

Bound-free pair production in heavy-ion collisions at high energies - a challenge for theorists and experimentalists

Rainer Schicker

Phys. Inst., Heidelberg

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Bound-free pair production

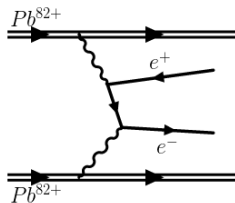
Double bound-free pair production

Secondary ion beams by electromagnetic interactions

Physics interest

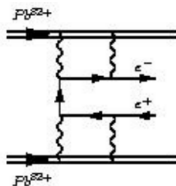
Pair production

- free pair production cross section in Born approx.: Landau, Lifshitz (1934), for Pb-Pb (LHC): $\sigma_{Born}(e^+e^-) \sim 200 \text{ kb}$.

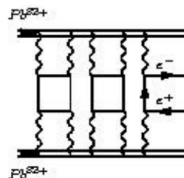


$\sigma_{Born}(e^+e^-, \text{PbPb, LHC}) \sim 200 \text{ kb}$

- $\sigma = \sigma_{Born} + \sigma_{Coul} + \sigma_{unit}$
- $\sigma_{Coul} \sim -0.14 \sigma_{Born}$
- $\sigma_{unit} \sim -0.033 \sigma_{Born}$

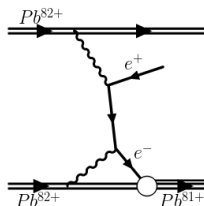


Coulomb corrections



Unitarity corrections

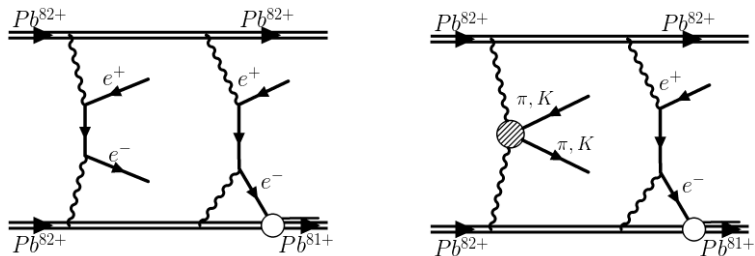
Bound-free pair production



- $Z_1 + Z_2 \rightarrow (Z_1 + e^-)_{1s_{1/2}, \dots} + e^+ + Z_2$
- $\sigma \propto Z_1^5 Z_2^2 (A \log \gamma_{CM} + B)$
- $\sigma \propto Z^7 (A \log \gamma_{CM} + B)$ for $Z_1 = Z_2$
- Bound-free pair-production at LHC:
Meier et al., Phys. Rev. A **63**, 032713 (2001)
- $\sigma_{BFPP}(\text{PbPb}, \text{LHC}) \sim 270 \text{ b per beam}$

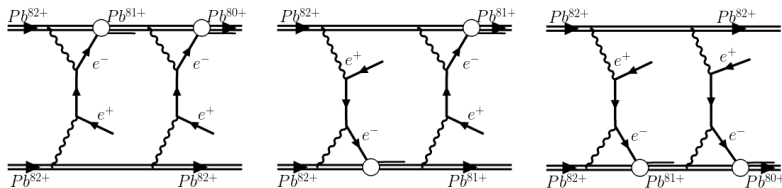
Multiple pair production

production of bound-free pair with a free pair



Double bound-free pair production

■ Double bound-free pair-production



$\sigma_{2 \times BFPP}(\text{PbPb, LHC}) > 6 \text{ mb}$ (priv. comm. V.Serbo)

- Coulomb corrections, unitarity corrections ?
- $\sigma(\text{Pb}^{81+}\text{Pb}^{81+}) = 2 \times \sigma(\text{Pb}^{82+}\text{Pb}^{80+})$?

