Detailed analysis of p+p elastic scattering $d\sigma/dt$ data

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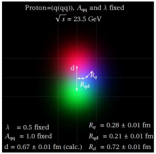
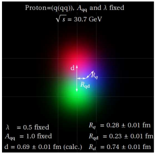
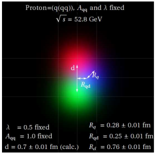
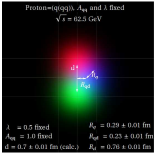
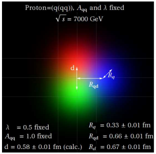
December 3, 2012



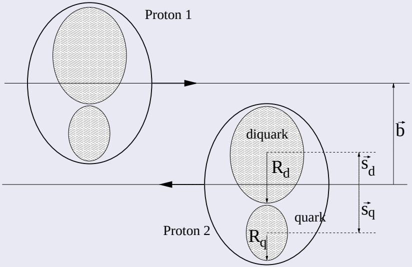








The scattering situation



The cross section

The **inelastic** $p + p$ cross-section for a fixed impact parameter b

$$\sigma(b) = \int d^2 s_q d^2 s'_q d^2 s_d d^2 s'_d D(s_q, s_d) D(s'_q, s'_d) \sigma(s_q, s_d; s'_q, s'_d; b) \tag{1}$$

A. Bialas, A. Bzdak, ActaPhys.Polon. B38:159-168,2007

Ingredients...

- Gaussian quark-diquark distribution

$$D\left(s_q, s_d\right) = \frac{1+\lambda^2}{\pi R_{qd}^2} e^{-\left(s_q^2+s_d^2\right)/R_{qd}^2} \delta^2\left(s_d + \lambda s_q\right), \lambda = m_q/m_d \quad (2)$$

- Probability of interaction

$$1-\sigma\left(s_q, s_d; s_q', s_d'; b\right) = \prod_{a,b\in\{q,d\}} 1-\sigma_{ab}\left(b+s_a'-s_b'\right) \quad (3)$$

$$\sigma_{ab}\left(s\right) \equiv d^2\sigma_{ab}\left(s\right)/d^2 s = A_{ab} e^{-s^2/\left(R_a+R_b\right)} \quad (4)$$

R. J. Glauber, Lectures in Theoretical Physics, Vol. 1. Interscience, New York 1959.

W. Czyz, L. C. Maximon, Ann. of Phys. 52 (1969) 59.

dσ/dt

From unitarity the elastic amplitude

$$t_{el}\left(b\right)=1-\sqrt{1-\sigma\left(b\right)} \tag{5}$$

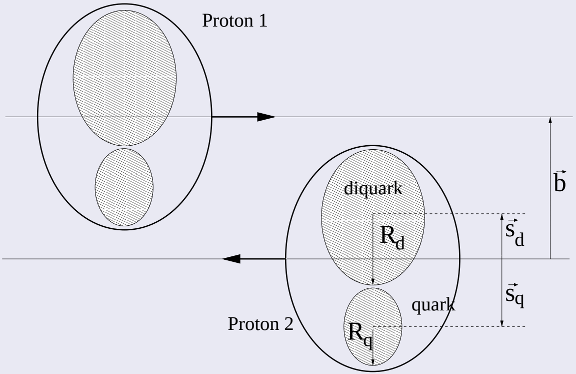
Elastic amplitude in momentum space

$$T\left(\Delta\right)=\int t_{el}\left(b\right)e^{i\vec{\Delta}\cdot\vec{b}}d^2b=2\pi\int t_{el}\left(b\right)J_0\left(\Delta b\right)bdb \tag{6}$$

