Search for Hybrid Baryons with CLAS12 experimental setup

Baryons 2016

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Outline

Physics motivation: Search of Hybrid Baryons contributions in the low Q^2 evolution of the cross section for $K^{+}\Lambda$ electro-production in CLAS12

- Endorsement of a LoI by the Program Advisory Committee, PAC43.
- PAC44 Proposal

• **CLAS12 and FT @ JLAB**: experimental setup description.

• **Simulation and fast mc reconstruction** of $K^{+}\Lambda$ electro-production events in CLAS12

• **Sensitivity to electrocouplings**: statistical significance, Legendre moments, hybrid baryon mass blind fitting analysis to study the sensitivity of our system to the presence of an hybrid contribution

Hybrid Baryons

Hybrid Baryons: baryons with explicit gluonic degrees of freedom

Augmenting the quarks q by gluons g leads to **additional states** in the spectrum relative to the expectations of the naive quark model. Phisically allowed (color singlets) states in the baryon spectrum may be constructed from |qqqg> «hybrid» basis states, in addition to the familiar |qqq> quark model states:

$|qqq\rangle|_{color} = 1 \otimes 8 \otimes 8 \otimes 10$,

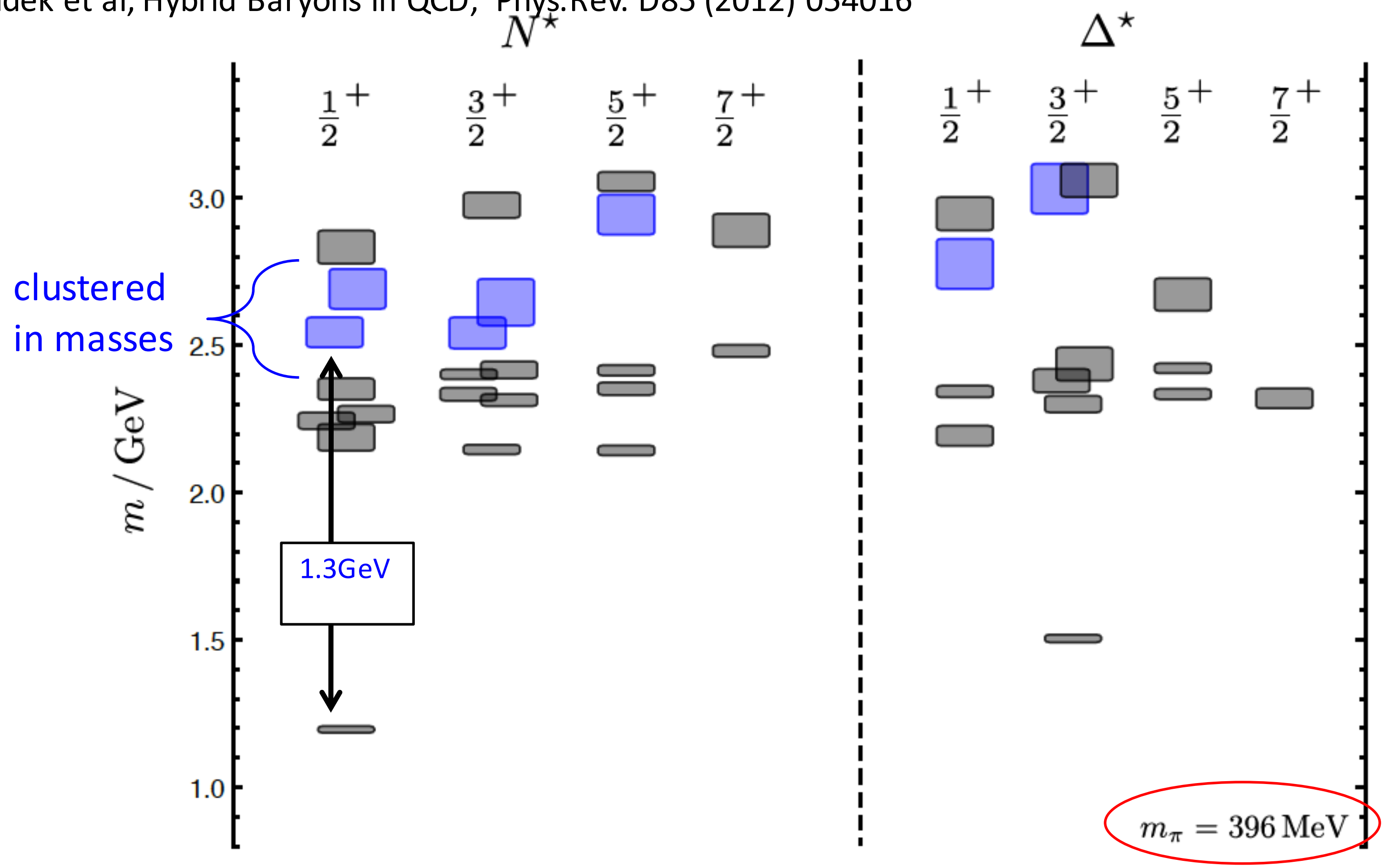
$|qqqg\rangle|_{color} = (1 \otimes 8 \otimes 8 \otimes 10) \otimes 8$

