# Extraction of photonuclear cross section

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Miniworkshop difrakce a ultraperiferálních srážek
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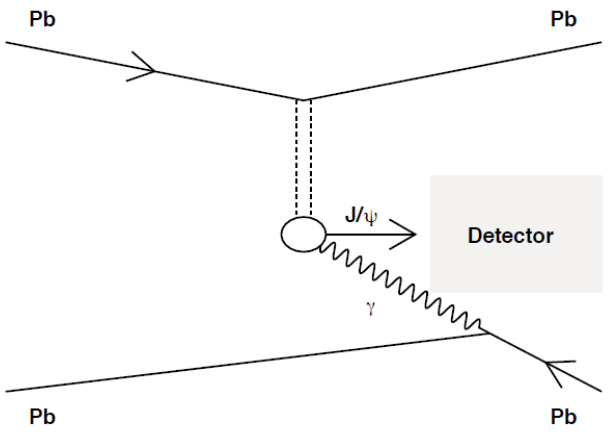
# Theory

Photon flux

Photon-target cross section

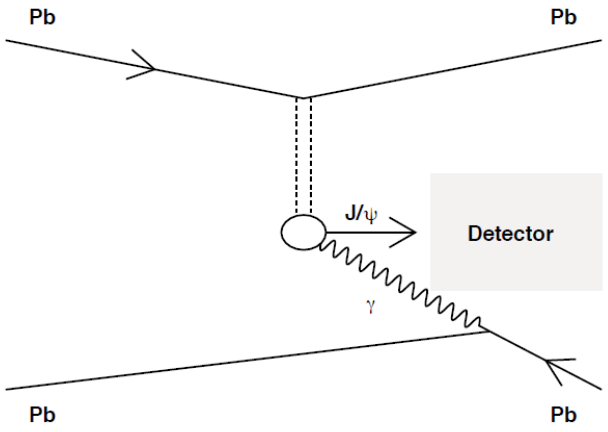
$$\frac{\mathrm{d}\sigma_{\mathrm{PbPb}}(y)}{\mathrm{d}y} = N_{\gamma}(y)\,\sigma_{\gamma\mathrm{Pb}}(y)$$

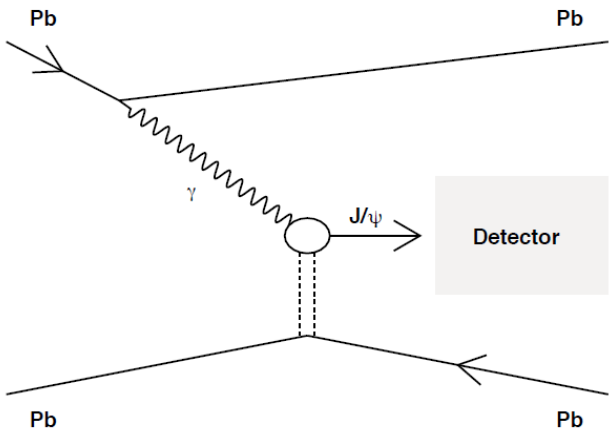


**Photon flux**

**Photon-target cross section**

$$\frac{\mathrm{d}\sigma_{\mathrm{PbPb}}(y)}{\mathrm{d}y} = N_\gamma(y)\,\sigma_{\gamma\mathrm{Pb}}(y) + N_\gamma(-y)\,\sigma_{\gamma\mathrm{Pb}}(-y)$$