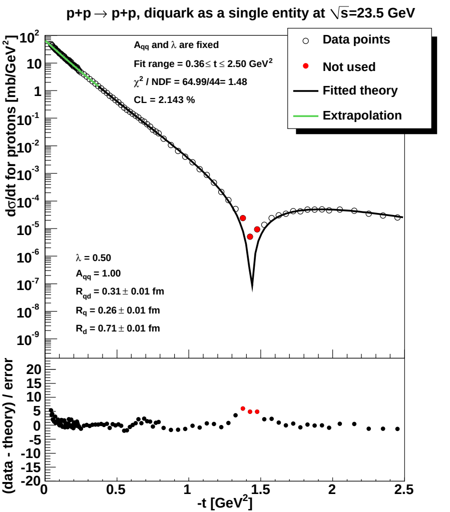
Since $t\simeq-\left|\Delta\right|^2$

$$\frac{d\sigma}{dt}=\frac{1}{4\pi}\left|T\left(\Delta\right)\right|^2 \tag{7}$$

The scattering when the diquark is a single entity



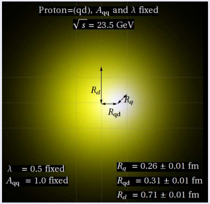
Fitted th. curve at 23 GeV ISR



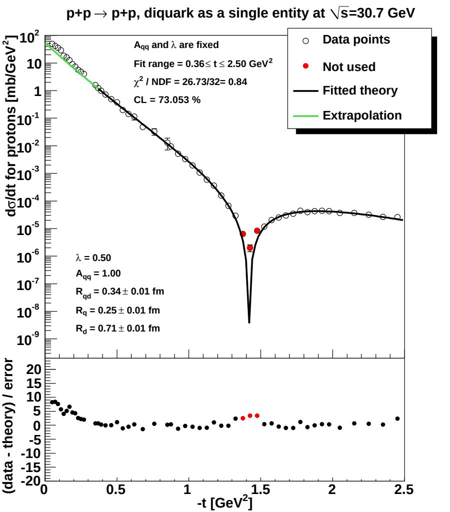
MINUIT parameters

CL	2.1 %
R_{qd}	0.31 ± 0.01 fm
R_{quark}	0.26 ± 0.01 fm
$R_{diquark}$	0.71 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



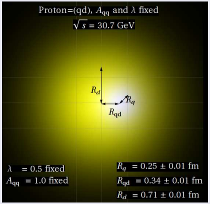
Fitted th. curve at 31 GeV ISR



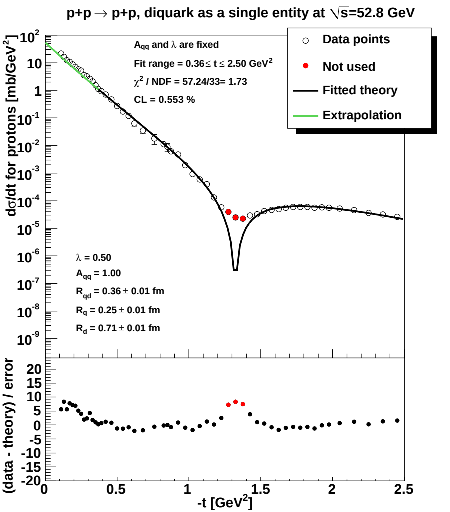
MINUIT parameters

CL	73.1 %
R_{qd}	0.34 ± 0.01 fm
R_{quark}	0.25 ± 0.01 fm
$R_{diquark}$	0.71 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



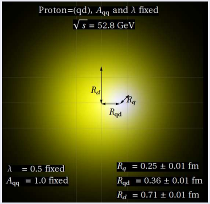
Fitted th. curve at 53 GeV ISR



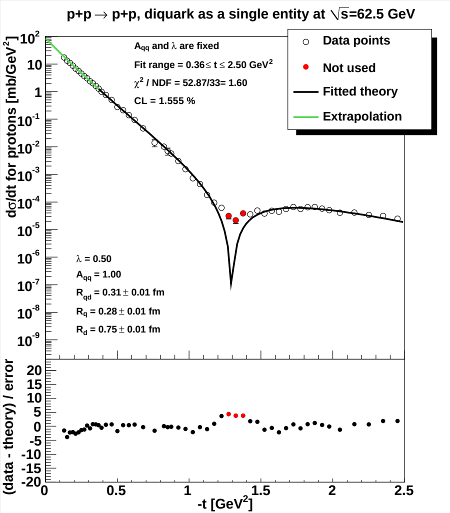
MINUIT parameters

CL	0.6 %
R_{qd}	0.36 ± 0.01 fm
R_{quark}	0.25 ± 0.01 fm
$R_{diquark}$	0.71 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