Hybrid Baryons in LQCD

QCD allows for the existence of Hybrid Baryons.

LQCD predicts several hybrid baryons states.

J. Dudek et al, Hybrid Baryons in QCD, Phys.Rev. D85 (2012) 054016



Regular states

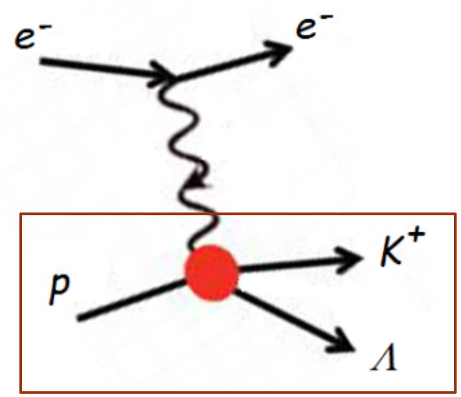
Hybrid states

The nucleon mass is shifted ~300 MeV to higher masses

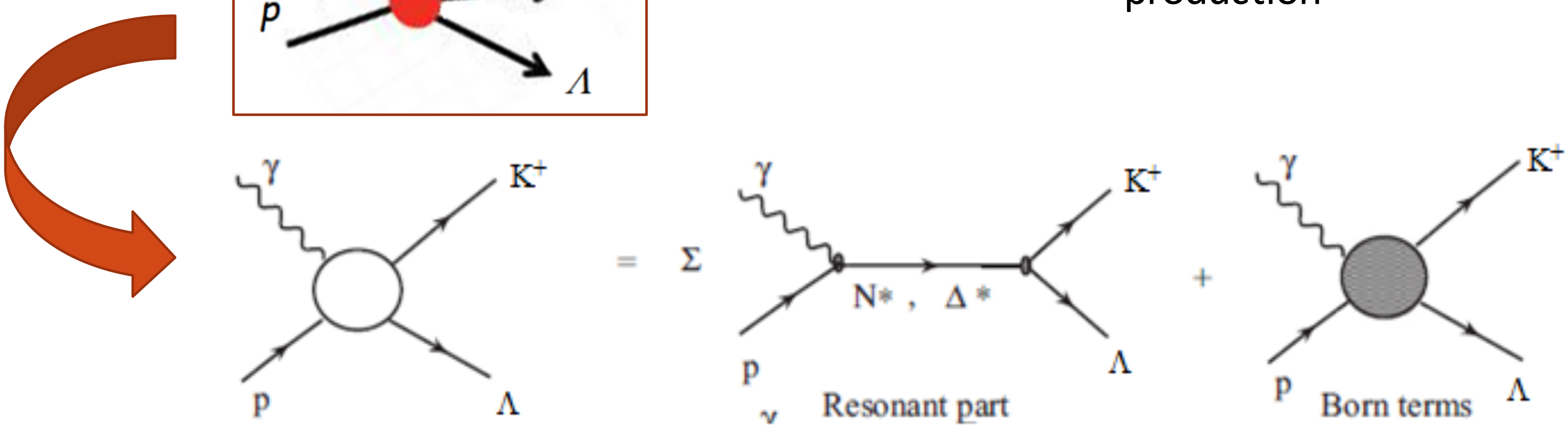
Differently from the case of hybrid mesons, hybrid baryons are predicted to have **same quantum numbers** of N* resonances

