



# QCD Corrections to Coloron Production

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*(in preparation)*





# Motivation



Ultra brief  
selection!!

- ✦ **Classic Axigluon** *P.H. Frampton and S.L. Glashow, Phys. Lett. B 190, 157 (1987); J. Bagger, C. Schmidt, and S. King, Phys. Rev. D 37, 1188–1196 (1988)*
- ✦ **Topgluon** *C.T. Hill, Phys. Lett. B 266, 419 (1991)*
- ✦ **Flavor-universal Coloron** *R.S. Chivukula, A.G. Cohen, & E.H. Simmons, Phys. Lett. B 380, 92 (1996)*
- ✦ **Chiral Color with  $g_L \neq g_R$**  *M.V. Martynov and A.D. Smirnov, Mod. Phys. Lett. A 24, 1897 (2009)*
- ✦ **New Axigluon** *P.H. Frampton, J. Shu, and K. Wang, Phys. Lett. B 683, 294 (2010)*
- ✦ *and many more..*



# Coloron Theory

C.T. Hill (1991)  
R.S. Chivukula  
et. al. (1996)



$$SU(3)_1 \times SU(3)_2$$



$$SU(3)_{\text{diag}}$$

- ➔ 8 massless gauge bosons
- ➔ 8 massive gauge bosons



# Coloron Theory

C.T. Hill (1991)  
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$$SU(3)_1 \times SU(3)_2$$



