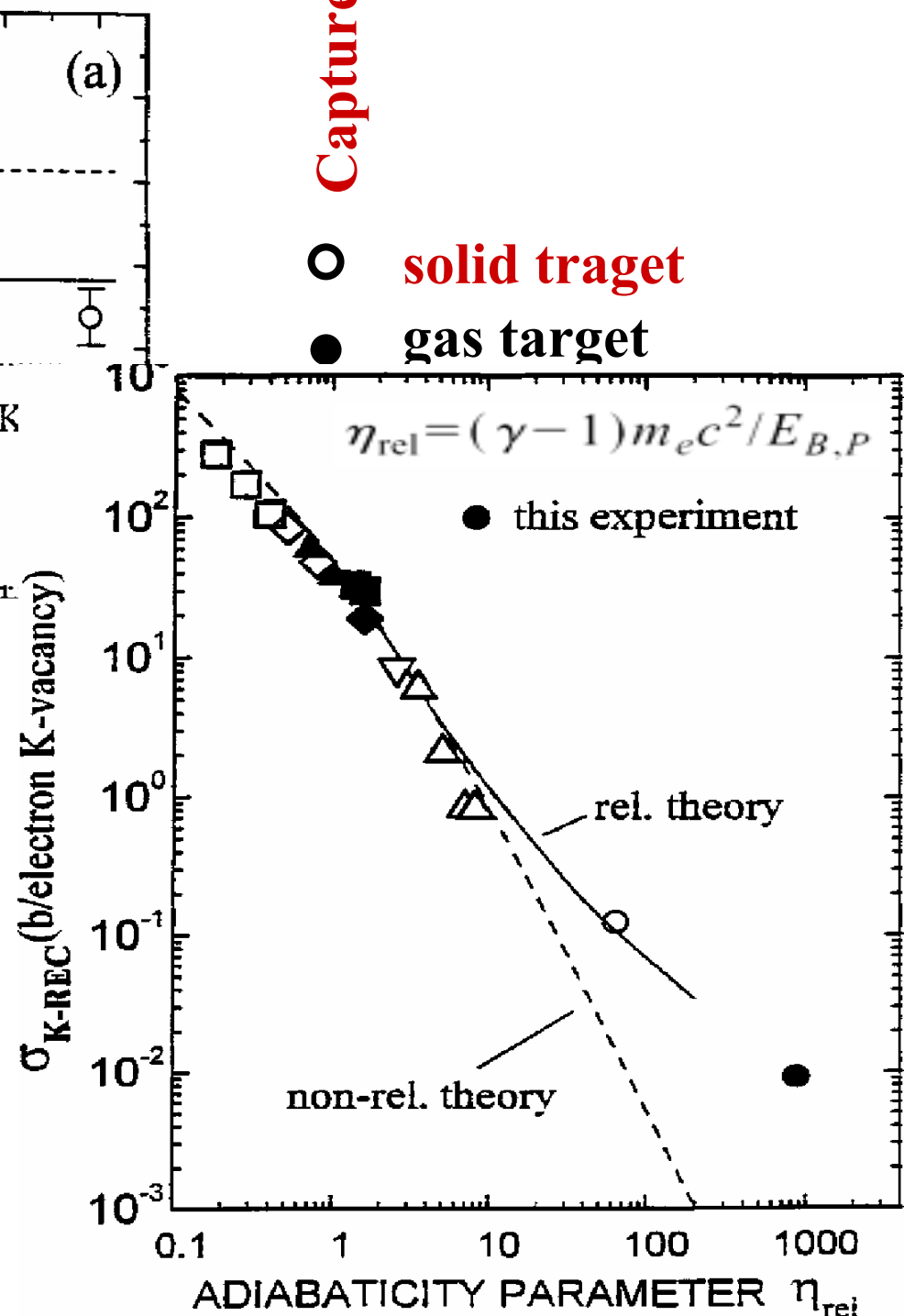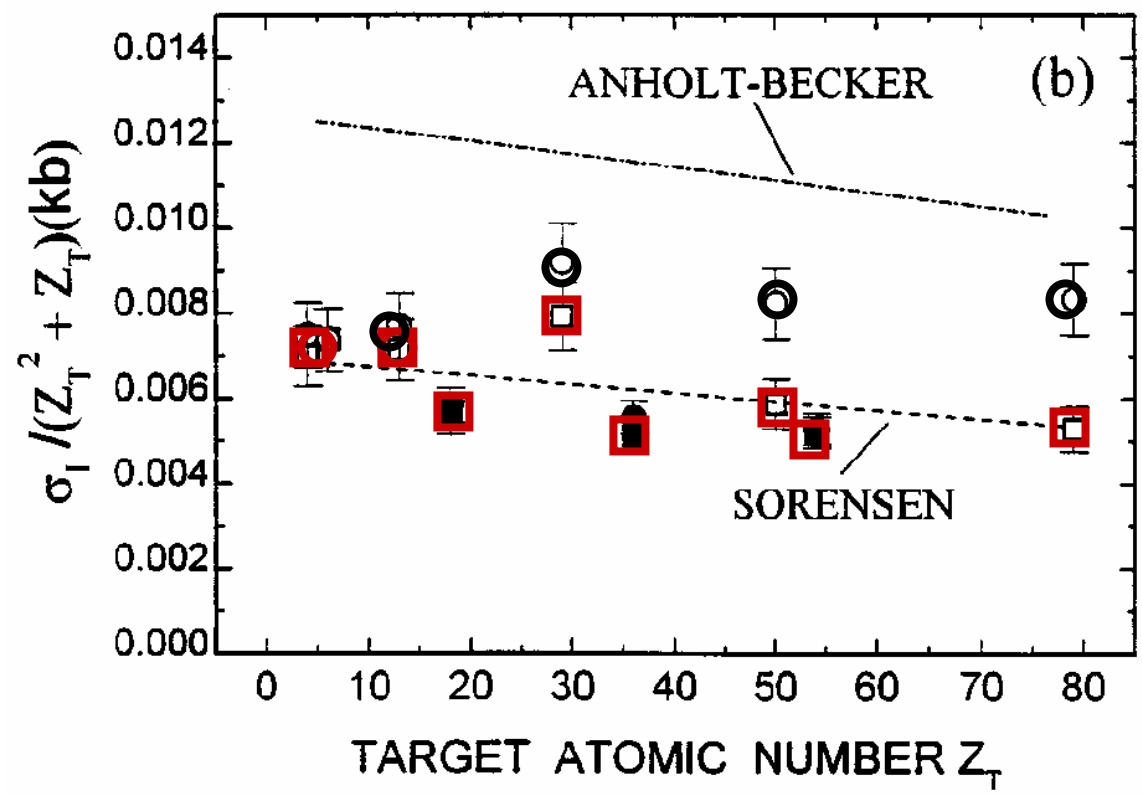
Sorensen: b$_{ad}$=γhc/E$_B$,