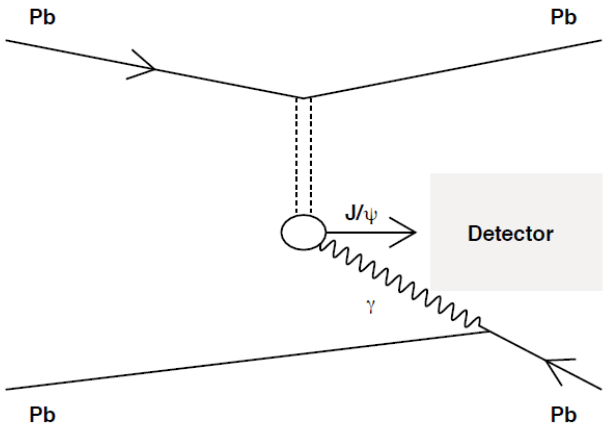



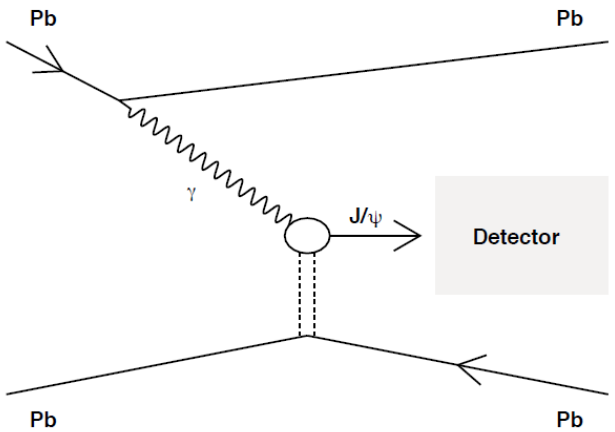
**Photon flux**

**Photon-target cross section**

$$\frac{\mathrm{d}\sigma_{\mathrm{PbPb}}(y)}{\mathrm{d}y} = N_\gamma(y)\,\sigma_{\gamma\mathrm{Pb}}(y) + N_\gamma(-y)\,\sigma_{\gamma\mathrm{Pb}}(-y)$$

