Pomeron spin-flip from single-spin asymmetry of forward protons

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Does the Pomeron flip proton helicity?

At first glance it does not, because treated perturbatively, the quark-gluon vertex conserves helicity. However, the sum the quark helicities is not equal to the proton one, since their momenta are not parallel. Besides, the anomalous color-magnetic moment of a quark generates a helicity-flip amplitude.

The fractional spin-flip:

$$\mathbf{r_5} = \frac{\mathbf{2m_N\Phi_5}}{\sqrt{-\mathbf{t}}\,\mathrm{Im}\,(\mathbf{\Phi_1}+\mathbf{\Phi_3})}$$

N.Buttimore, E.Leader, J.Soffer, T.L.Trueman & B.K. PRD59(1999)114010

$$\mathbf{\Phi_1} = \langle + + |\hat{\mathbf{M}}| + +\rangle\ ; \quad \mathbf{\Phi_3} = \langle + - |\hat{\mathbf{M}}| + -\rangle\ ; \quad \mathbf{\Phi_5} = \langle + + |\hat{\mathbf{M}}| + -\rangle\ .$$

Even if r5 is sizable, it hardly can be seen in the hadronic single-spin asymmetry

$$\mathbf{A_N}\,\frac{\mathbf{d\sigma}}{\mathbf{dt}} = \mathbf{2}\mathrm{Im}\{\mathbf{\Phi_5^*}(\mathbf{\Phi_1}+\mathbf{\Phi_3})\}$$

Indeed, if Regge factorization holds, the relative phase shift vanishes.

