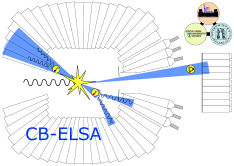
The Production of Baryon Resonances using Real Photons

Andrew Wilson

Universtät Bonn, Bonn, Germany

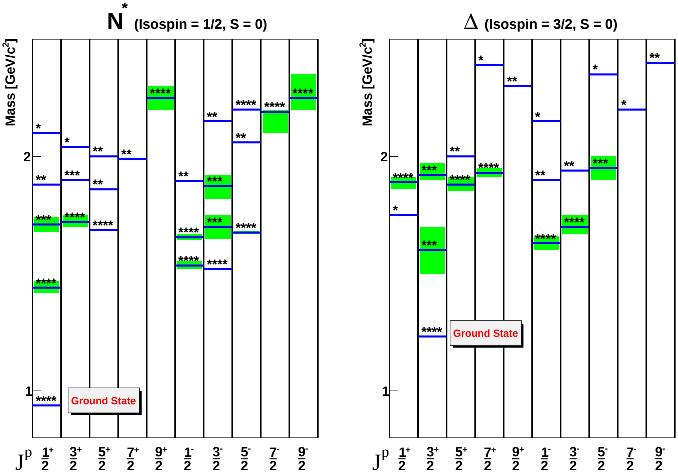
October 5-12, 2013
EMMI Rapid Reaction Meeting

universitätbonn
Rheinische
Friedrich-Wilhelms-
Universität Bonn



Currently Known Light Quark Baryons

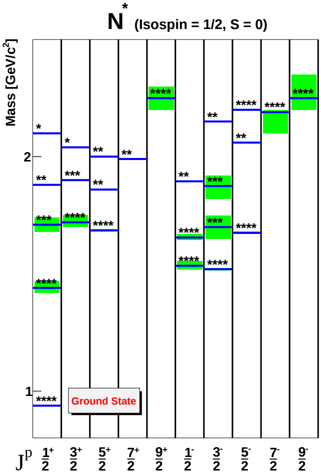
J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)

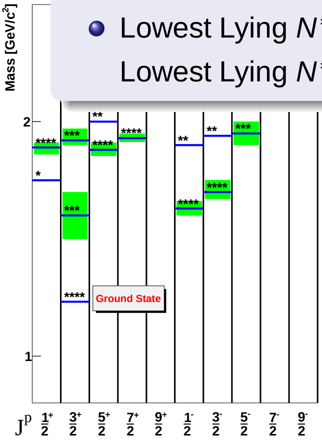


Mass uncertainty only reported for *** and **** resonances

Currently Known Light Quark Baryons

J. Beringer et al. (Particle Data Group), P





Issues to Notice

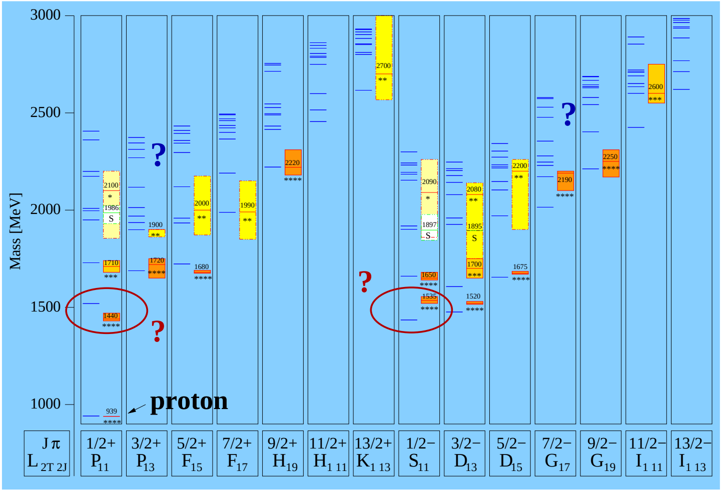
- Parity doublets
- Lowest Lying $N^* \frac{1}{2}^+ <$ Lowest Lying $N^* \frac{1}{2}^-$

Mass uncertainty only reported for *** and **** resonances

Constituent Quark Models

N^* Spectrum (Isospin=$\frac{1}{2}$, S = 0)