Separating Q^3G from Q^3 states: $A_{1/2,\,3/2}(Q^2)$ and $S_{1/2}(Q^2)$

Transverse elicity amplitude $A_{1/2}(Q^2)$, $A_{3/2}(Q^2)$ and longitudinal elicity amplitude $S_{1/2}(Q^2)$ allow to distinguish Q^3G from Q^3 states

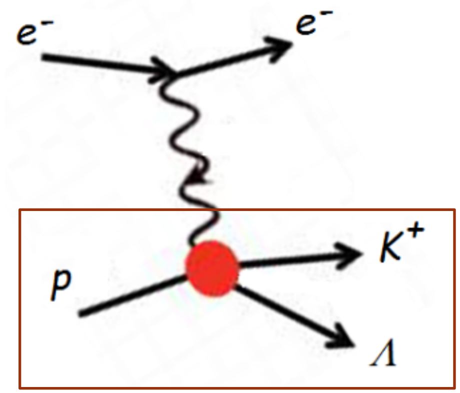


Electroexcitation via quasi-real photon exchange can be considered for practical purposes photo-production



V. I. Mokeev, CLAS Collaboration, PHYSICAL REVIEW C 86, 035203 (2012)

Separating Q^3G from Q^3 states: $A_{1/2,\,3/2}(Q^2)$ and $S_{1/2}(Q^2)$



Resonant contribution in the helicity rapresentation

Helicities of final state hadrons

Helicities of γ and p

N* helicity = $\lambda_\gamma - \lambda_p$

$$\langle \lambda_f | T_r | \lambda_\gamma \lambda_p \rangle = \sum_{N^*} \frac{\boxed{\langle \lambda_f | T_{dec} | \lambda_R \rangle} \boxed{\langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle}}{M_r^2 - W^2 - i\Gamma_r(W) M_r}$$ where

Resonance mass

Invariant mass

Energy dependent total width

The N^* **hadronic decay amplitudes** can be expanded in **partial waves** of total momentum J

$$\langle \lambda_f | T_{dec} | \lambda_R \rangle = \langle \lambda_f | T^{J_r}_{dec} | \lambda_R \rangle d^{J_r}_{\mu\nu}(\cos\theta^*) e^{i\mu\phi^*}$$ where $$\langle \lambda_f | T^{J_r}_{dec} | \lambda_R \rangle = \frac{2\sqrt{2\pi}\sqrt{2J_r+1} M_r \sqrt{\Gamma_{\lambda_f}}}{\sqrt{\langle p_i^r \rangle}} \sqrt{\frac{\langle p_i^r \rangle}{\langle p_i \rangle}}$$

The **resonance electroexcitation amplitudes** can be related to the $\gamma_v NN^*$ electrocouplings $\mathbf{A_{1/2}}$, $\mathbf{A_{3/2}}$, and $\mathbf{S_{1/2}}$ for nucleons