Interference with Coulomb amplitude offers a unique possibility to measure r5

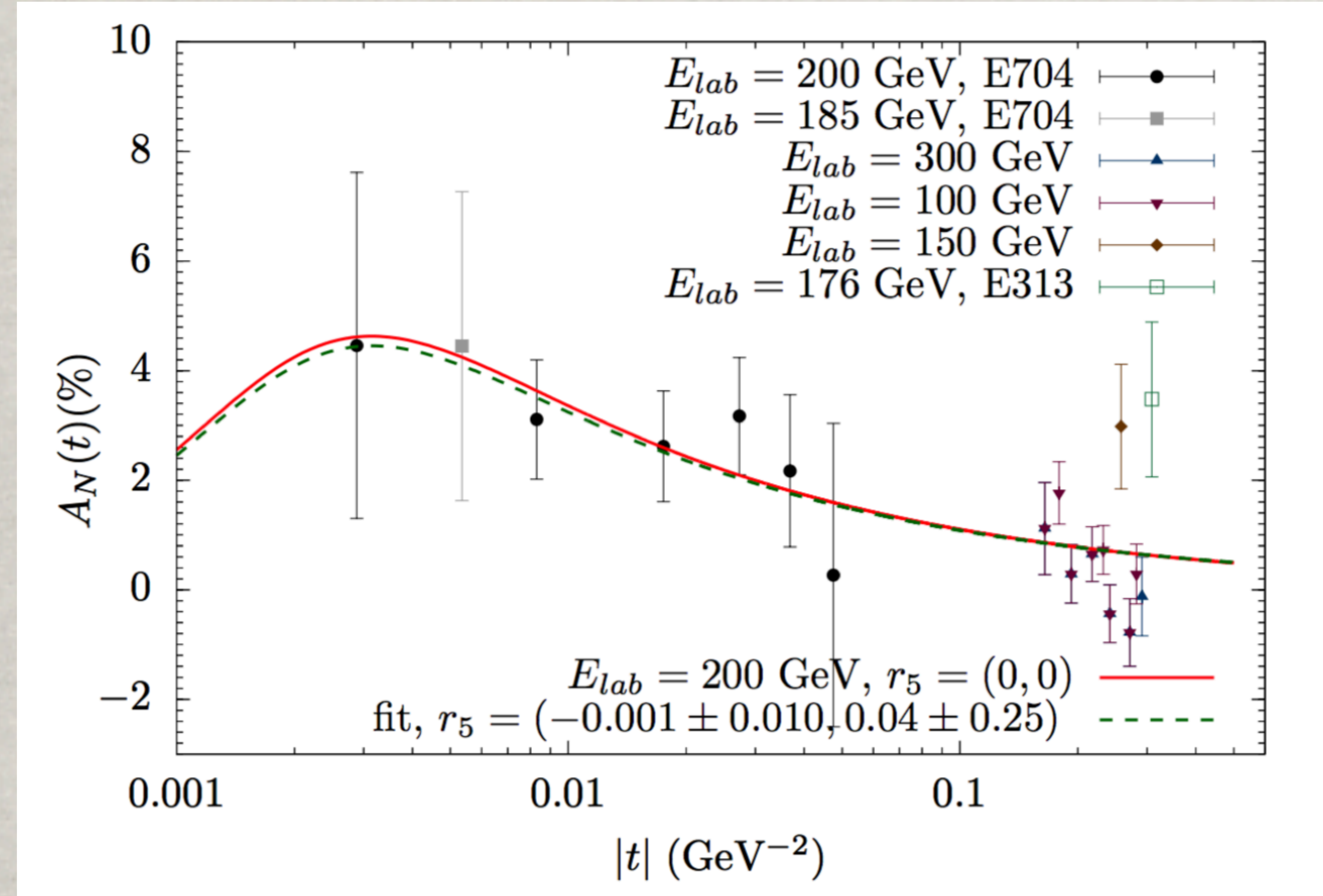
B.G.Zakharov & B.K. PLB226 (1989)156

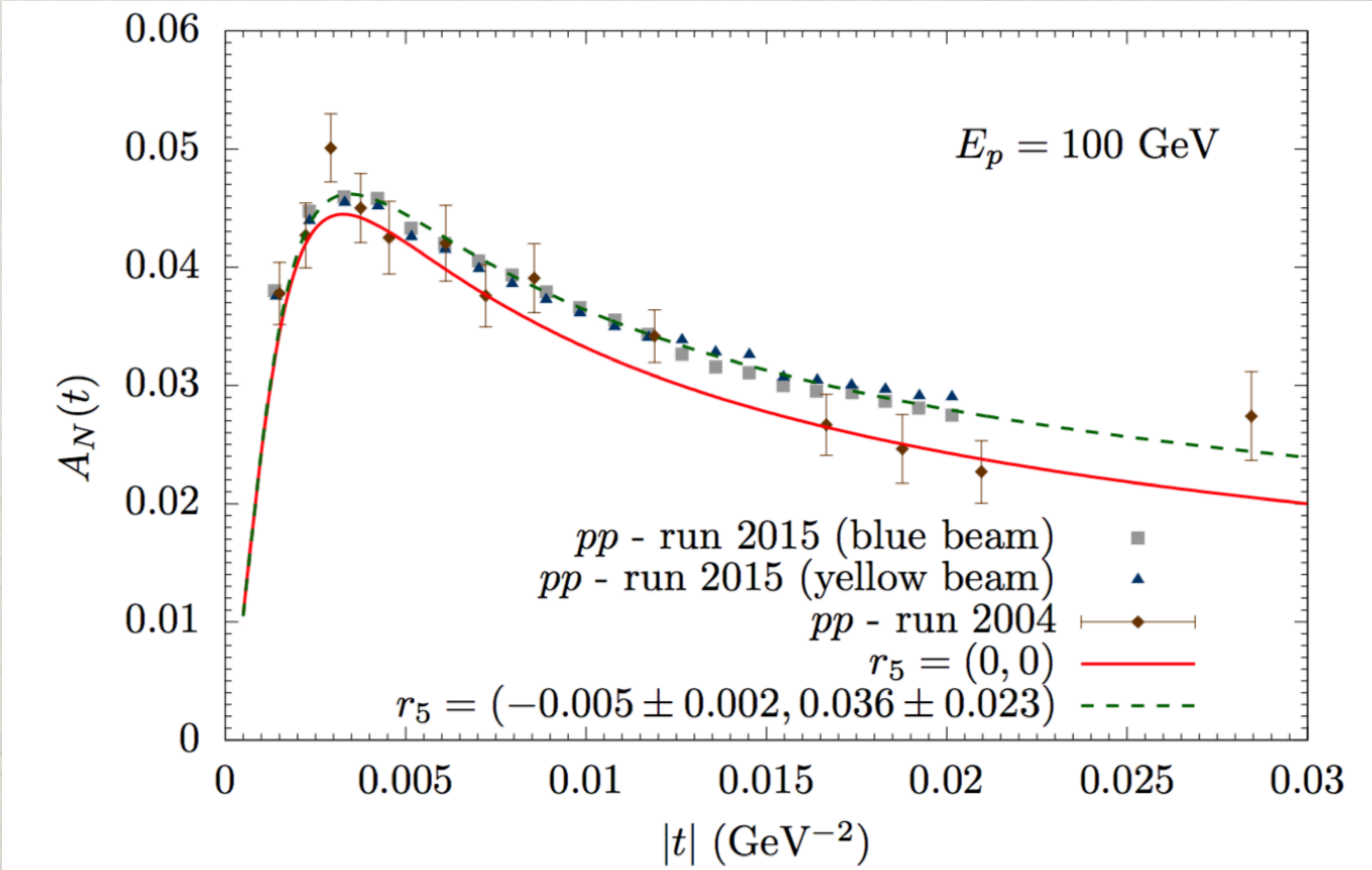
Coulomb-nuclear interference (CNI)

The Coulomb amplitude is know, both spin-flip and non-flip parts. The hadronic non-flip amplitude is known as well from data. Assuming r5=0 the asymmetry $A_N(t)$ can be fully predicted **L.I.Lapidus & B.K. Sov. J. Nucl. Phys. 19(1974) 114**

$$A_N(t) = \frac{4\,(t/t_p)^{3/2}}{3(t/t_p)^2+1}\;A_N(t_p) \qquad t_p = -8\sqrt{3}\,\frac{\pi\,\alpha}{\sigma_{tot}^{pp}}$$

$\mu_p - 1 \approx 1.79$
anomalous magnetic moment of the proton





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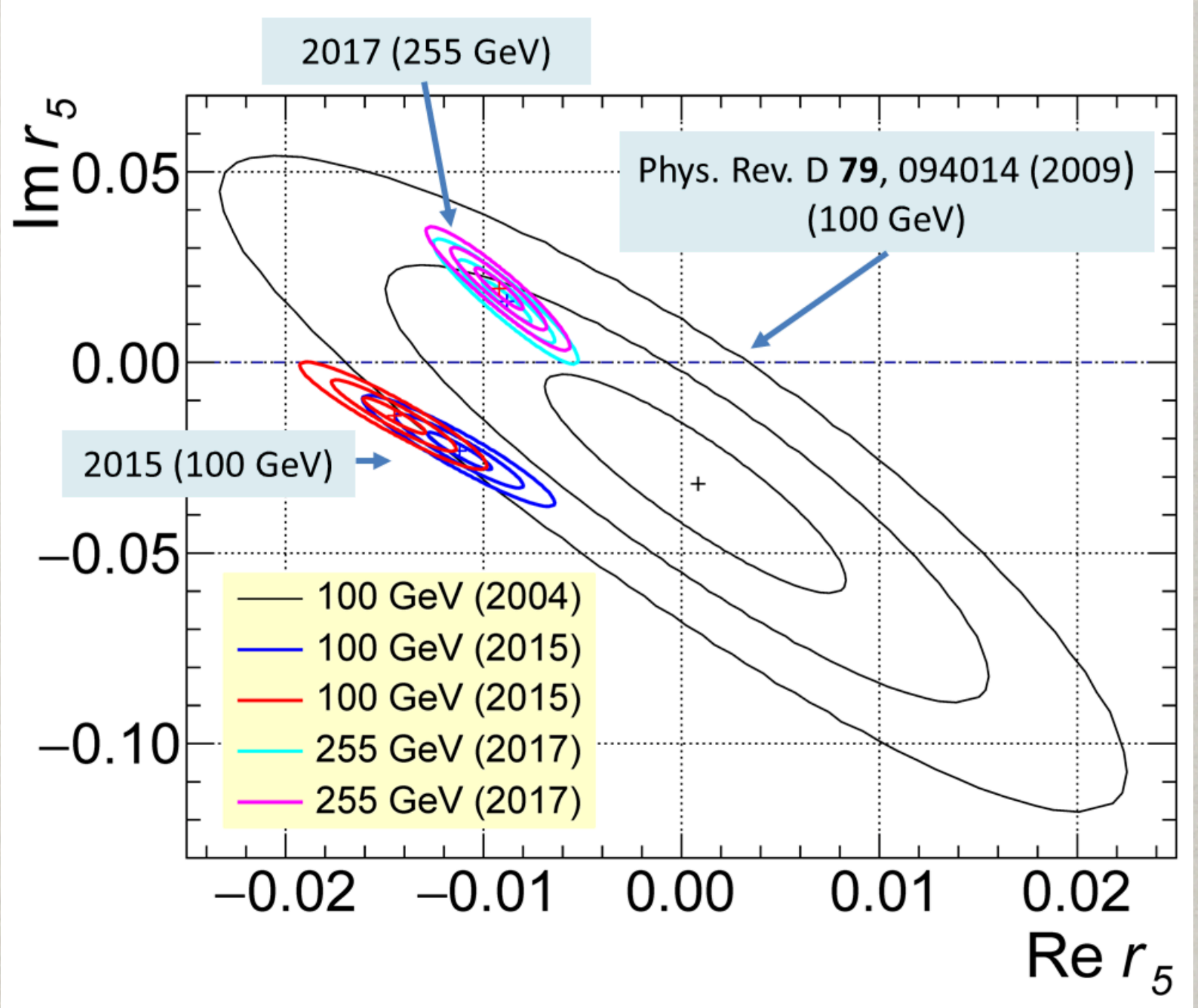
pp results