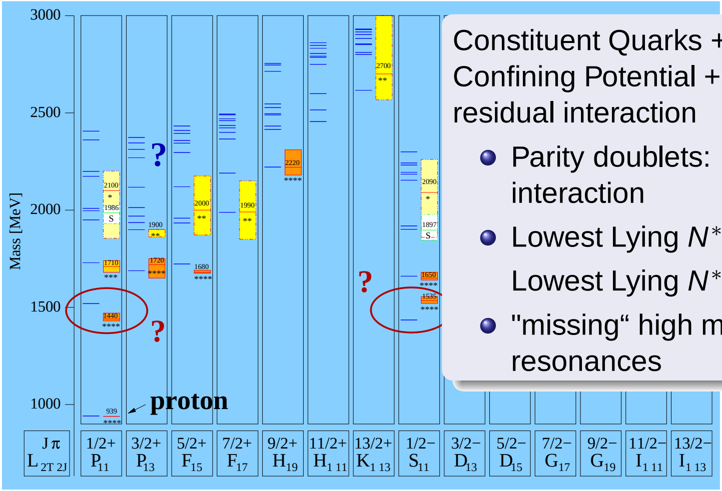
U. Loring, B. C. Metsch and H. R. Petry, Eur. Phys. J. A **10** (2001) 395



Constituent Quark Models

N^* Spectrum (Isospin=$\frac{1}{2}$, S = 0)

U. Loring, B. C. Metsch and H. R. Petry, Eur. Phys. J. A **10** (2001) 395



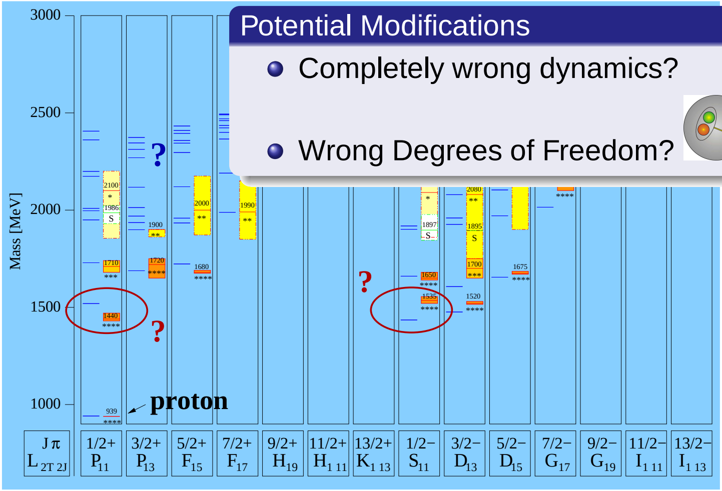
Constituent Quarks + Confining Potential + residual interaction

- Parity doublets: ’t Hoof interaction
- Lowest Lying $N^*\ \frac{1}{2}^+$ < Lowest Lying $N^*\ \frac{1}{2}^-$
- "missing“ high mass resonances

Constituent Quark Models

N^* Spectrum (Isospin=$\frac{1}{2}$, S = 0)

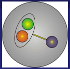
U. Loring, B. C. Metsch and H. R. Petry, Eur. Phys. J. A **10** (2001) 395



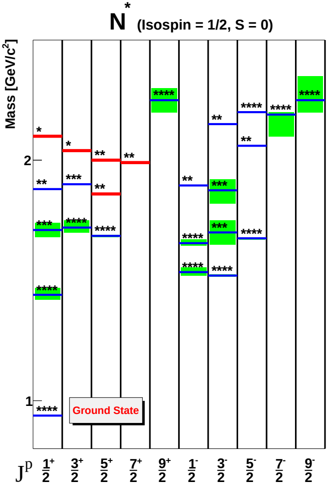
Potential Modifications

- Completely wrong dynamics?
- Wrong Degrees of Freedom?

Diquark Models



V. Crede and W. Roberts, Rept. Prog. Phys. **76** (2013) 076301.



Reduces number of states

Possibly restricts too much!