b$_{ad} \geq$ b$_{screen}$ (γ>5) $\rightarrow \sigma_{ioniz} \approx$ const
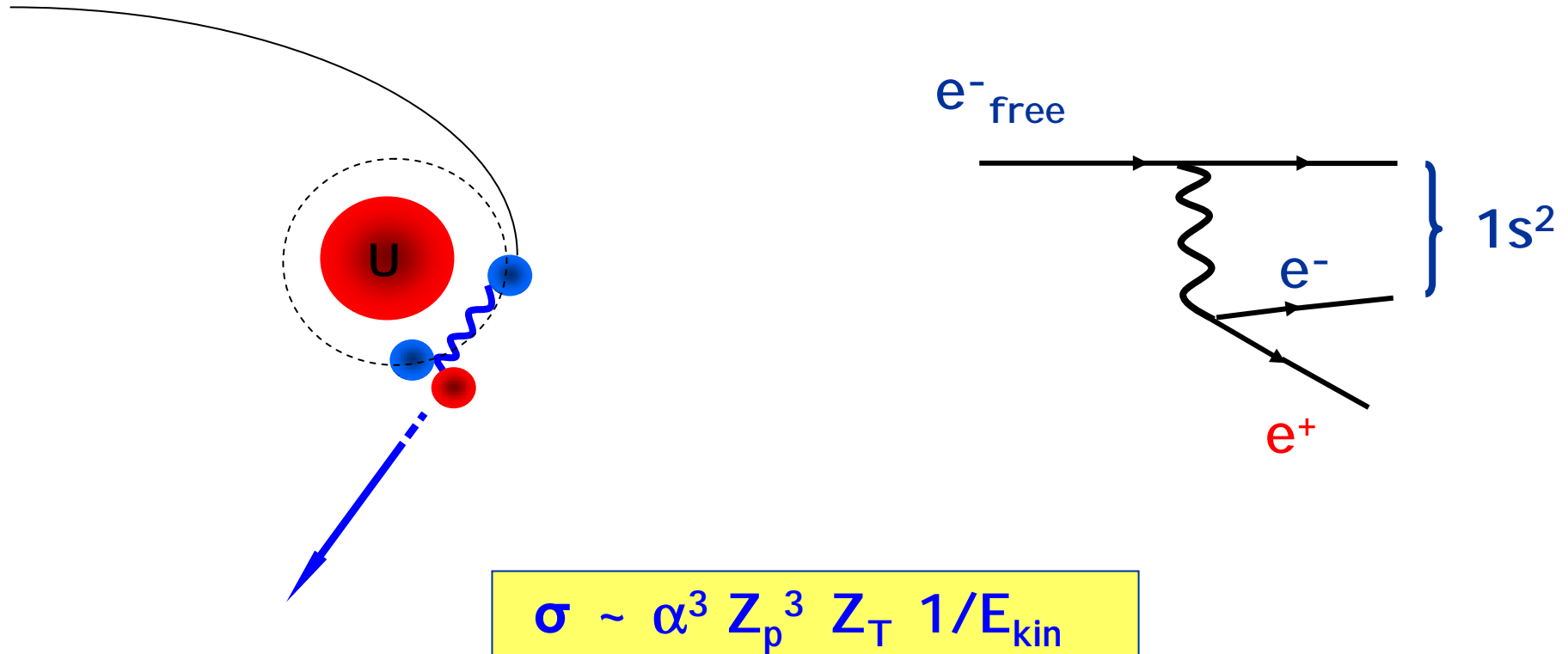**but not in b-dependence?**