From a talk by
Andrei Poblaguev



While accuracy is rather good, this is not an ultimate source of information about the Pomeron spin-flip. The energy is not high enough to neglect contribution to r5 from iso-vector Reggeons (ρ, a2) with large spin-flip.

CNI in pA elastic scattering

Nuclear targets strongly suppress, or completely exclude iso-vector Reggeons.

B.K. hep-ph/9801414

$$A_N^{pA}(s,t)\left(\frac{d\sigma_{el}^{pA}}{dt}\right)=\frac{Z\alpha\sigma_{tot}^{pA}}{2m_p q}\,F_A^C(q^2)F_A^H(q^2)\left[\mu_p-1-2\mathrm{Im}\,r_5\right]$$

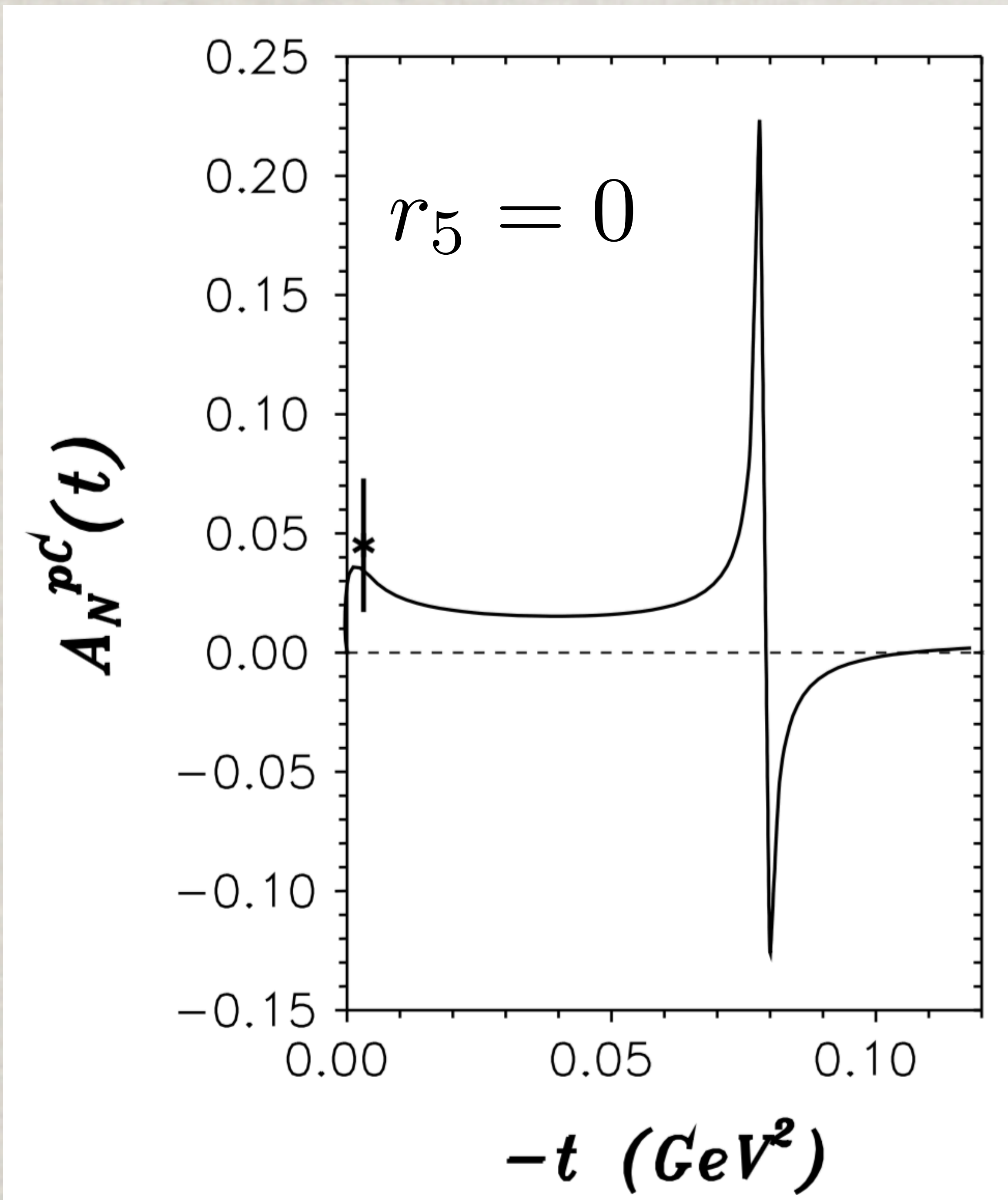
$$\frac{d\sigma_{el}^{pA}}{dt}=\frac{\left[\sigma_{tot}^{pA}F_A^H(t)\right]^2}{16\pi}+4\pi\left(\frac{Z\alpha F_A^C(t)}{t}\right)^2$$