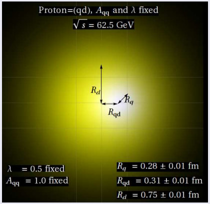
Fitted th. curve at 62 GeV ISR



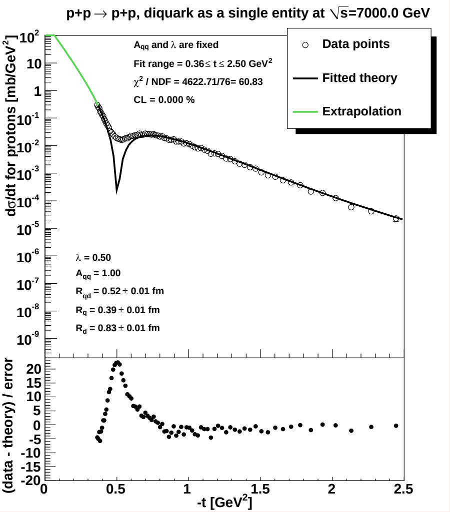
MINUIT parameters

CL	1.6 %
R_{qd}	0.31 ± 0.01 fm
R_{quark}	0.28 ± 0.01 fm
$R_{diquark}$	0.75 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



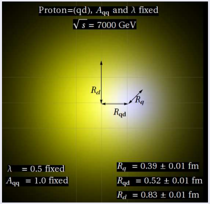
Fitted th. curve at 7 TeV TOTEM



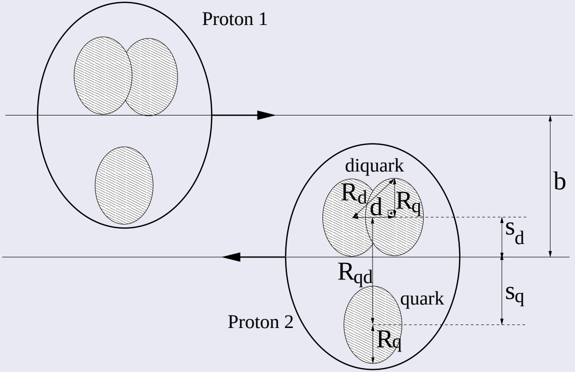
MINUIT parameters

CL	0.0 %
R_{qd}	0.52 ± 0.01 fm
R_{quark}	0.39 ± 0.01 fm
$R_{diquark}$	0.83 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



The scattering when the diquark is a composite object



Diquark is a composite object

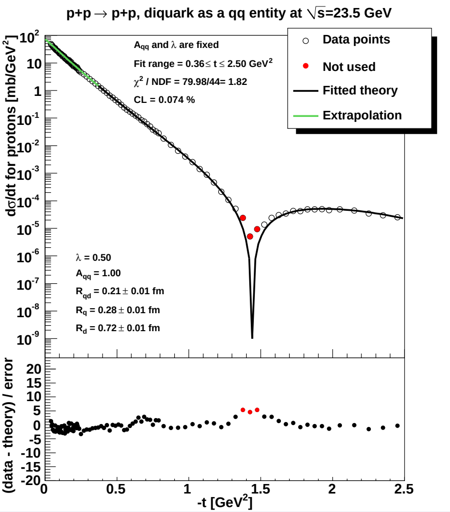
The quark distribution inside the **diquark**

$$D\left(s_{q1},s_{q2}\right)=\frac{1}{\pi d^2}e^{-\left(s_{q1}^2+s_{q2}^2\right)/2d^2}\delta^2\left(s_{q1}+s_{q2}\right) \tag{8}$$

$$\Rightarrow \sigma_{qd}\left(s\right)=\frac{4A_{qq}R_q^2}{R_d^2+R_q^2}e^{-s^2\frac{1}{R_d^2+R_q^2}}-\frac{A_{qq}^2R_q^2}{R_d^2}e^{-s^2/R_q^2} \tag{9}$$