$$SU(3)_{\text{diag}}$$

QCD

gluons

➔ 8 massless gauge bosons

colorons

➔ 8 massive gauge bosons



# Coloron Theory

$$SU(3)_1 \times SU(3)_2$$

$$\xi_1$$

$$\xi_2$$



$$VEV \equiv f$$

$$SU(3)_{\text{diag}}$$

$$\left( \frac{\xi_2}{\xi_1} \equiv \cot \theta \right)$$



8 gluons

$$g_3 = \xi_1 \cos \theta = \xi_2 \sin \theta$$



8 colorons

$$m_C = \frac{g_3 f}{\sin \theta \cos \theta}$$

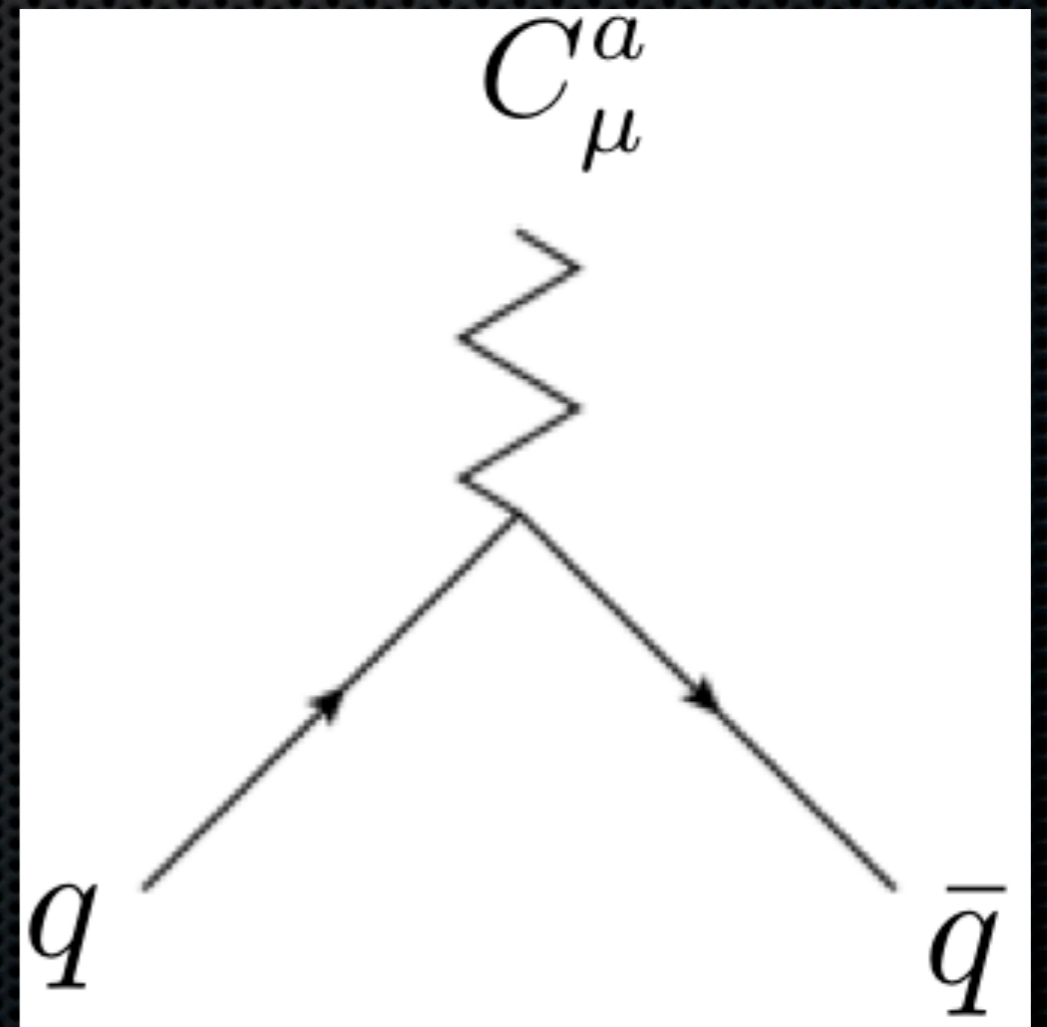


# Coloron Production

- ✦ Use the Narrow-Width Approximation;
- ✦ All the external states are on-shell;
- ✦ General Chiral coupling to the fermions:

$$i\gamma^\mu (g_L P_L + g_R P_R) t^a$$

$$\{g_L, g_R\} \in \{-g_3 \tan \theta, g_3 \cot \theta\}$$

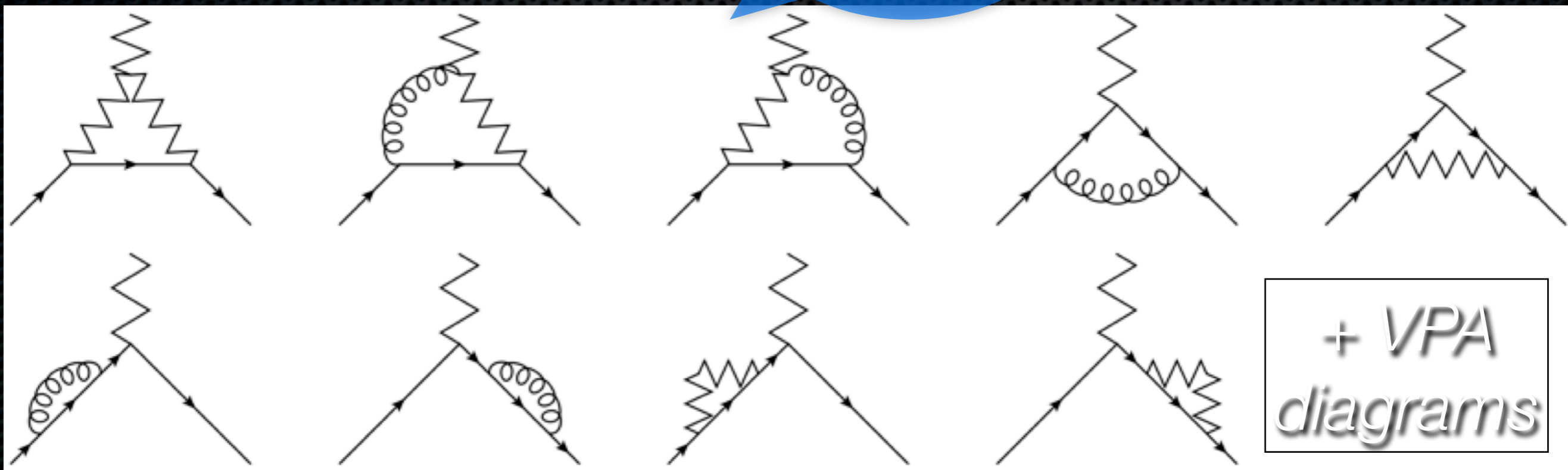




# QCD Virtual Corrections

no  $ggC$ -vertex in  $d4$ -operators!!

UV- & IR-divergent!



Total amplitude  $\propto C_2(r)$  &  $C_2(G)$

$\Rightarrow$  Different than e.g. QCD corrections to  $W$  production!!



# UV-Treatment: *Pinch Technique*



The QED Ward-Identity does not apply in general non-Abelian theories!