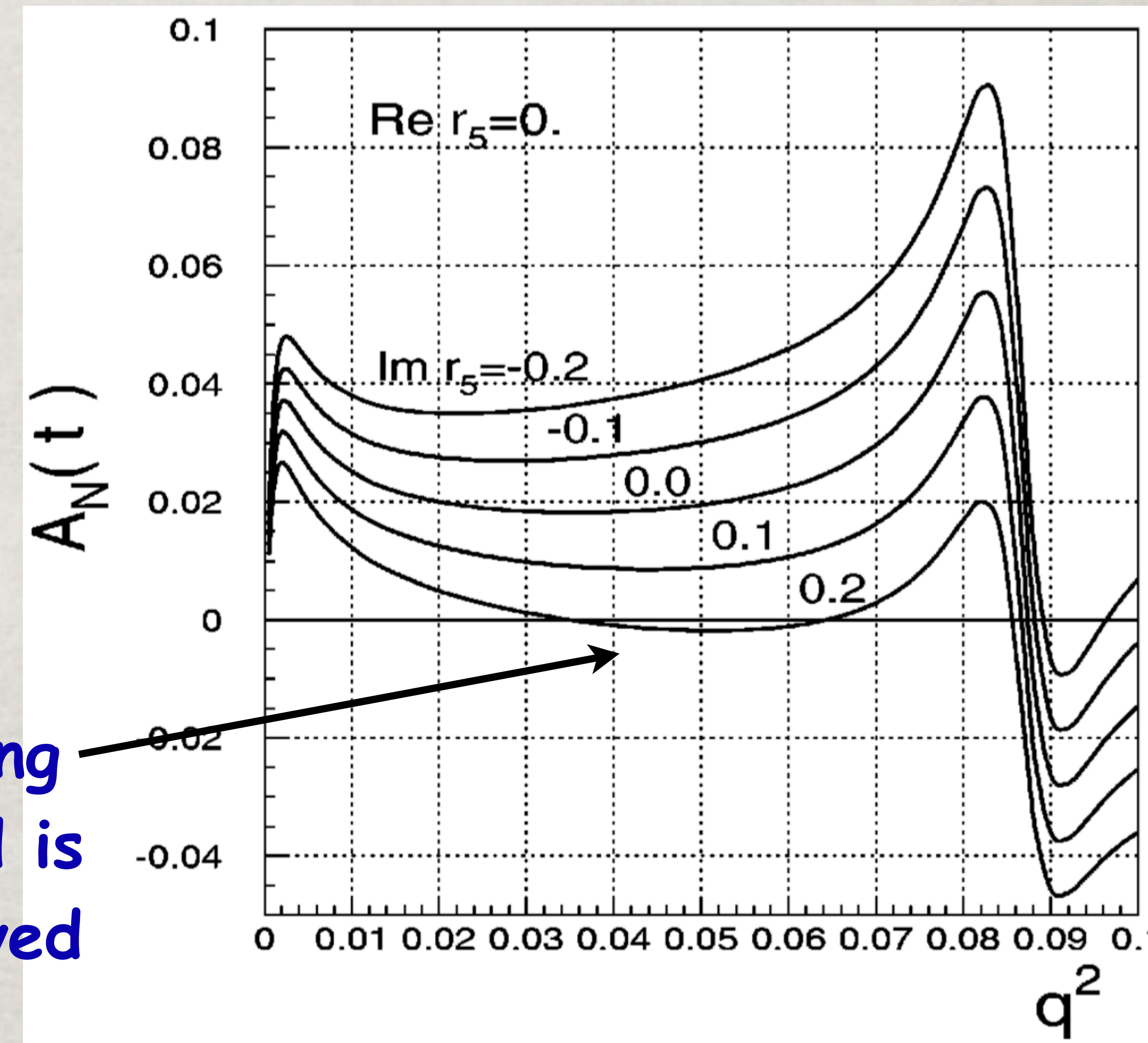
$$F_A^H(q^2)=\frac{1}{2\sigma_{tot}^{pA}}\int d^2b\;e^{i\vec{q}\vec{b}}\left[1-e^{-\frac{1}{2}\sigma_{tot}^{pN}T(b)}\right]$$