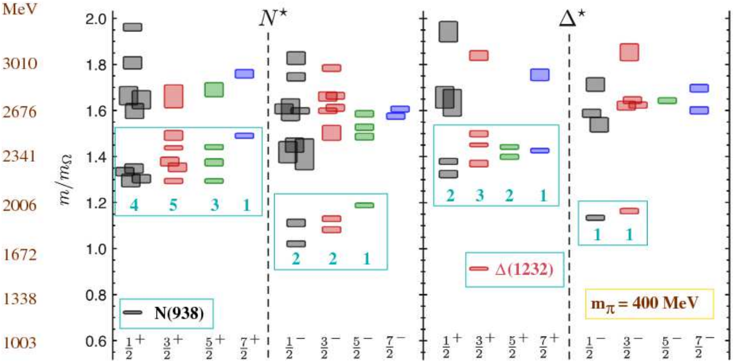
The highlighted states can not be identified in diquark models.

However, all highlighted states are not well established.

Solving QCD Lagrangian on the Lattice

- Unphysical π mass with no guarantee of behavior at physical mass
- Lattice Results similar counting to Symmetric quark models.
- N^* Lowest Lying $\frac{1}{2}^+ < N^*$ Lowest Lying $\frac{1}{2}^-$

Using Chiral perturbation theory to extrapolate. (unreliable so far)



R.Edwards et al.,
Phys. Rev. D84 (2011) 074508

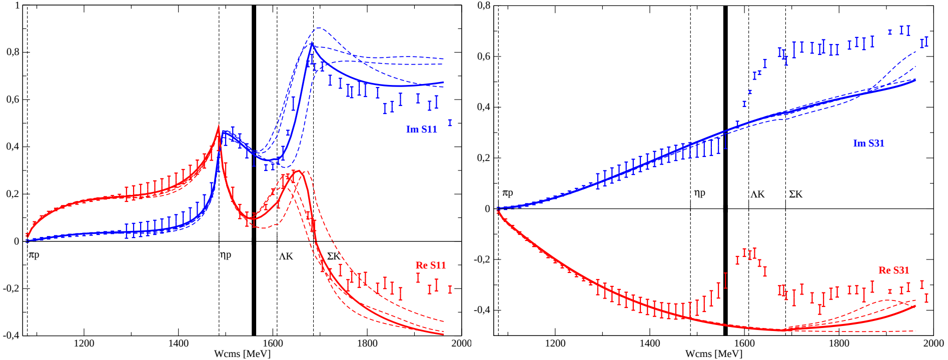
Dynamically Generated Resonances

Reasons for N^* Lowest Lying $\frac{1}{2}^+ < N^*$ Lowest Lying $\frac{1}{2}^-$

$N(1440)\frac{1}{2}^- \rightarrow N\pi$ molecular state?

$N(1535)\frac{1}{2}^+ \rightarrow N\eta$, $K\Sigma$ or ΛK molecular state?

Possible, mixing with quark model state to shift the observed mass



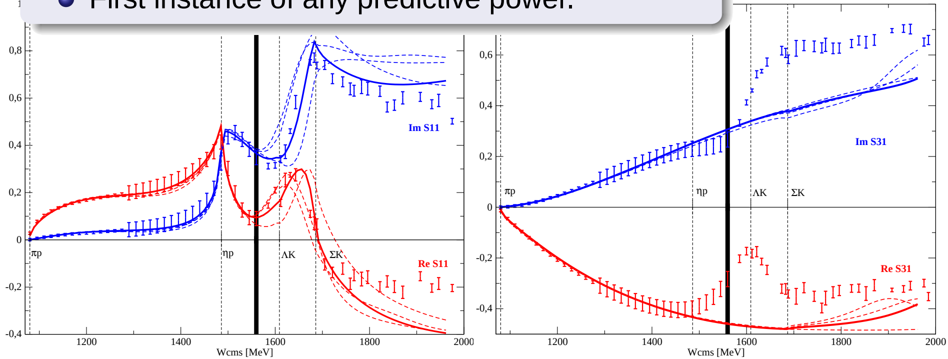
P. C. Bruns, M. Mai and U. G. Meissner, Phys. Lett. B **697** (2011) 254.