→ UV-cancellation between the vertex- and the quark self-energy corrections? **X**





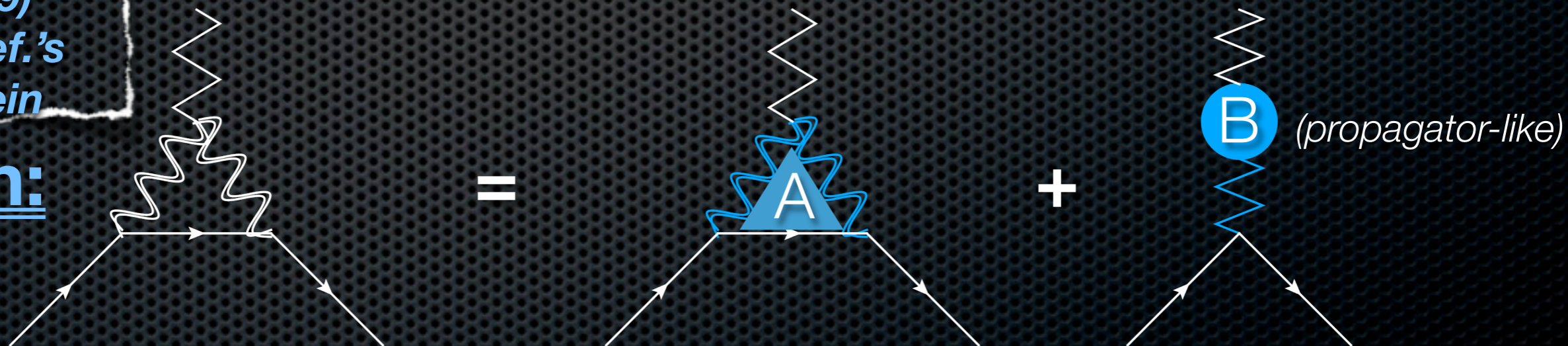
# UV-Treatment: *Pinch Technique*

The QED Ward-Identity does not apply in general non-Abelian theories!

☞ UV-cancellation between the vertex- and the quark self-energy corrections? **✗**

*Binosi & Papavassiliou (2009) and ref.'s therein*

**Pinch:**





# UV-Treatment: *Pinch Technique*

The QED Ward-Identity does not apply in general non-Abelian theories!

UV-cancellation between the vertex- and the quark self-energy corrections? **X**

QED-like WI!

*Binosi & Papavassiliou (2009) and ref.'s therein*

**Pinch:**



UV-cancellation between the vertex- and the quark self-energy corrections? **✓**



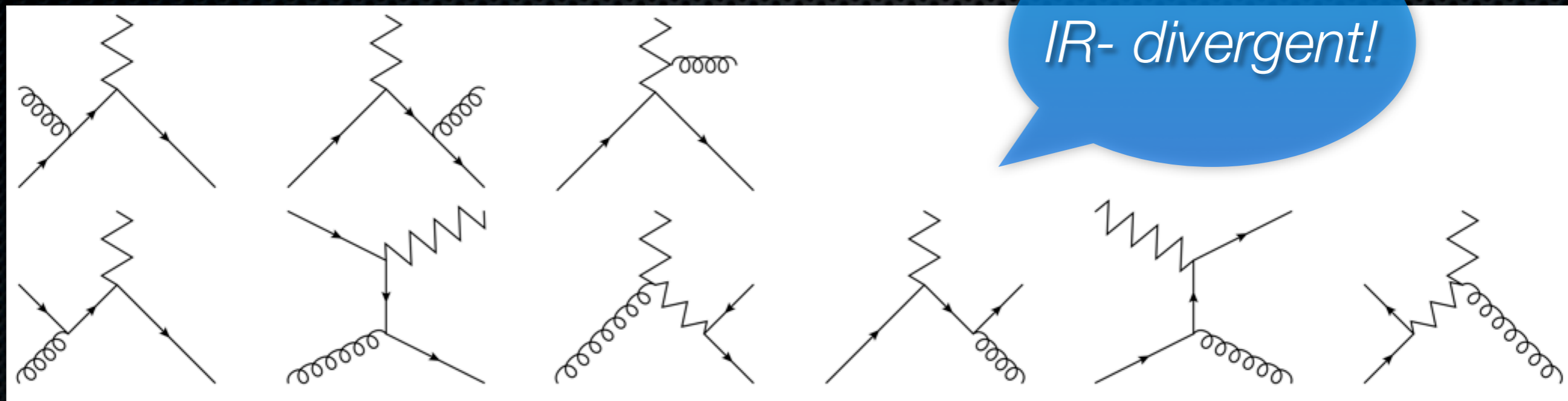
# Virtual Corrections Summary



- ✦ The sum of the **quark self-energy** corrections and the PT-treated **vertex** corrections is **UV-finite**, but contains **IR-divergences**;
- ✦ All the **UV-divergences** are only in the **VPA** diagrams (Pinch Technique), and cancel with counter-terms  
⇒ *Coupling (and mass) renormalization*;
- ✦ **VPA** diagrams are also **IR-divergent**;
- ✦ All the **IR-divergences** must cancel with the **real emission** processes at the cross section level!