$$F_A^C(q^2)=\frac{1}{A}\int d^2b\;e^{i\vec{q}\vec{b}}T(b)$$

CNI in pC elastic scattering

T.L.Trueman & B.K. PRD64(2001)034004

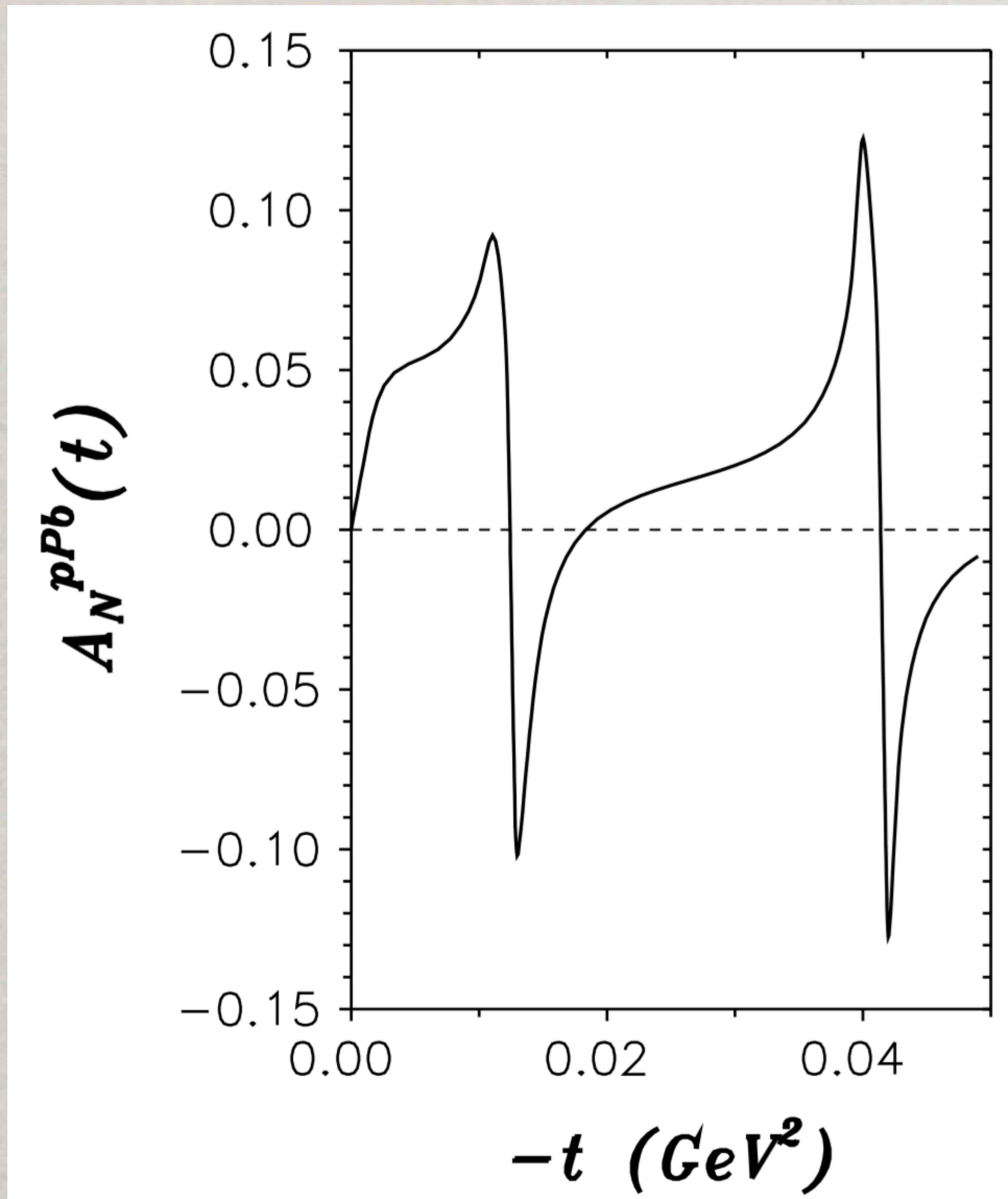


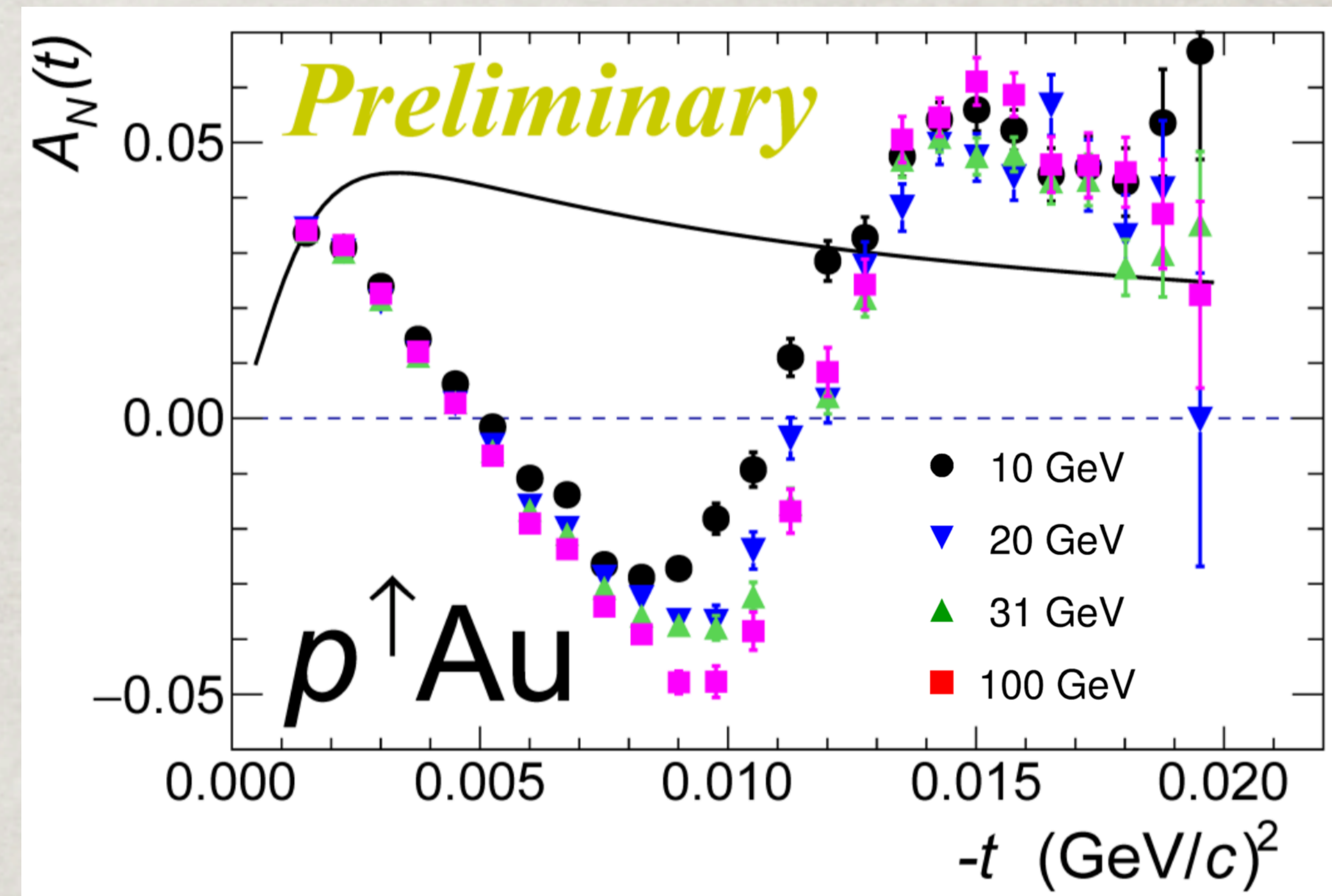


Crossing indeed is observed

Calculations with a most realistic oscillatory parametrization for the nuclear density, including Coulomb phase shift, real parts, etc. Proposed as a parameter free polarimetry.