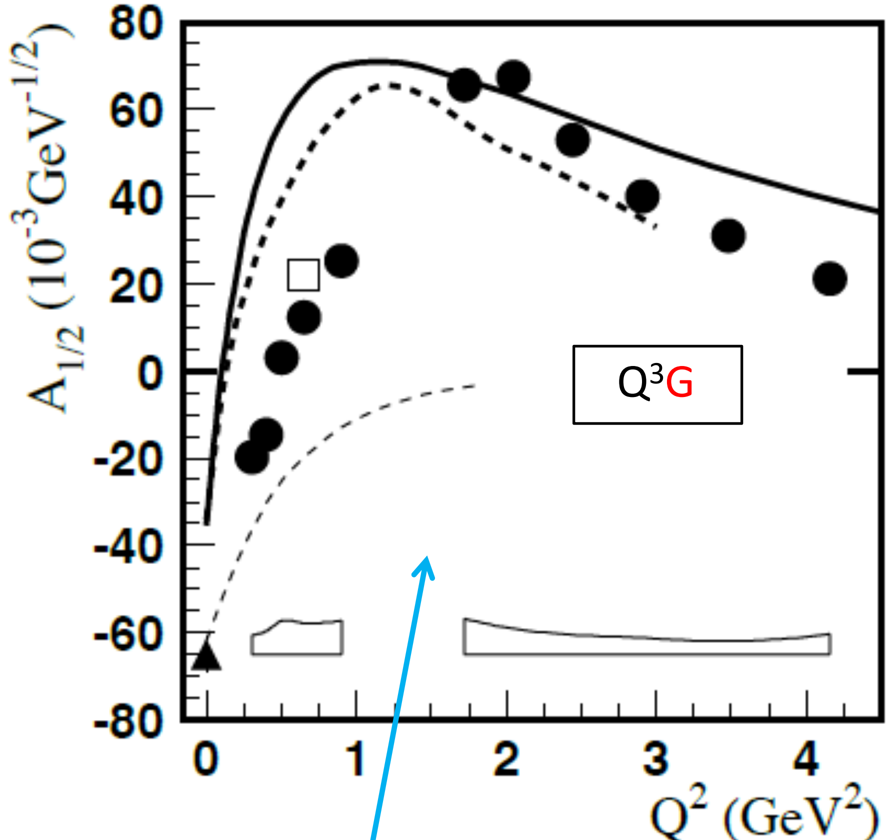
$$\langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle = \frac{W}{M_r} \sqrt{\frac{8 M_N M_r q_{\gamma_r}}{4\pi\alpha}} \sqrt{\frac{q_{\gamma_r}}{q_\gamma}} A_{1/2,3/2}(Q^2) \quad \text{with} \quad |\lambda_\gamma - \lambda_p| = \frac{1}{2}, \frac{3}{2} \text{ for transverse photons,}$$

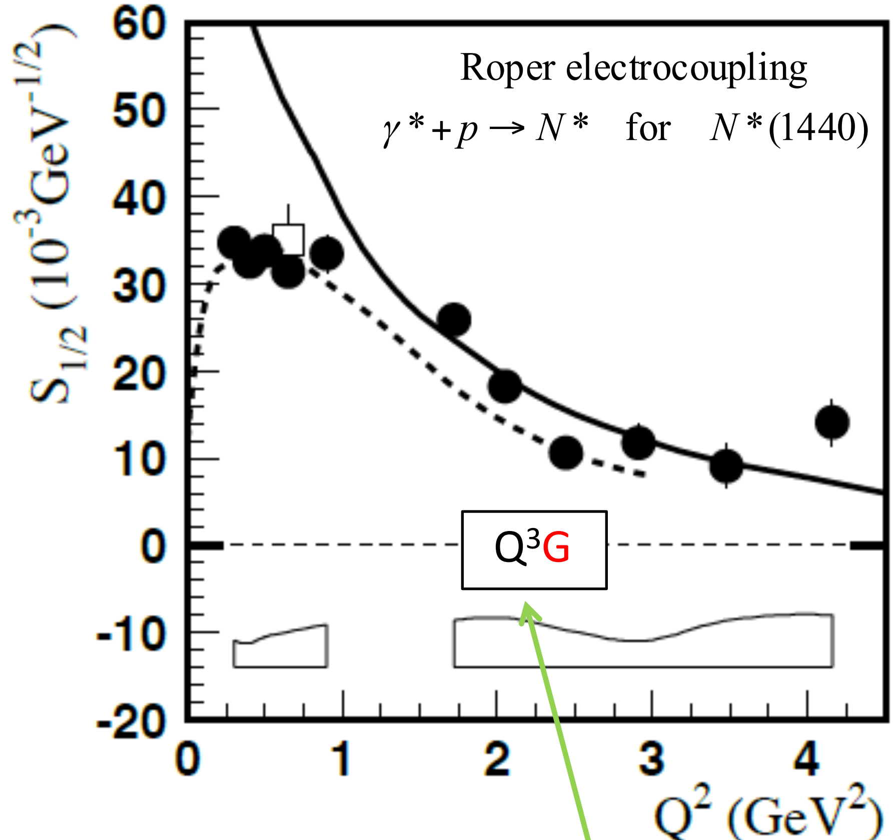
$$\langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle = \frac{W}{M_r} \sqrt{\frac{16 M_N M_r q_{\gamma_r}}{4\pi\alpha}} \sqrt{\frac{q_{\gamma_r}}{q_\gamma}} S_{1/2}(Q^2) \text{ for longitudinal photons}$$