$$\Rightarrow \sigma_{dd} \text{ is similar (not shown)...} \tag{10}$$

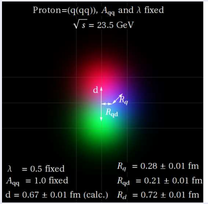
Fitted th. curve at 23 GeV ISR



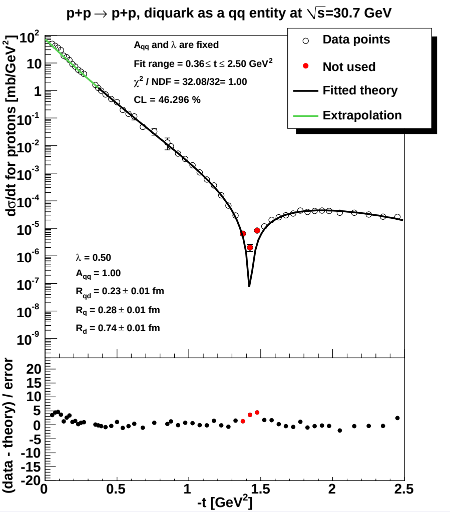
MINUIT parameters

CL	0.1 %
R_{qd}	0.21 ± 0.01 fm
R_{quark}	0.28 ± 0.01 fm
$R_{diquark}$	0.72 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



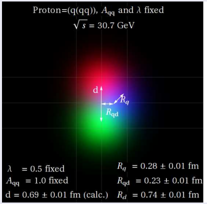
Fitted th. curve at 31 GeV ISR



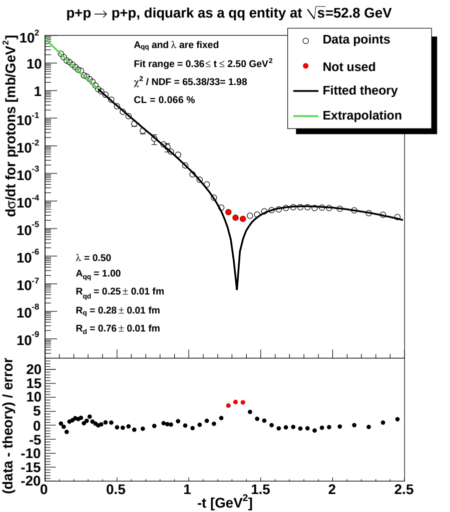
MINUIT parameters

CL	46.3 %
R_{qd}	0.23 ± 0.01 fm
R_{quark}	0.28 ± 0.01 fm
$R_{diquark}$	0.74 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



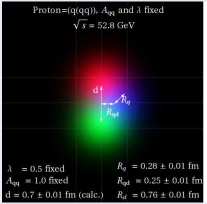
Fitted th. curve at 53 GeV ISR



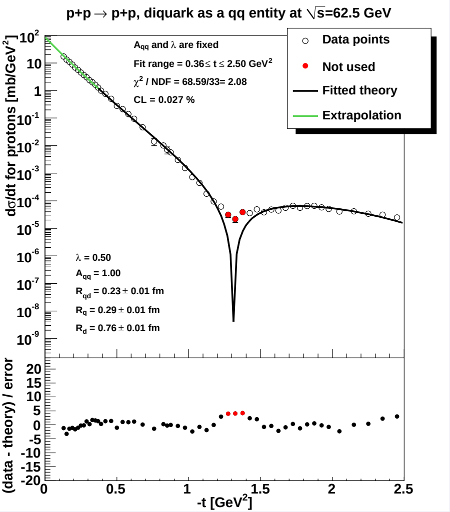
MINUIT parameters

CL	0.1 %
R_{qd}	0.25 ± 0.01 fm
R_{quark}	0.28 ± 0.01 fm
$R_{diquark}$	0.76 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