CNI in pAu elastic scattering





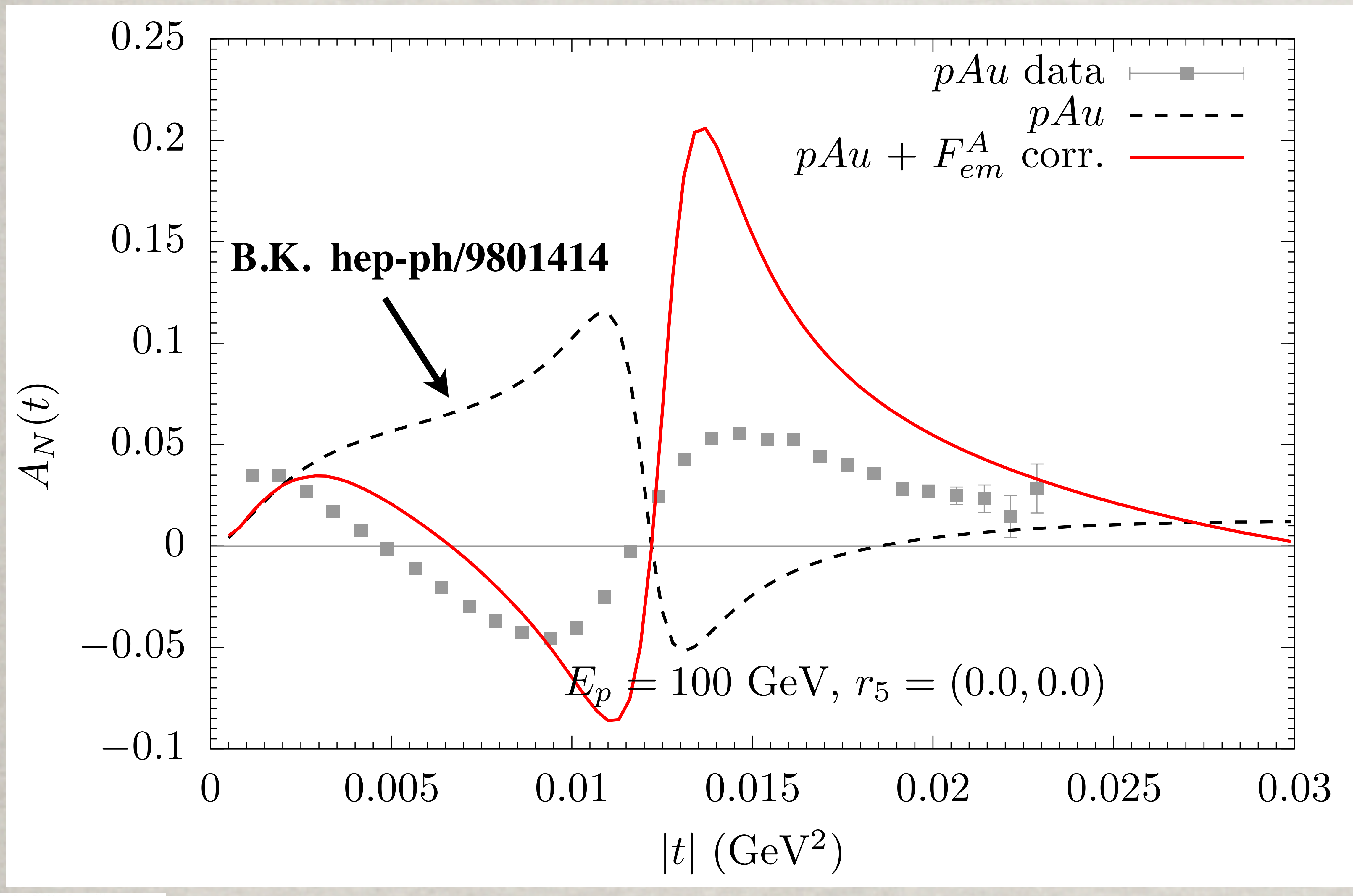
Troubles are due to incorrect electromagnetic formfactor:

CNI in ultra-peripheral pA collisions

$$\mathbf{F_A^{em}(q_T) = \frac{1}{A}\int d^3r\, e^{i\tilde{q}\cdot\tilde{r}}\rho_A(r) = \frac{1}{A}\int d^2b\, e^{i\tilde{q}_T\cdot\tilde{b}}T_A(b)}$$

$$\mathbf{F_A^{em}(q_T) = \frac{1}{A_{eff}}\int d^2b\, e^{i\tilde{q}_T\cdot\tilde{b}}T_A(b)}\, \exp\left[-\frac{1}{2}\sigma^{pp}_{tot}T_A(b)\right]$$