V. I. Mokeev, CLAS Collaboration, PHYSICAL REVIEW C 86, 035203 (2012)

Separating Q^3G from Q^3 states

Transverse helicity amplitude $A_{1/2}(Q^2)$ and longitudinal helicity amplitude $S_{1/2}(Q^2)$ allow to distinguish Q^3G from Q^3 states





A drop of the transverse helicity amplitudes $A_{1/2}(Q^2)$ faster than for ordinary three quark states, because of extra glue-component in valence structure

A suppressed longitudinal amplitude $S_{1/2}(Q^2)$ in comparison with transverse electro-excitation amplitude

I. G. Aznauryan et al., CLAS Collaboration, PHYSICAL REVIEW C 80, 055203 (2009)

Signature

Based on available knowledge, the ***signature*** for hybrid baryons may consist of ***:***

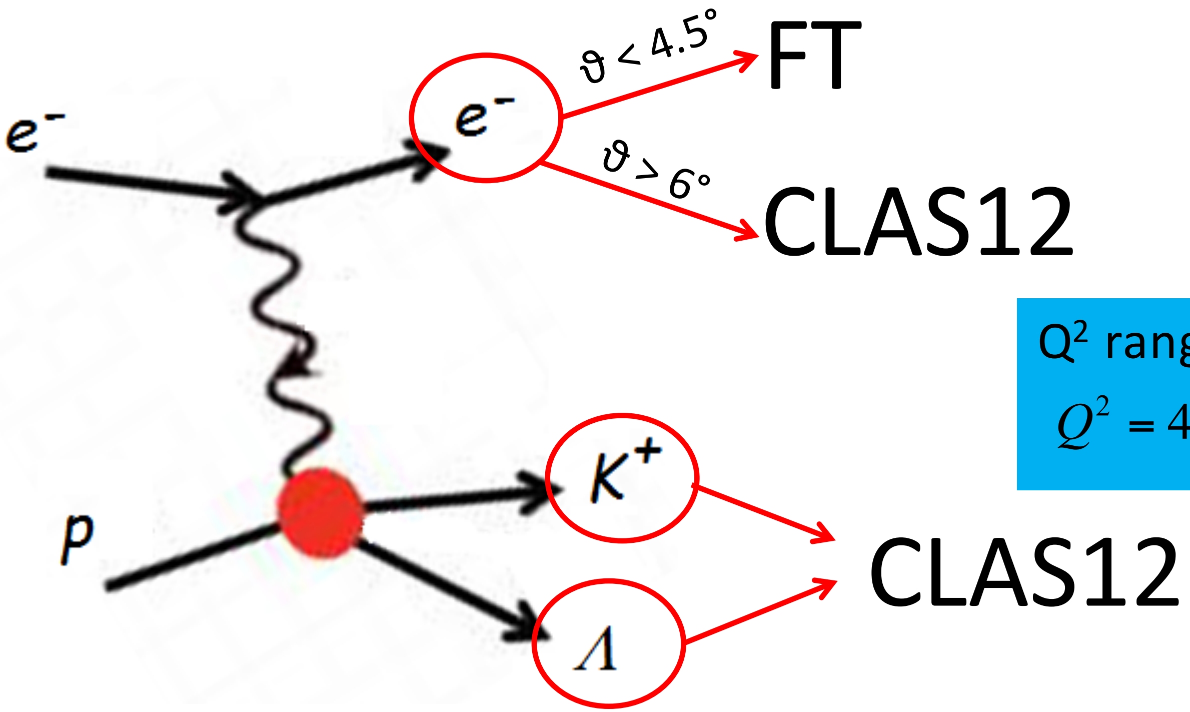
• Extra resonances with masses with $J^p=1/2^+$ from 1.8 GeV to 2.5 GeV and decays to $N\pi\pi$ or KY final states

•A drop of the transverse helicity amplitudes $A_{1/2}(Q^2)$ and $A_{3/2}(Q^2)$ faster than for ordinary three quark states, because of extra glue-component in valence structure

•A suppressed longitudinal amplitude $S_{1/2}(Q^2)$ in comparison with transverse electro-excitation amplitude

Experiment

Scattered electrons will be detected in Forward Tagger for angles from 2.5° to 4.5°. FT allows to probe the **crucial Q^2 range** where hybrid baryons may be identified due to their fast dropping $A_{1/2}(Q^2)$ amplitude and the suppression of the scalar $S_{1/2}$ (Q^2) amplitude.