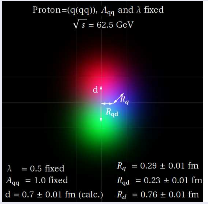
Fitted th. curve at 62 GeV ISR



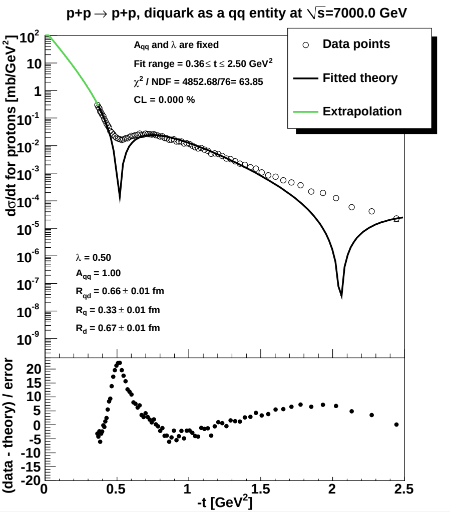
MINUIT parameters

CL	0.0 %
R_{qd}	0.23 ± 0.01 fm
R_{quark}	0.29 ± 0.01 fm
$R_{diquark}$	0.76 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



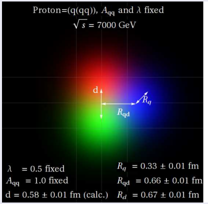
Fitted th. curve at 7 TeV TOTEM



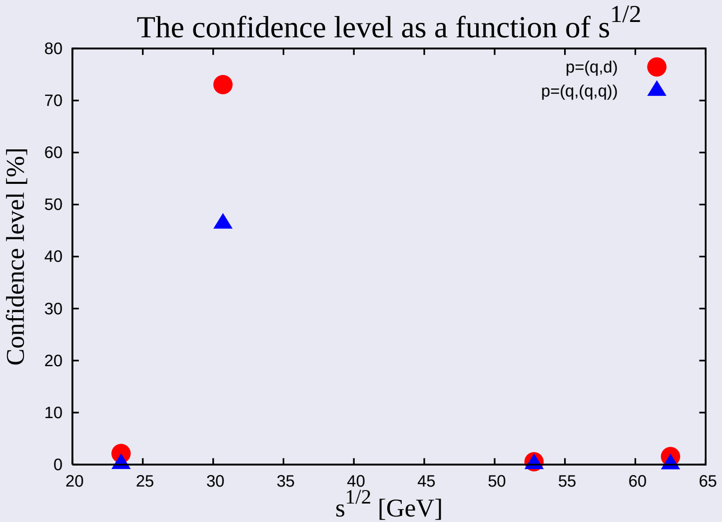
MINUIT parameters

CL	0.0 %
R_{qd}	0.66 ± 0.01 fm
R_{quark}	0.33 ± 0.01 fm
$R_{diquark}$	0.67 ± 0.01 fm
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