This corrections lead to dramatic modifications of $\mathbf{A_N(t)}$

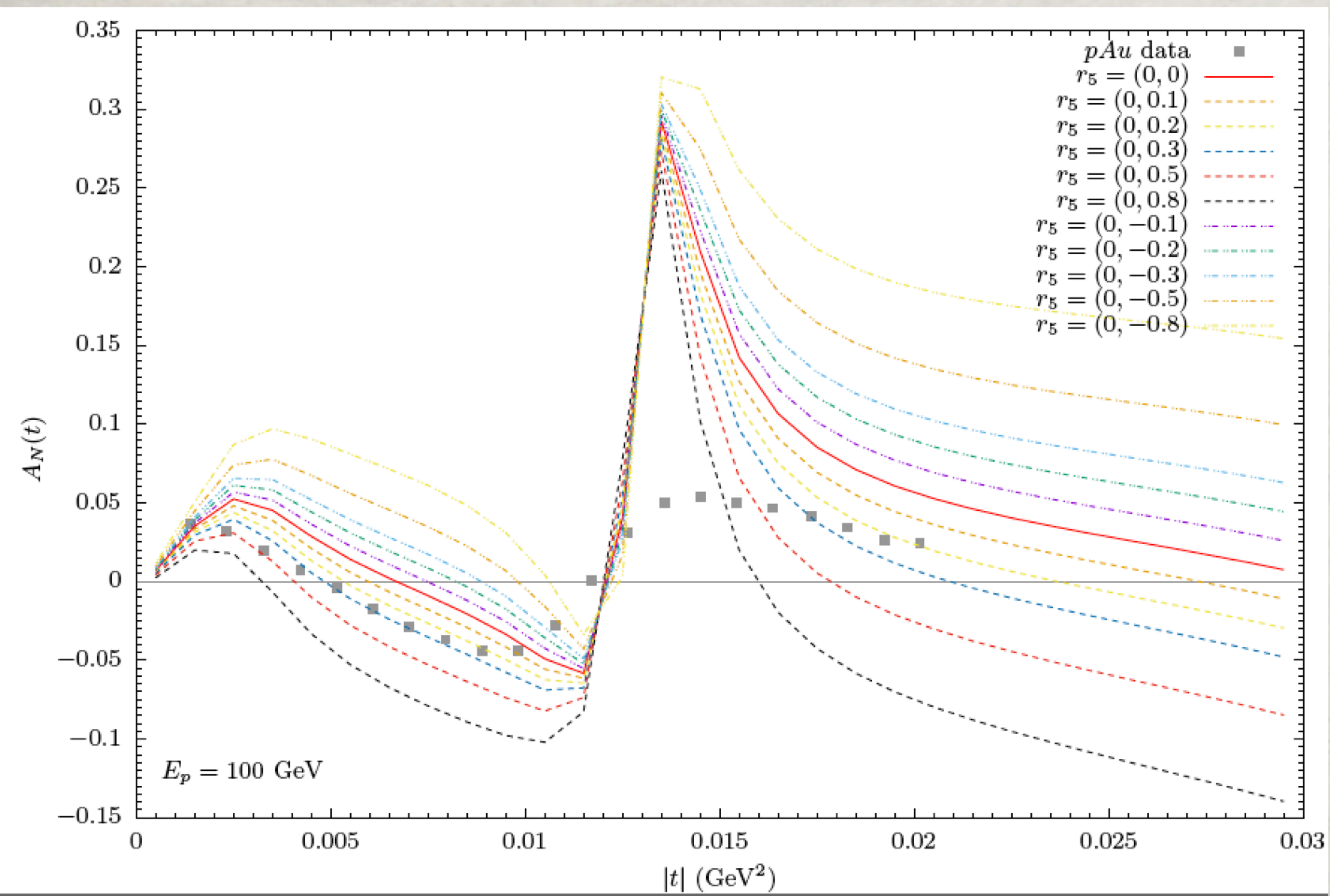


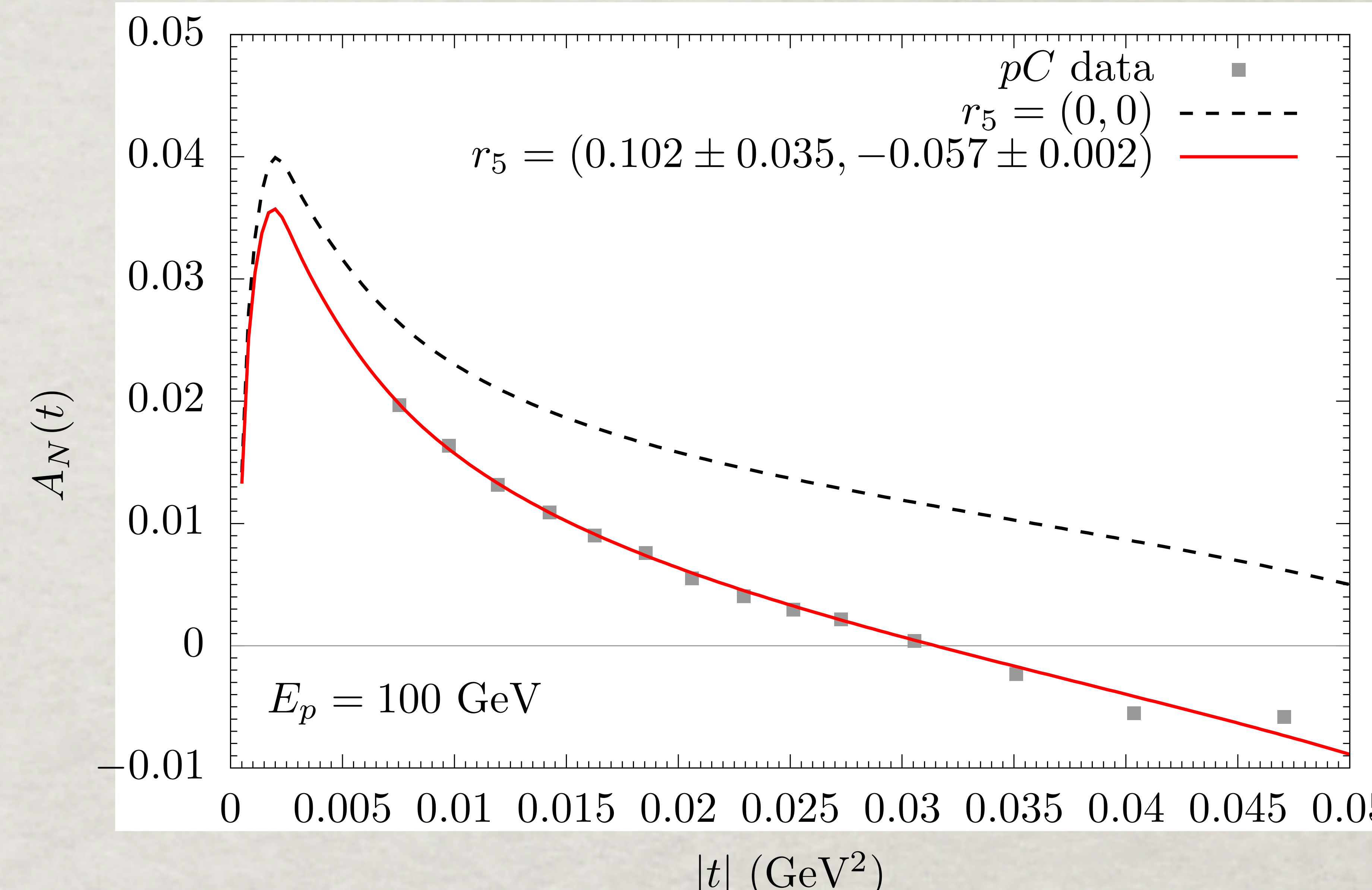
The electromagnetic amplitude gets the main contribution from ultra-peripheral collisions (UPC), while the hadronic amplitude is not zero only at small impact parameters, $\mathrm{b < R_A}$

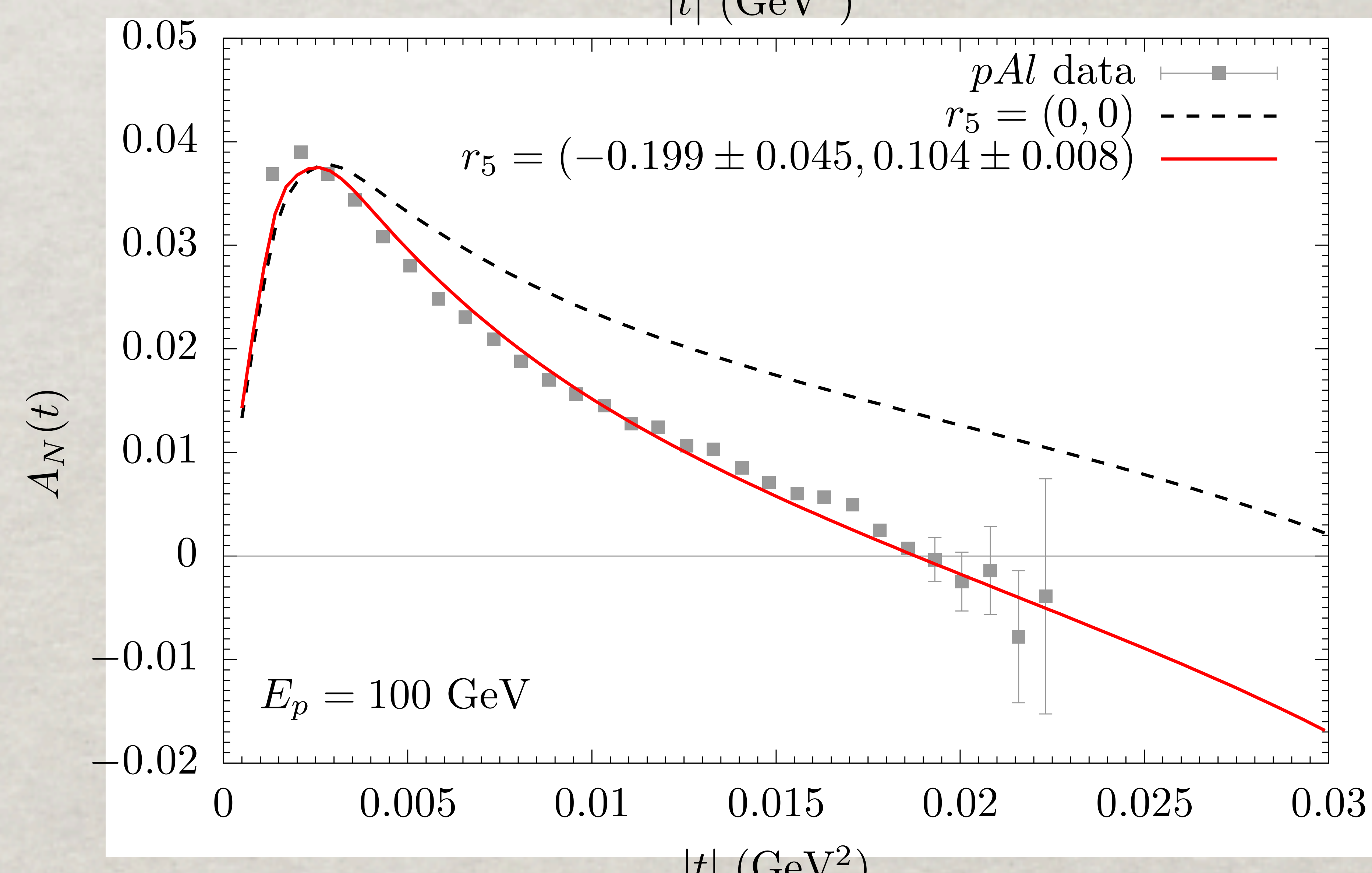
How can amplitudes with so different impact parameters interfere?
- They do due to coherence.