# QCD Real Corrections



- ✦ **Gluon emission** (inclusive) cross section: **S**oft and **C**ollinear **D**ivergences  $\Rightarrow$  **SD** supposed to cancel with the IR in the virtual corrections' cross section (each *color factor* independently!), **CD** renormalizes the (anti-)quark *PDF*;
- ✦ **Compton** (inclusive) cross section: Only **CD**  $\Rightarrow$  gluon *PDF* renormalization!



# For Now..



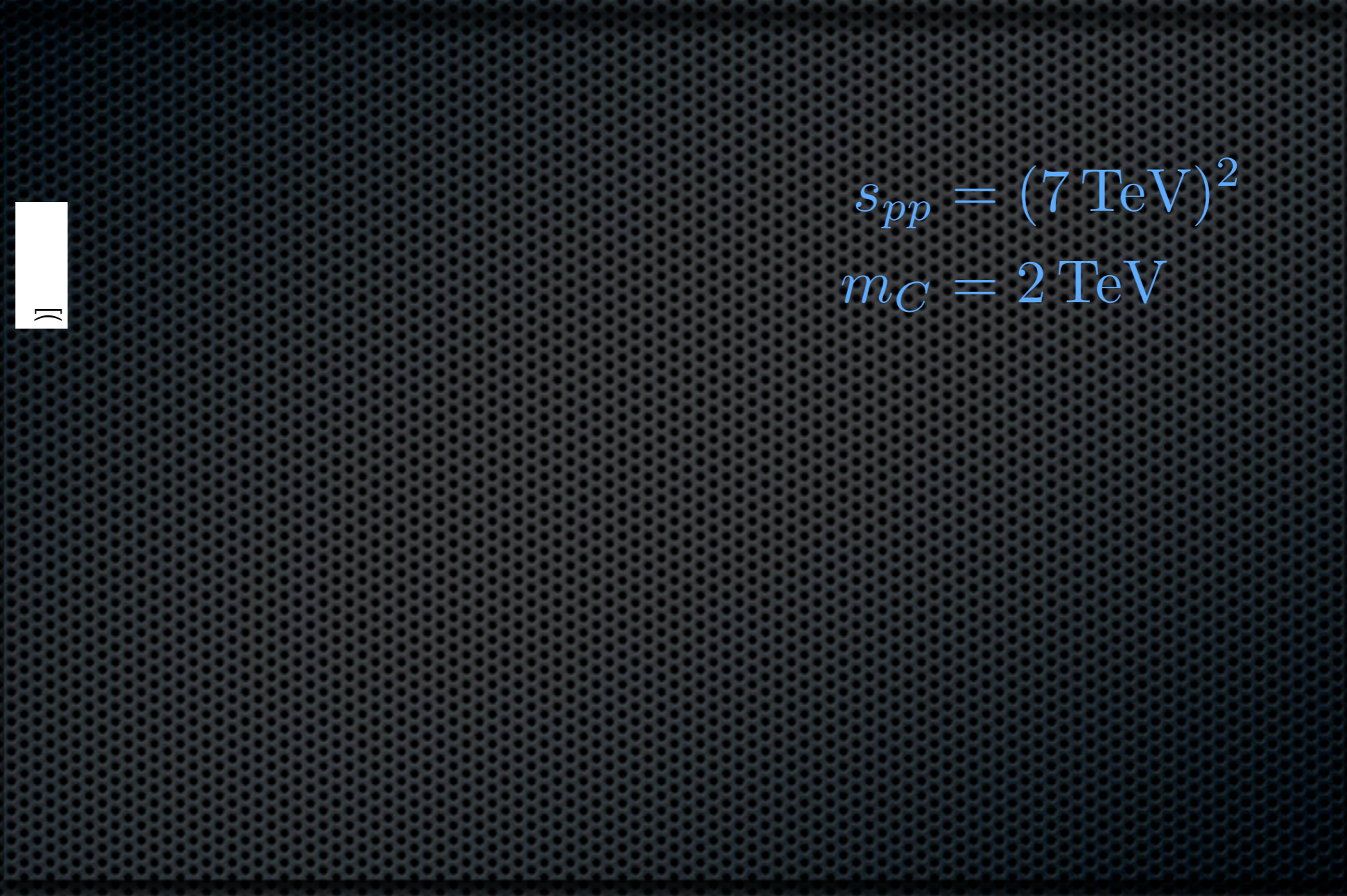
## UNDER CONSTRUCTION



The full calculation of the *inclusive cross section* and *phenomenology analyses* coming soon!!