- At mid rapidity
  - Both contributions are same



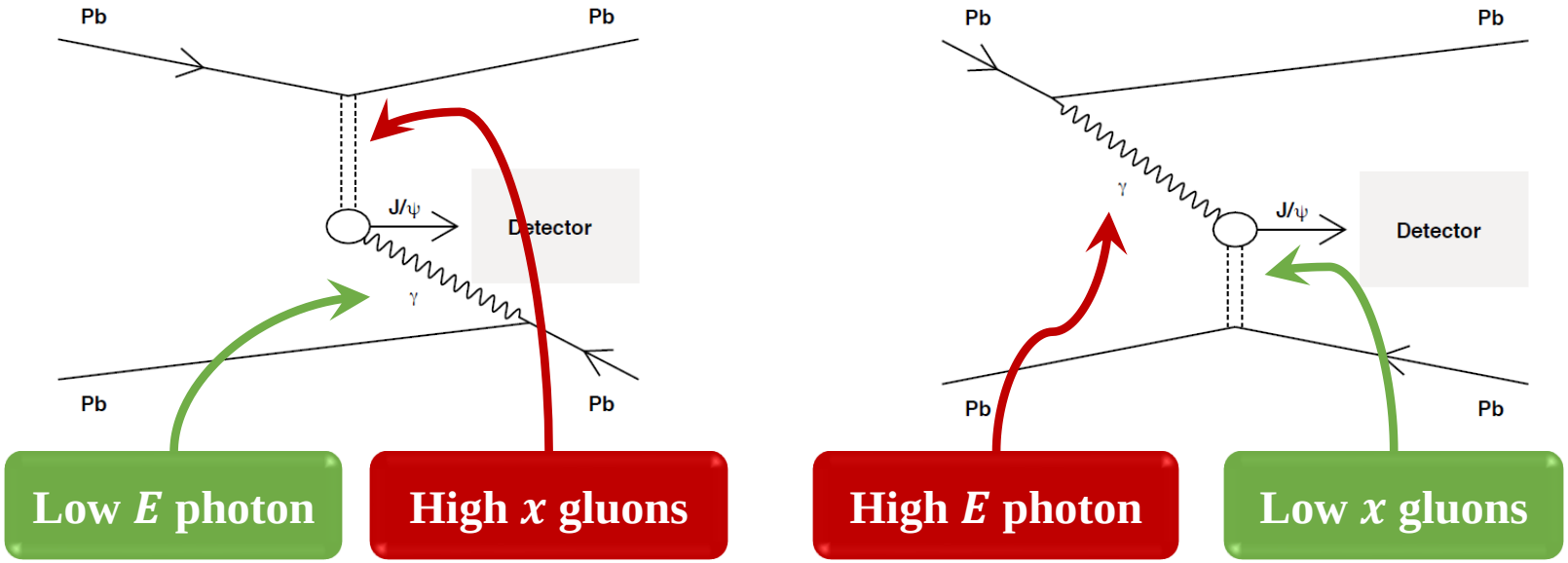



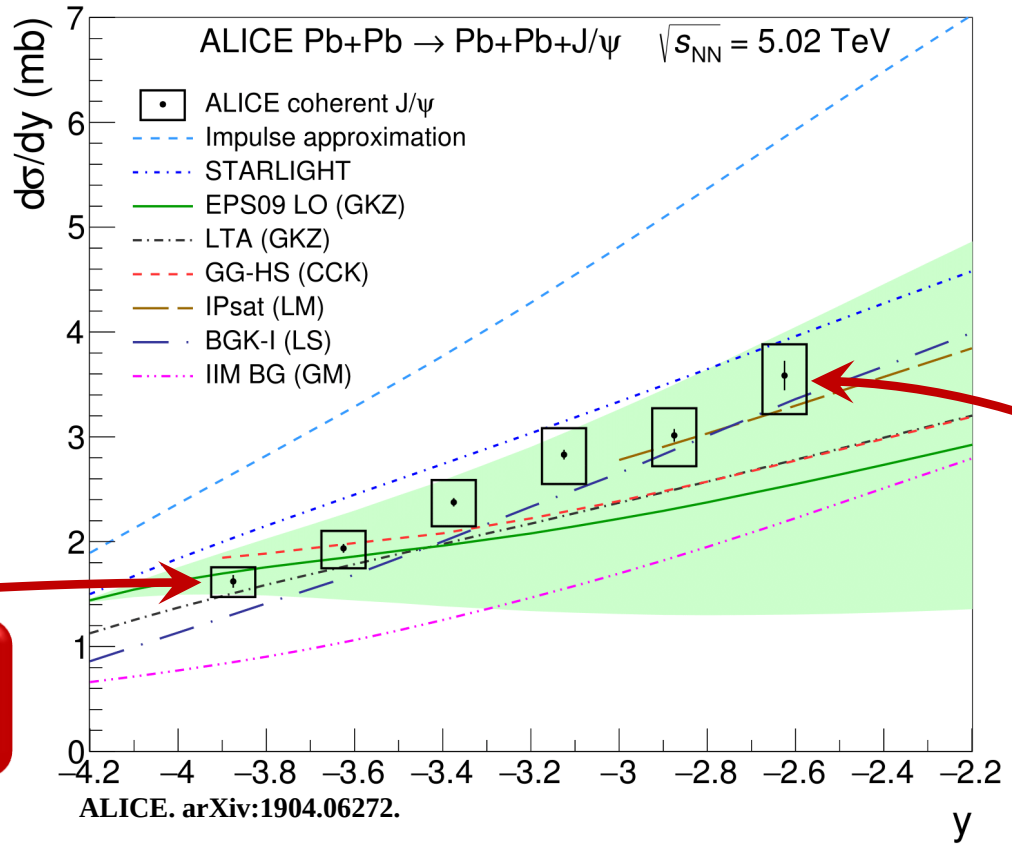
Photon flux

Photon-target cross section

$$\frac{d\sigma_{PbPb}(y)}{dy} = N_\gamma(y)\sigma_{\gamma Pb}(y) + N_\gamma(-y)\sigma_{\gamma Pb}(-y)$$

- At mid rapidity
  - Both contributions are same
- At forward rapidity
  - **Contributions are different**






ALICE. arXiv:1904.06272.