Secondary Pb-beams at hadron colliders

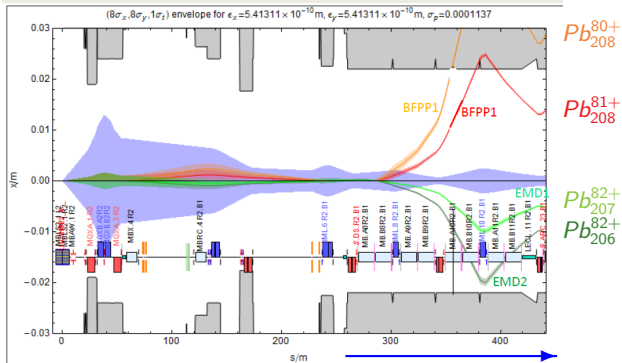
- magn. rigidity:

$$B\rho = \frac{Z}{A} \frac{p}{q}$$

- sec. Pb-beams:

$$\frac{Z}{A} \neq \frac{82}{208}$$

Secondary beams from Beam 1 in IR2 (horizontal plane)



J.M. Jowett, Workshop on photon-induced collisions at the LHC, 4 June 2014

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*John Jowett, Workshop on
photon-induced collisions at the LHC,
CERN, June 2-4, 2014*

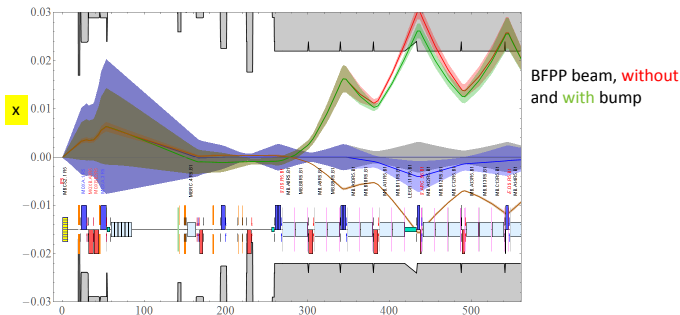
Active collimators - detectors ?

- active collimators:

- ▶ at LHC: not possible (no space)
- ▶ at FCC: up for discussion

Secondary Pb-beams at hadron colliders

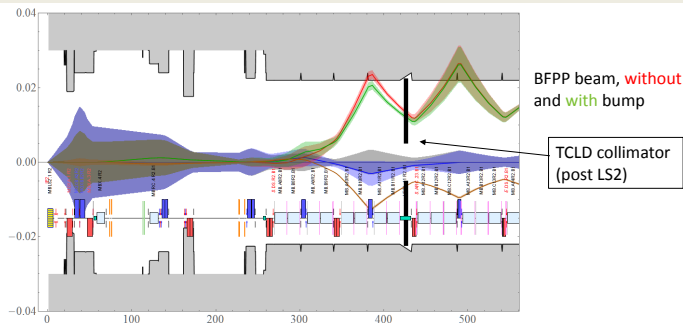
Orbit bumps mitigate BFPP for CMS (or ATLAS)



- Primary loss location close to the connection cryostat - details slightly optics-dependent (if necessary, bumps should avoid quenches at the start of physics)
- Extra BLMs were specifically added for heavy-ion operation in loss region
- Variations of bump possible, uses moderate fraction of available corrector strengths
- We applied bumps like these with ~ 3 mm amplitude around CMS and ATLAS from the beginning of the run

Secondary Pb-beams at hadron colliders

Orbit bumps **alone** are not effective for ALICE



- IR2 has different quadrupole polarity and dispersion from IR1/IR5
- Primary BFPF loss location is further upstream from connection cryostat
- Solution is to modify connection cryostat to include a collimator to absorb the BFPF beam —**design is being launched now to be ready for LS2 installation**
- With levelled luminosity in ALICE, quenches were not seen in Run 2

Summary

- cross section bound-free pair production
 - ▶ unitarity, Coulomb corrections ?
- cross section double bound-free pair production
 - ▶ $\sigma(\text{Pb}^{81+}\text{Pb}^{81+}) = 2 \times \sigma(\text{Pb}^{82+}\text{Pb}^{80+})$?
 - ▶ unitarity, Coulomb corrections ?
- Multiple lepton pair production
- Pion/Kaon pair photoproduction
- Measurement of bound-free/double bound-free/free pair bound-free pair cross sections not feasible at the LHC
- Measurements of bound-free/double bound-free/free pair bound-free pair cross sections a possible option at the FCC ?