CNI in ultra-peripheral pA collisions

Further adjustments are possible

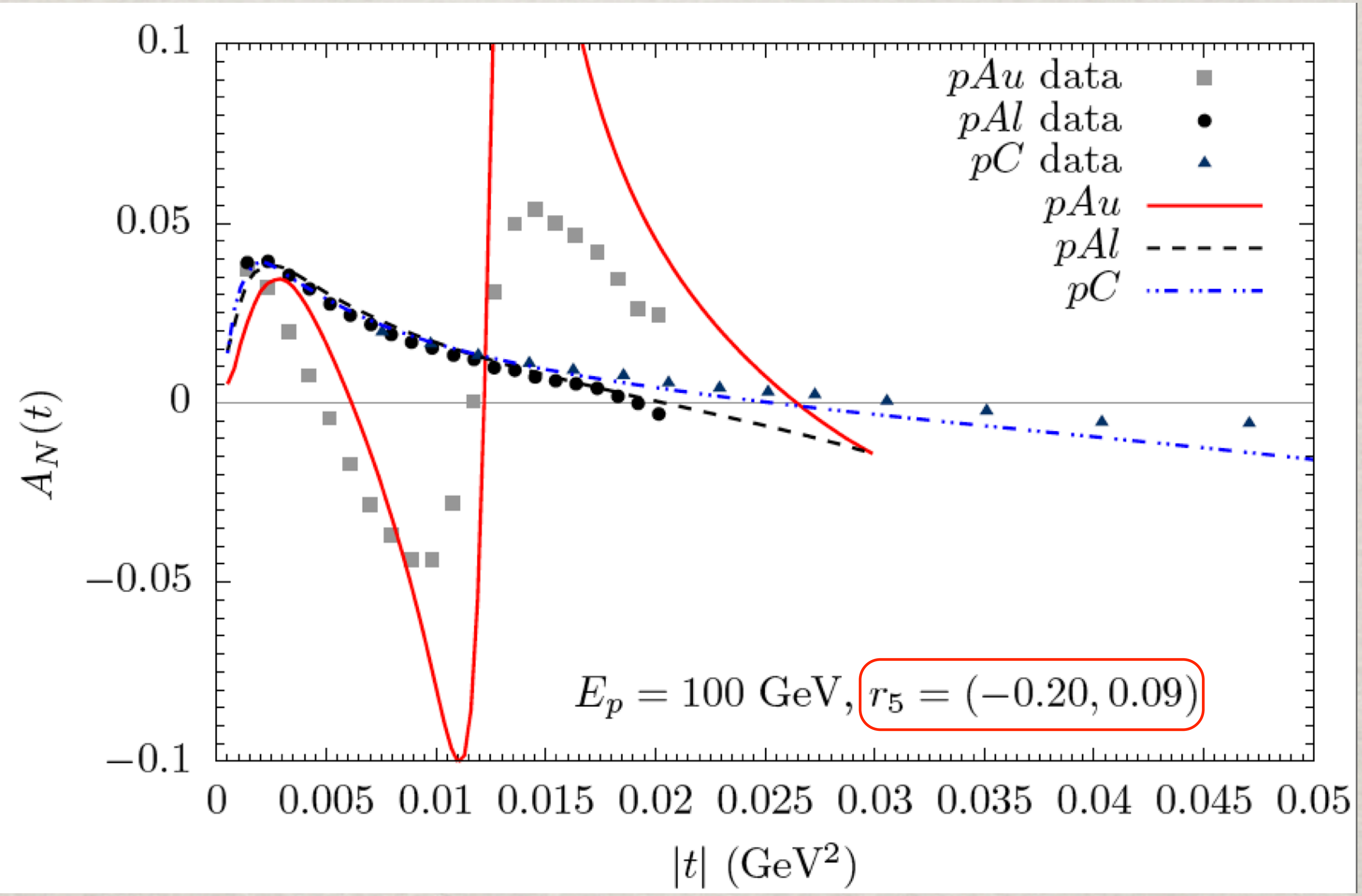






r5 from pA elastic scatterning

The global fit give a reasonable values for
Re and Im of r5, but not reliable so far



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Summary

- While precise measurements of single-spin asymmetry of forward protons allows a rather accurate determination of the fractional spin-flip amplitude r5, its interpretation is still questionable, because of the contribution of Reggeons with large spin-flip.

- Nuclear targets suppress or completely eliminated the contribution of iso-vector Reggeons with a large spin-flip. Recent measurements in the CNI region for D, C, Al and Au open new opportunities for study of r5.

- A novel mechanism of interference of electromagnetic UPC with central hadronic collisions is proposed attampting at explanations of p-Au data for CNI generated A_N

- Nevertheless, an accurate determination of r5 from pA data is still a challenge