$\sim 95\%: x = 3.3 \cdot 10^{-2}$
$\sim 5\%: x = 1.1 \cdot 10^{-5}$

$\sim 60\%: x = 0.7 \cdot 10^{-2}$
$\sim 40\%: x = 5.1 \cdot 10^{-5}$

$$\sigma_{0N0N} = n_{0N0N}(+y)\,\sigma_{\gamma Pb}(+y) + n_{0N0N}(-y)\,\sigma_{\gamma Pb}(-y)$$

**Measured**

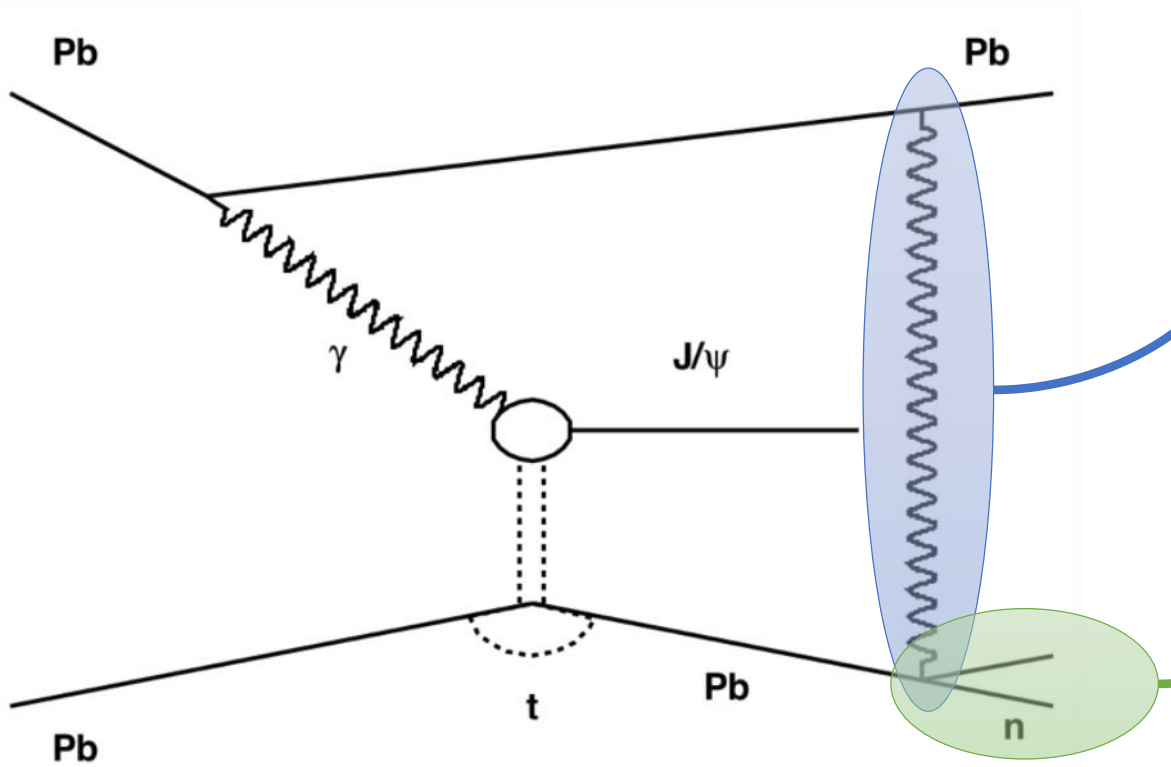
**Computed**

**Unknown cross sections**

- There are both contributions
  - Two unknown variables
  - One equation

} ✗ **Can‘t be distinguished**

- Possible solution!




- **Independent** soft electromagnetic interactions

- Excitation of the outgoing lead ion
  - Emits **forward neutrons** upon de-excitation

- This can be measured and used to differentiate the high $x$ and low $x$ contribution!