Dynamically Generated Resonances

Solving the Bethe-Salpeter Equation + χPT

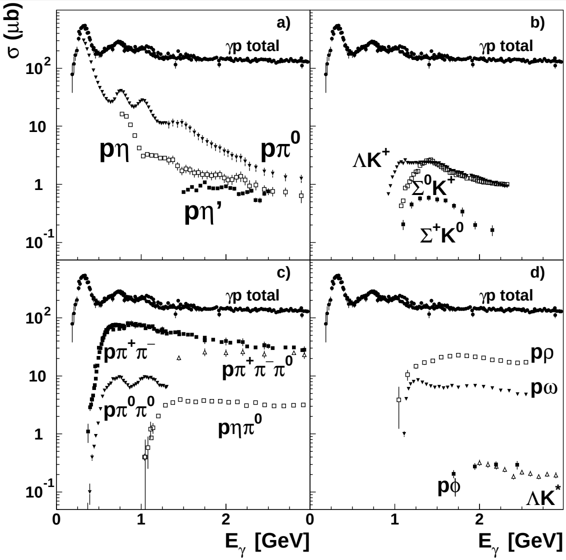
- Fit to elastic πN scattering waves (SAID)
- Fit to $N(1535)\frac{1}{2}^-$ describes $N(1650)\frac{1}{2}^+$
- Does not describe $\Delta(1650)\frac{1}{2}^+$
- First instance of any predictive power.

e observed



P. C. Bruns, M. Mai and U. G. Meissner, Phys. Lett. B **697** (2011) 254.

Resonance Production by Photons



E. Klempt and J. -M. Richard, Rev. Mod. Phys. **82** (2010) 1095.

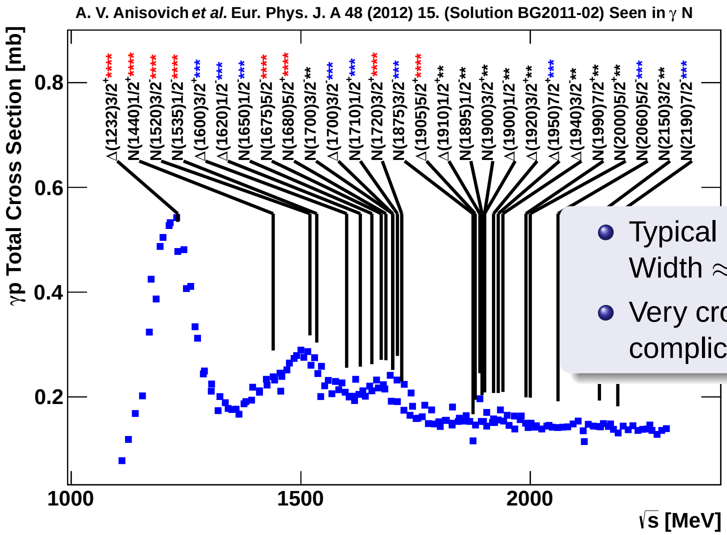
Expected Mechanisms

- Virtual Meson Interaction (VMD or t-channel)
- Electromagnetic interactions with quark degrees of freedom

Overall Characteristics

- Threshold Baryon Resonance Production
- *t*-channel / diffractive Production
- Multiparticle Final States dominate large energies

Resonance Production by Photons (BnGa)



- Typical Resonance Width ≈ 100 MeV
- Very crowded and complicated space

Polarization Observables

The helicity amplitudes must be measured independently binned all kinematic variables.

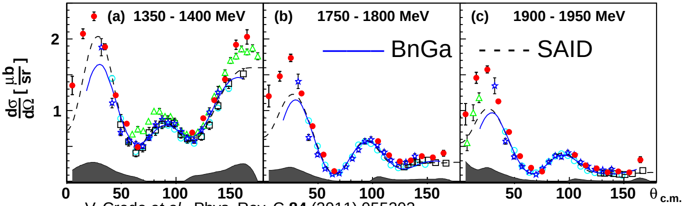
Two-body Final State Polarization Observables

Photon polarization		Target polarization			Recoil nucleon polarization			Target and recoil polarizations			
		X	Y	Z(beam)	X'	Y'	Z'	X' X	X' Z	Z' X	Z' Z
unpolarized	σ	-	**T**	-	-	**P**	-	**T_x**	**L_x**	**T_z**	**L_z**
linear	Σ	**H**	(-P)	**G**	**O_x**	(-T)	**O_z**	($-L_z$)	(T_z)	(L_x)	($-T_x$)
circular	-	**F**	-	**E**	**C_x**	-	**C_z**	-	-	-	-

Single Polarization Observables

Double Polarization Observables

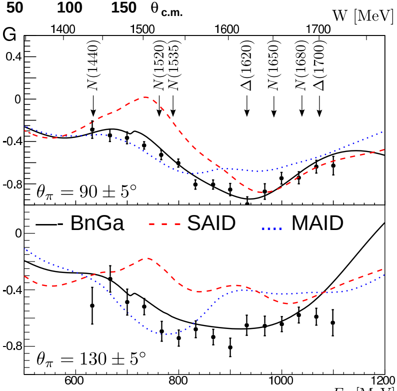
π^0 Meson Photoproduction : Well known?