# Very Preliminary Result



$$s_{pp} = (7 \text{ TeV})^2$$
$$m_C = 2 \text{ TeV}$$

**$P_T$** -distribution of the *Real Emission* (gluon + quark + anti-quark) Cross Section (arbitrary units)



# Summary



- *NLO corrections* to the extended color sector with general chirality (previous work only tree-level, with specific chirality, or vector-like);
- *UV-divergences* only to renormalize coloron coupling (and mass)  
- *Pinch Technique*;
- *IR soft divergences* cancel among the virtual diagrams and the gluon real emission diagrams cross sections;
- *IR collinear divergences* renormalize the (anti-)quark and gluon *PDFs* inside the proton;
- $\alpha_3$ -*corrected* production cross section coming soon!
- *Phenomenology analyses* coming soon!



Thank you...

*..stay tuned!!*





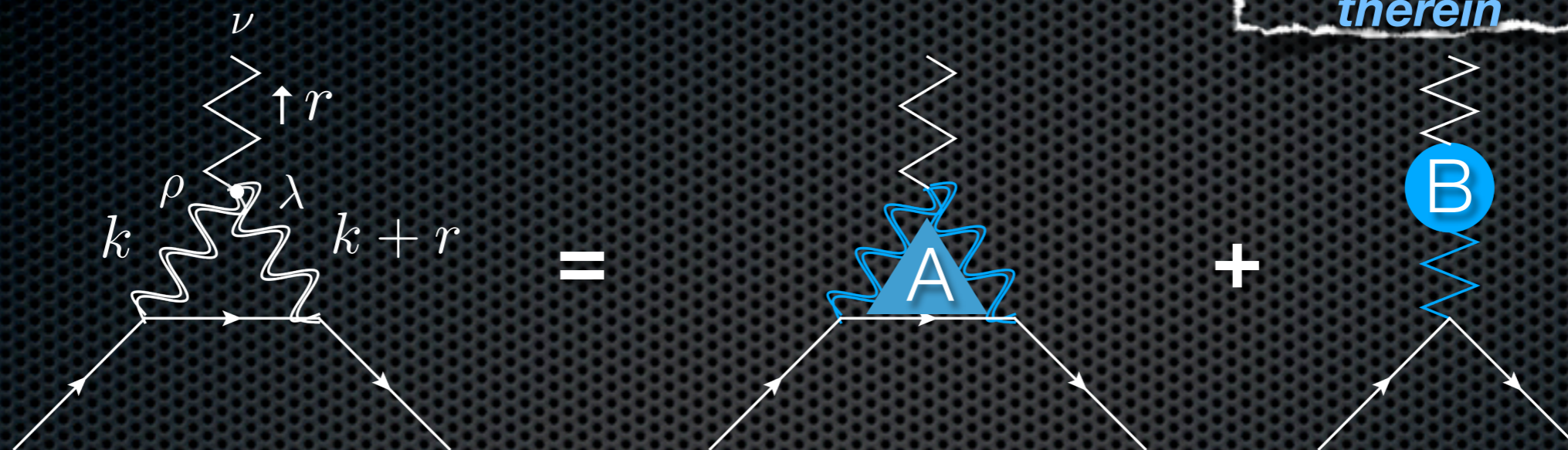


Backups...



# Pinch Technique

Binosi &  
Papavassiliou  
(2009)  
and ref.'s  
therein



$$\Gamma^{\nu\rho\lambda} = (-k + r)^\lambda g^{\nu\rho} + (2k + r)^\nu g^{\rho\lambda} - (2r + k)^\rho g^{\nu\lambda}$$

$$\equiv \Gamma_A^{\nu\rho\lambda} + \Gamma_B^{\nu\rho\lambda}$$

$$\Gamma_A^{\nu\rho\lambda} \equiv (2k + r)^\nu g^{\rho\lambda} + 2r^\lambda g^{\nu\rho} - 2r^\rho g^{\nu\lambda}$$

$$\Gamma_B^{\nu\rho\lambda} \equiv -k^\rho g^{\nu\lambda} - (k + r)^\lambda g^{\nu\rho}$$

👉  $-r_\nu \Gamma_A^{\nu\rho\lambda} = -[(k + r)^2 - k^2] g^{\rho\lambda}$  Each term eliminates a gauge propagator in the full diagram

⇒ construction of a **QED-like WI**

👉 Diagram with  $\Gamma_B$  is propagator-like ⇒ contributes to the VPA