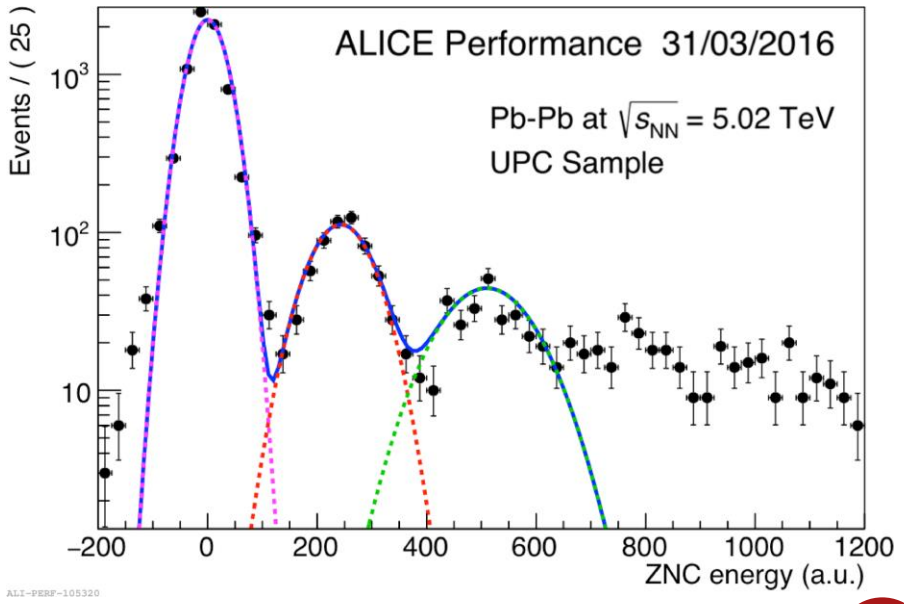
$$\sigma_{0N0N} = n_{0N0N}(+y)\,\sigma_{\gamma Pb}(+y) + n_{0N0N}(-y)\,\sigma_{\gamma Pb}(-y)$$

$$\sigma_{0NXN} = n_{0NXN}(+y)\,\sigma_{\gamma Pb}(+y) + n_{0NXN}(-y)\,\sigma_{\gamma Pb}(-y)$$

**Measured**

**Computed**

**Exctracted cross sections**




- There are both contributions
  - Two unknown variables
  - Two equations

**Can be distinguished**

$$\sigma_{\gamma\mathrm{Pb}}(-y) = \left( n_\gamma^P(y) \frac{d\sigma^U_{\mathrm{PbPb}}}{dy} - n_\gamma^U(y) \frac{d\sigma^P_{\mathrm{PbPb}}}{dy} \right) / F(y), \tag{14}$$

and

$$\sigma_{\gamma\mathrm{Pb}}(y) = \left( n_\gamma^U(-y) \frac{d\sigma^P_{\mathrm{PbPb}}}{dy} - n_\gamma^P(-y) \frac{d\sigma^U_{\mathrm{PbPb}}}{dy} \right) / F(y) \tag{15}$$

where

$$F(y) \equiv n_\gamma^P(y) n_\gamma^U(-y) - n_\gamma^U(y) n_\gamma^P(-y). \tag{16}$$

In here, $P$ and $U$ are two arbitrary cross sections which are measured at the same rapidity, but in a different range of impact parameters.