V. Crede *et al.*, Phys. Rev. C **84** (2011) 055203.

$\gamma p \rightarrow p\pi^0$

- Most well know reaction
- PWA's describe Differential Cross Sections well.
- Polarized Observables provide more information to constrain PWA solutions.

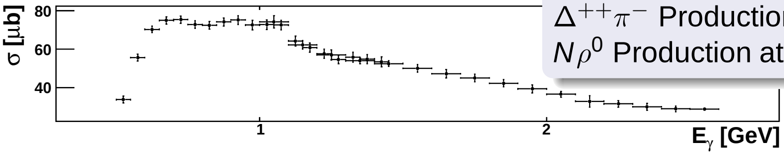


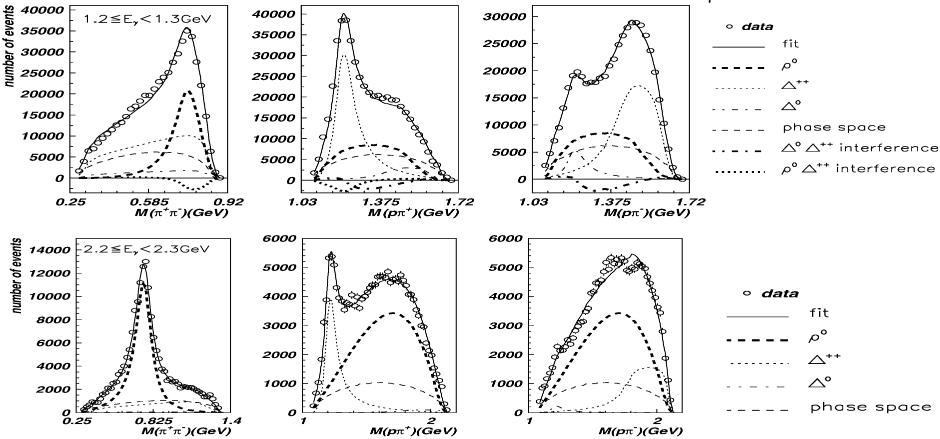
A. Thiel, Phys. Rev. Lett. **109** (2012) 102001.

G: transversely polarized beam photons / longitudinally polarized protons

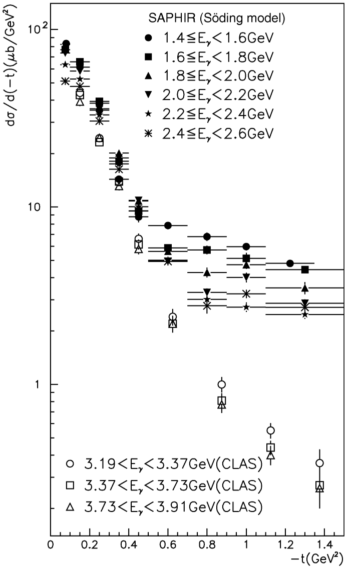
$\gamma p \to p\pi^+\pi^-$ (SAPHIR)

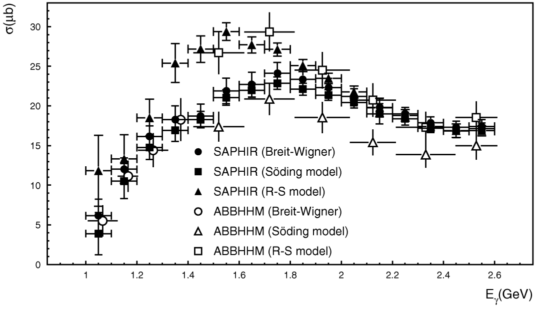
$\Delta^{++}\pi^-$ Production at low E.
$N\rho^0$ Production at higher E.