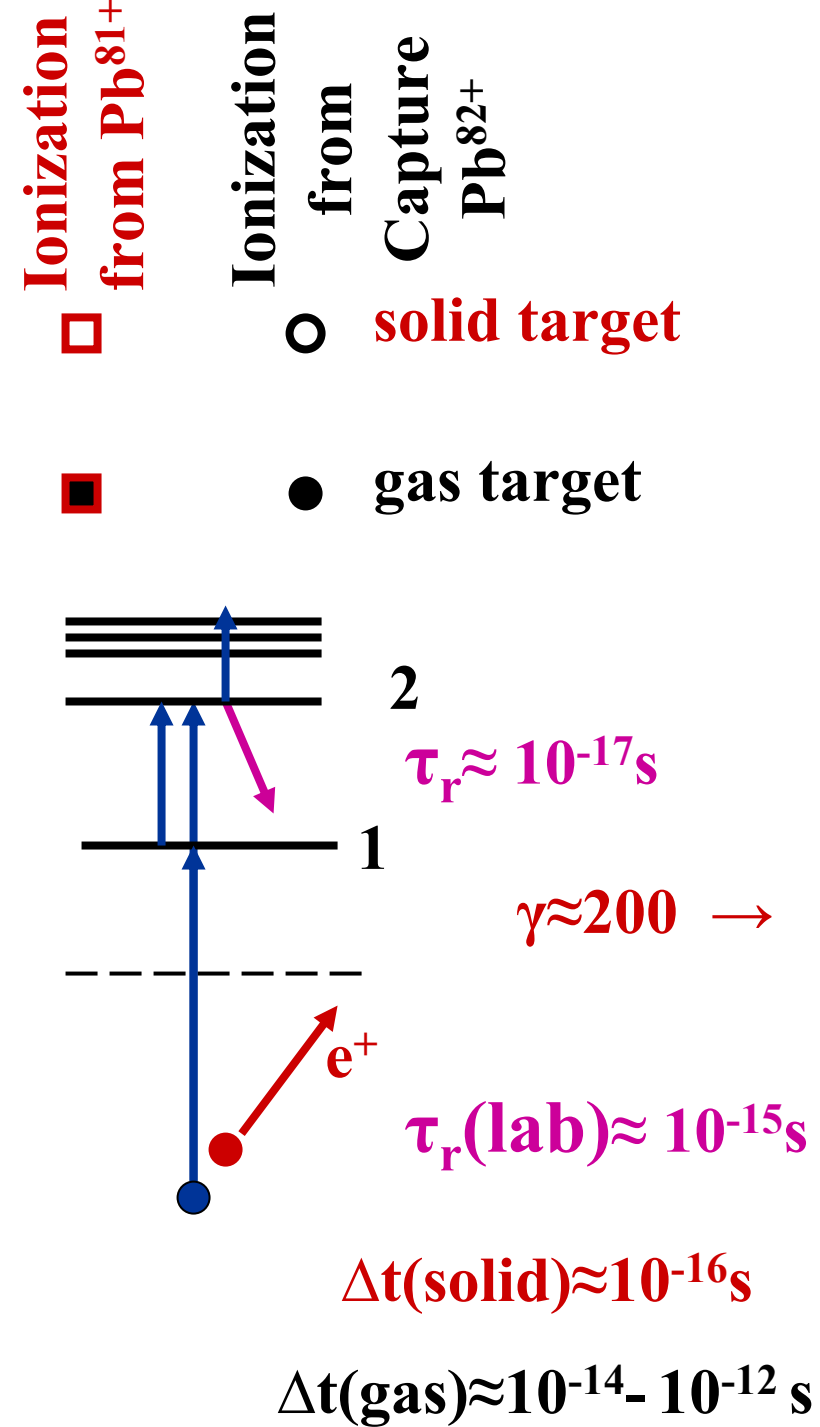
Electron momentum from Proj. Ioniz. 160 GeV/u Pb$^{81+}\rightarrow$ Al