# Running the code

$$\frac{d\sigma_{PbPb}(y)}{dy} = N_\gamma(y)\sigma_{\gamma Pb}(y) + N_\gamma(-y)\sigma_{\gamma Pb}(-y)$$

```
void UPC_XS(Double_t prob_1_0n0n, Double_t prob_1_Xn0n, Double_t prob_1_XnXn,
            Double_t prob_2_0n0n, Double_t prob_2_Xn0n, Double_t prob_2_XnXn,
            Double_t flux_1, Double_t flux_2, Double_t xs_1, Double_t xs_2)
// in this case, one gives the fluxes, probabilities of neutrons classes
// and gA cross sections at both rapidities (denoted by 1 and 2 here) to
// obtain the UPC cross sections
// NOTE: flux_2 corresponds to the higher WgA
// NOTE: Xn0n stands for (Xn0n+0nXn)
```

```
Processing Test_UPC_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   UPC XSs:
     total = 2.81475
     0n0n = 2.32794
     Xn0n = 0.368769
     XnXn = 0.118036
```

$$\sigma_{\gamma\mathrm{Pb}}(-y) = \left( n_\gamma^P(y) \frac{d\sigma^U_{\mathrm{PbPb}}}{dy} - n_\gamma^U(y) \frac{d\sigma^P_{\mathrm{PbPb}}}{dy} \right) / F(y), \tag{14}$$

and

$$\sigma_{\gamma\mathrm{Pb}}(y) = \left( n_\gamma^U(-y) \frac{d\sigma^P_{\mathrm{PbPb}}}{dy} - n_\gamma^P(-y) \frac{d\sigma^U_{\mathrm{PbPb}}}{dy} \right) / F(y) \tag{15}$$

where

$$F(y) \equiv n_\gamma^P(y) n_\gamma^U(-y) - n_\gamma^U(y) n_\gamma^P(-y). \tag{16}$$

```
void gA_XS(Double_t prob_1_0n0n, Double_t prob_1_Xn0n, Double_t prob_1_XnXn,
           Double_t prob_2_0n0n, Double_t prob_2_Xn0n, Double_t prob_2_XnXn,
           Double_t flux_1, Double_t flux_2,
           Double_t xs_0n0n, Double_t xs_Xn0n, Double_t xs_XnXn)
// in this case, one gives the fluxes, probabilities of neutrons classes
// and UPC cross sections for neutron classes to
// obtain the gA cross sections from three pairs of data
// NOTE: flux_2 corresponds to the higher WgA
```

```
Processing Test_gA_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   gA XSs:
     from (0n0n,Xn0n), = (0.0128431,0.0512777)
     from (0n0n,XnXn), = (0.0128431,0.0512775)
     from (Xn0n,XnXn), = (0.0128437,0.0512757)
```

- Correct inputs
- Correct outputs

```
Processing Test_gA_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   gA XSs:
     from (0n0n,Xn0n), = (0.0128431,0.0512777)
     from (0n0n,XnXn), = (0.0128431,0.0512775)
     from (Xn0n,XnXn), = (0.0128437,0.0512757)
```

- + 10% error all inputs
- +10% error all outputs

```
Processing Test_gA_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   gA XSs:
     from (0n0n,Xn0n), = (0.0141274,0.0564055)
     from (0n0n,XnXn), = (0.0141274,0.0564052)
     from (Xn0n,XnXn), = (0.014128,0.0564032)
```

- - 10% error all inputs
- - 10% error all outputs

```
Processing Test_gA_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   gA XSs:
     from (0n0n,Xn0n), = (0.0115588,0.04615)
     from (0n0n,XnXn), = (0.0115588,0.0461497)
     from (Xn0n,XnXn), = (0.0115593,0.0461481)
```

- Inputs
  - 0n0n: +5% error
  - Xn0n: -5% error
  - XnXn: 0% error

```
Processing Test_gA_XS.C...
 Computing case y = <-4.0,-2.5>

   tot prob_1 = 0.999916 ... tot prob_2 = 0.999174
   gA XSs:
     from (0n0n,Xn0n), = (0.0173746,-0.0119403)
     from (0n0n,XnXn), = (0.0138123,0.0483101)
     from (Xn0n,XnXn), = (-0.116257,0.44654)
```

- Outputs
  - Some close some all over the place…
  - We need to be careful

# Thank you for your attention!

# Backup