Q^2 range of interest: 0.05 - 2 GeV^2

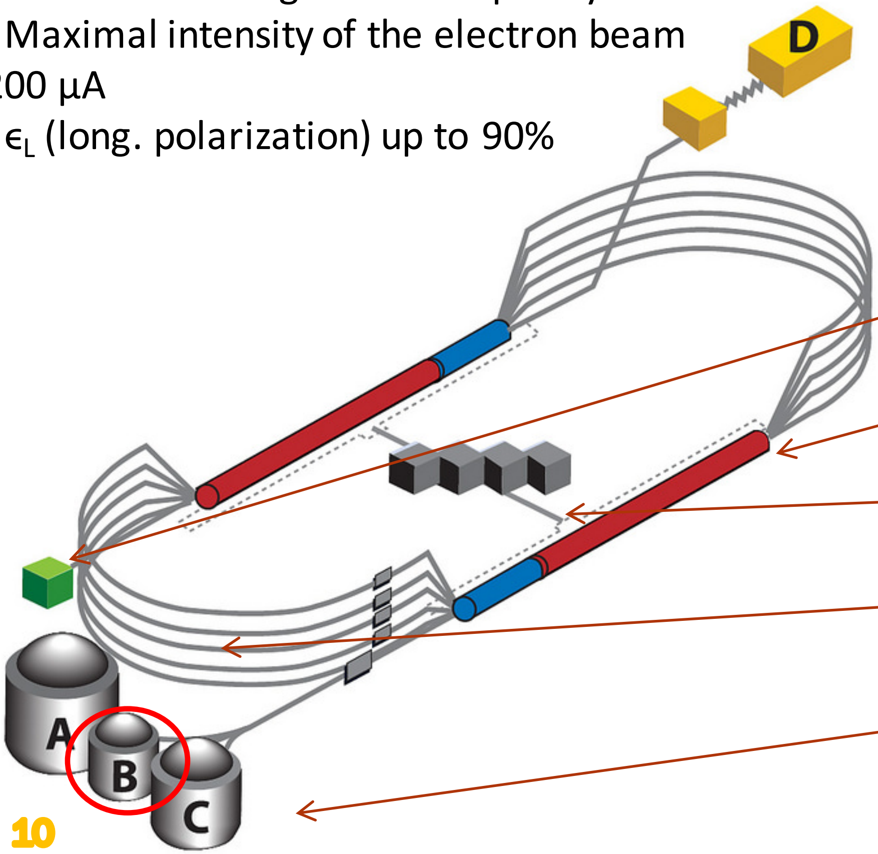
$$Q^2 = 4E_{Beam}E_{e'}\sin^2\frac{\vartheta}{2} \quad \Rightarrow \quad \vartheta < 5°$$

Scattered electrons will be detected in the Forward Detector of CLAS12 for scattering angles greater than about 6°. Charged hadrons will be measured in the full range from 6° to 130°.

Experimental setup: CEBAF

Important parameters:

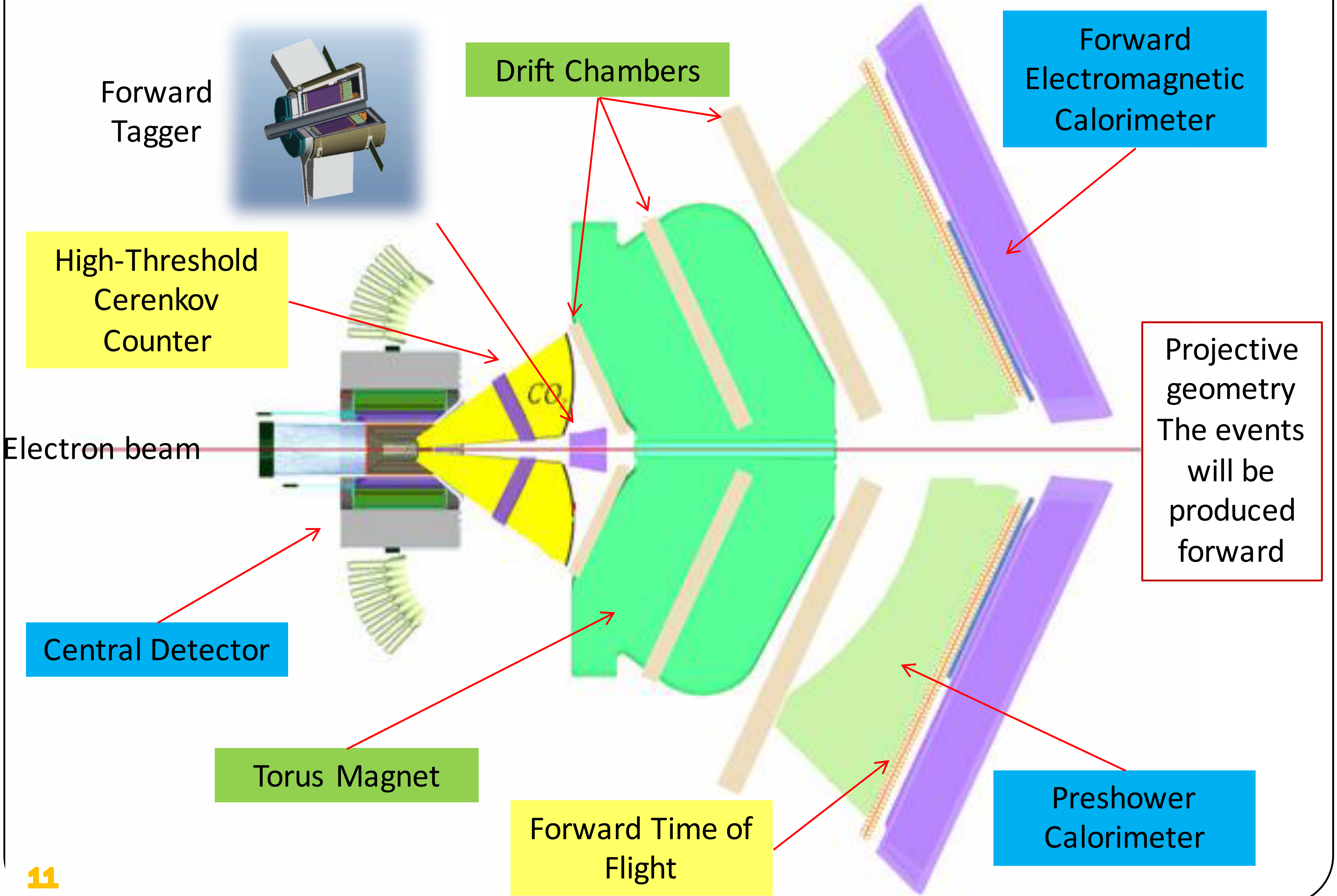
- Iniector energy 45 MeV
- Temporal separation of the bunches 0,7 ns
- Halls A, B, C receive a 11 GeV electron beam, Hall D a 12 GeV electron with a 2 ns time interval
- The beam can be considered almost continuum because of the high work frequency
- Maximal intensity of the electron beam 200 μA
- ϵ_L (long. polarization) up to 90%