$\gamma p \to p\rho^0$ (SAPHIR)

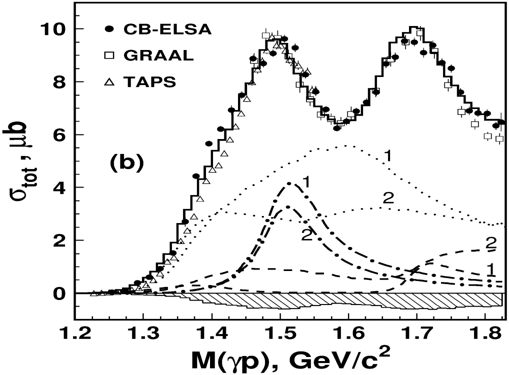




- Large *t*-channel contribution.
- Some resonance contributions can be seen.

C. Wu *et al.*, Eur. Phys. J. A **23** (2005) 317.

$\gamma p \to p\pi^0\pi^0$



A. V. Sarantsev*et al.*, Phys. Lett. B **659** (2008) 94.

Solution 2 has been favored.

D_{33} or $\Delta\frac{1}{2}^+$ dotted line

P_{11} or $N\frac{1}{2}^+$ dashed line

D_{13} or $N\frac{3}{2}^-$ dashed-dotted line

D_{33} - D_{13} interference causes dip between peaks.

Largest Contributions

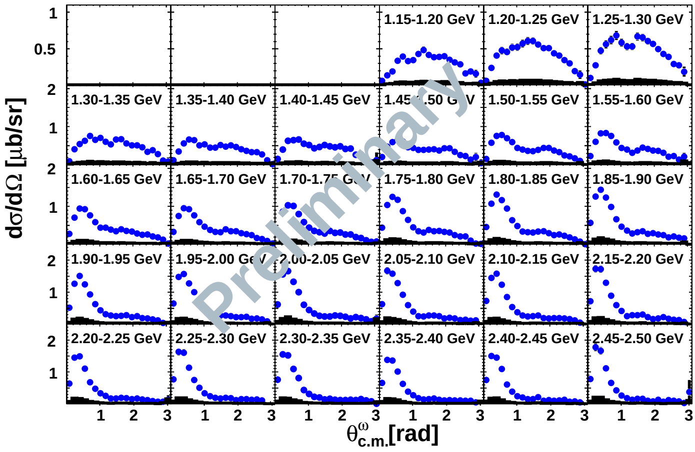
P_{11}: $N(1440)\frac{1}{2}^+ \to N\pi, N\sigma, \Delta\pi$, $N(1840)\frac{1}{2}^+$

D_{13}: $N(1520)\frac{3}{2}^-$

D_{33}: $\Delta(1700)\frac{3}{2}^+$

$\gamma p \rightarrow p\omega$

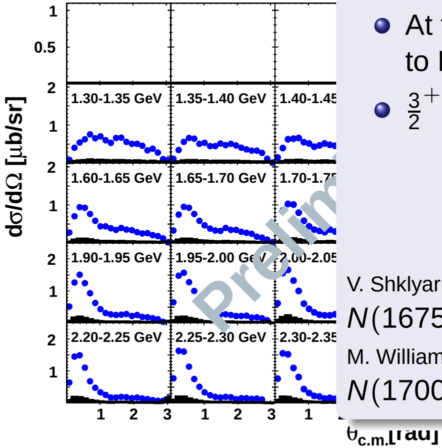
My own research $\rightarrow$ to be published soon.



Labeled with incoming photon energy.

$\gamma p \to p\omega$

My own research → to be |



BnGa Analysis

- Pomeron exchange is large overall.
- At threshold, $\frac{3}{2}^-$ wave is equivalent to Pomeron exchange.
- $\frac{3}{2}^+$ and $\frac{5}{2}^-$ waves are significant.

Earlier Analyses
Threshold Contributions

V. Shklyar *et al.*,Phys. Rev. C **71** (2005) 055206.
$N(1675)\frac{5}{2}^-$, $N(1680)\frac{5}{2}^+$

M. Williams *et al.* Phys. Rev. C **80** (2009) 065209.
$N(1700)\frac{3}{2}^-$, $N(1685)\frac{5}{2}^+$

Labeled with incoming photon energy.

- Large amount of recent photoproduction results in process of being published
- PWA Solution Refinement coming?
- Higher multiplicities and heavier particle final states?

Thank you