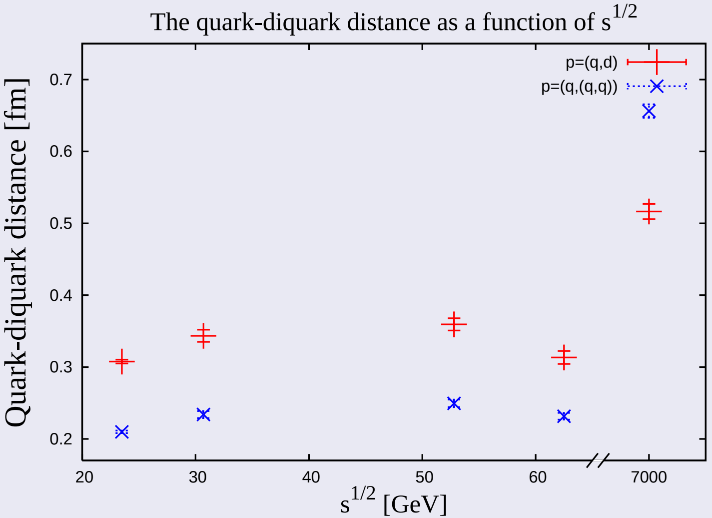
Visualisation



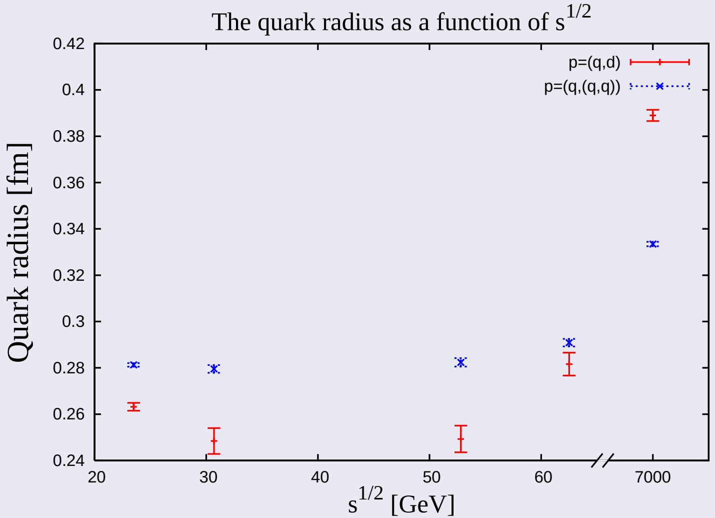
The confidence level over $\sqrt{s}$



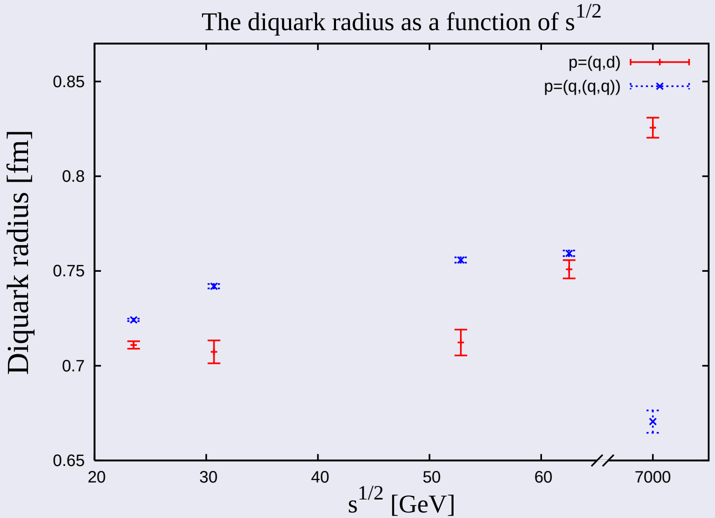
The proton radius over $\sqrt{s}$



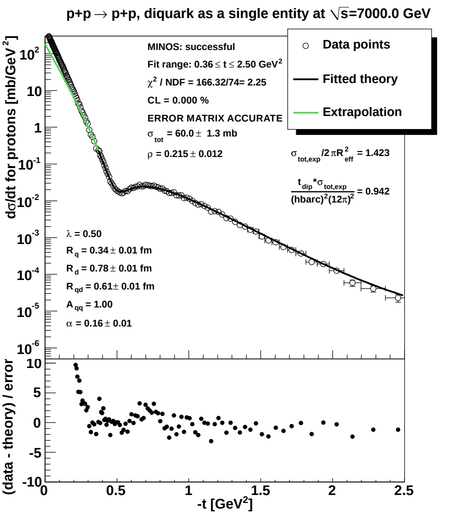
The quark radius over $\sqrt{s}$



The diquark radius over $\sqrt{s}$



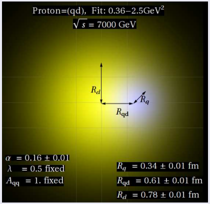
With complex amplitude...



MINUIT parameters

CL	0.0 %
R_q	0.34 ± 0.01 fm
$R_{diquark}$	0.78 ± 0.01 fm
R_{qd}	0.61 ± 0.01 fm
α	0.16 ± 0.01
λ	0.50 (fixed)
A_{qq}	1.00 (fixed)

Visualisation



Conclusions...

Systematic study of fit quality as well as the fit parameters under similar circumstances has been performed for the Bialas - Bzdak model in a wide energy range from ISR to LHC energies.

- Partial description of the data.
- Proton seems to grow with energy but CL is bad at 7 TeV.
- Best result was obtained if the A_{qq} amplitude is fixed to 1.
- Better description and results with **complex** amplitude.

Acknowledgement

Thank you for your attention !