Theory A.B.Voitkiv, N. Grun J. P. B34,267,2001

width??

Letter of intent for SIS200 or HESR, look for

$$U^{92+} + Z_T \rightarrow U^{90+} + Z_T{}^{-1} + e^+$$

e^-_{free}

$1s^2$

e^-

e^+

$$\sigma \sim \alpha^3\ Z_p{}^3\ Z_T\ 1/E_{kin}$$

Solid target for high target density, measure $U^{92+} + C(graphite) \rightarrow U^{90+} + e^+$ in coincidence, but projectile re-ionization, selection of C and U(1s) $\rightarrow \sigma \approx 50b$ (re-ioniz. avoided in HESR gas target)

Di-Electronic Resonant Capture by Pair Production

$$U^{92+} + Z_T \rightarrow U^{90+} + e^+$$
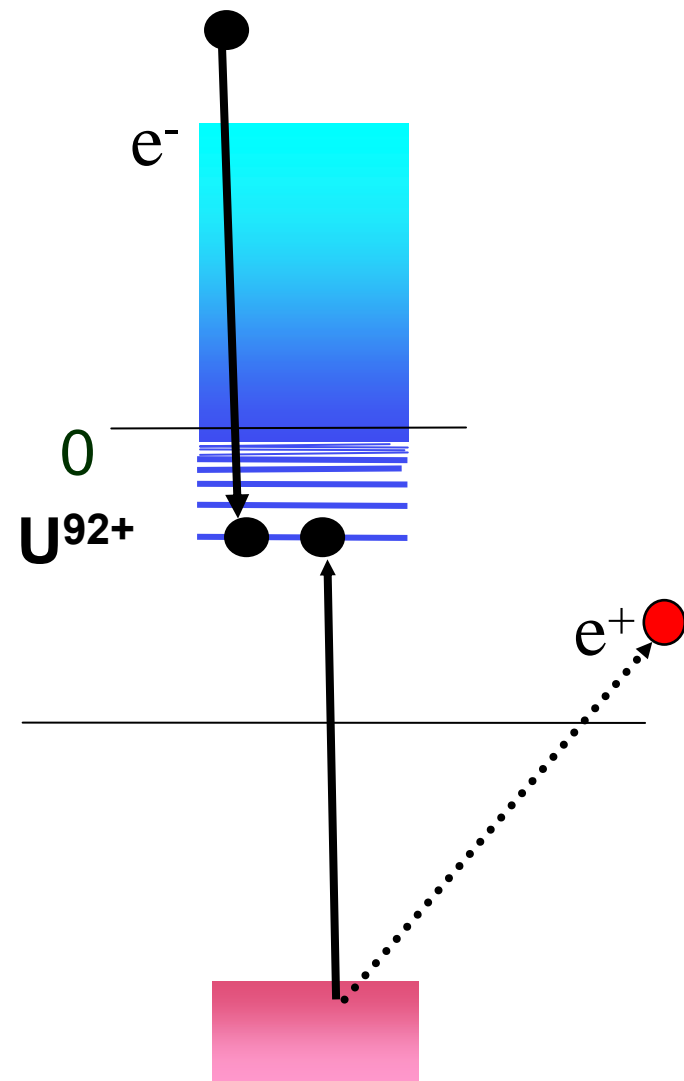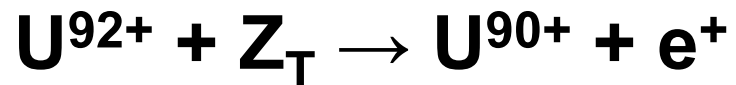
Energy balance
$$E^k_{e-} = E^k_{e+} + E(1s^2) + 2mc^2$$

$$E_{1s} = (1 - \sqrt{1-(\alpha Z)^2})\, mc^2$$

$$E_{thr} \geq (1 + \sqrt{1-(\alpha Z)^2})\, mc^2 + E_{e+}$$

$$\approx 1\ \text{MeV}$$

$$\longrightarrow \quad E^U_{thr} \approx 2\ \text{GeV/u}$$

Conclusions

- Electron-positron pair production in peripheric (Coulombic) collisions: Understand momentum distributions, Scaling with nuclear charges Z^2 $\rightarrow$ **Multiple pairs not yet seen,** To be looked in b-dependence, theories diff. with unitarity

- Dominance of e-capture from continuum at this high energy established! But, **capture to excited state not seen in the target density dependence!**

- Ionization of bound electrons shows importance of screening (anti-screening) effect.

- Electron emission cusp from ionization seen, **that is much narrower than expected.**

- **Proposal for di-electronic capture by pair production that could be observed for Ekin ≥ 2 GeV/u.**

Stockholm, Sweden

http://www.physto.se/icpeac
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