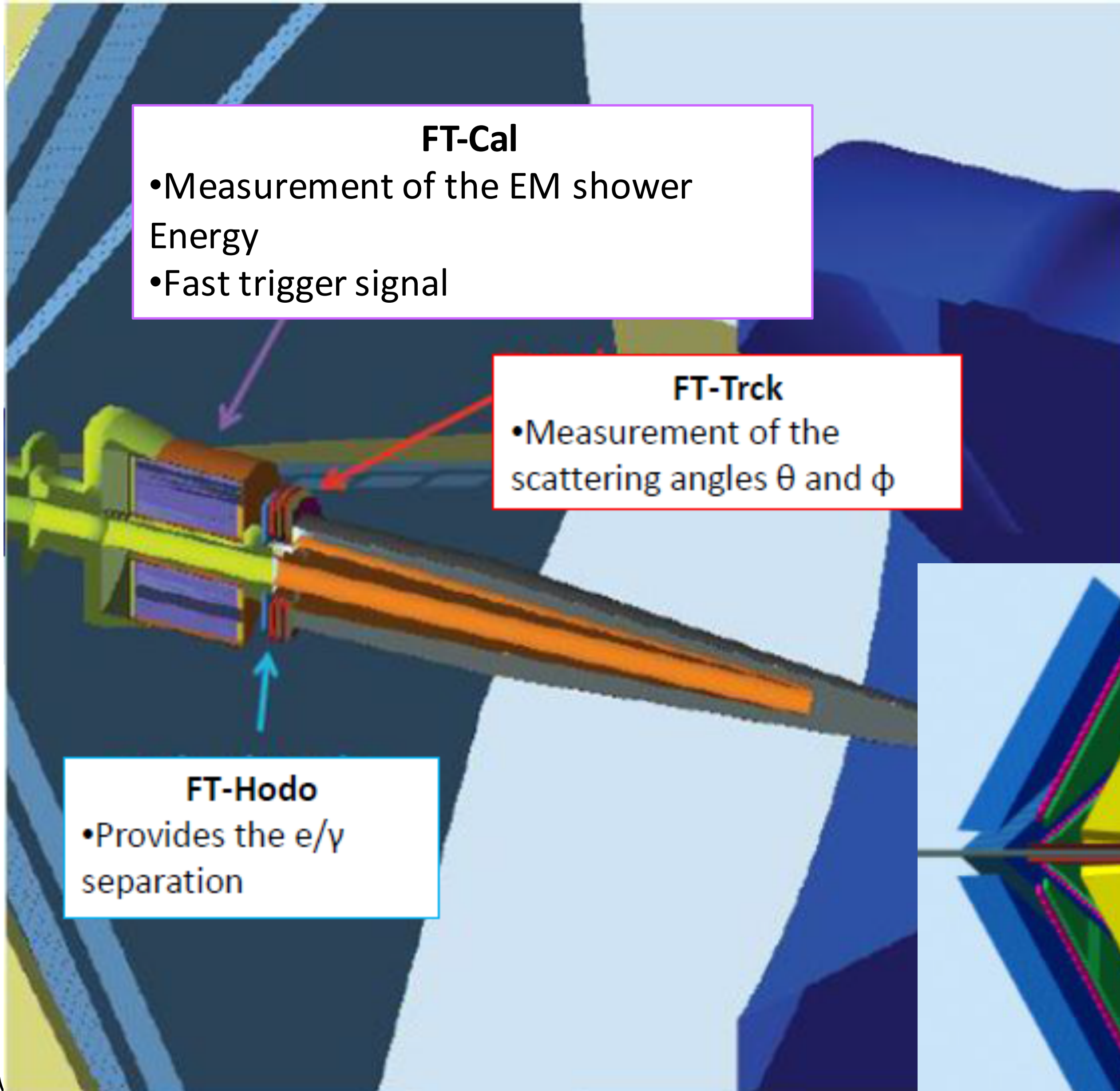
Components:

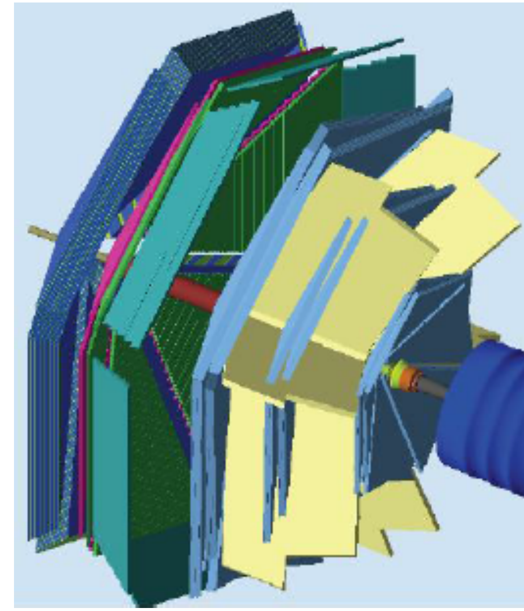
- **Iniector**: At nearly the speed of light, the electron beam circulates the 7/8 mile track in 24 millionths of a second
- **LINAC**: superconducting technology is used to drive electrons to higher and higher energies.
- **Refrigeration plant**: provides liquid helium for ultra-low-temperature, superconducting operation
- **Magnets**: in the arcs steer the electron beam from one straight section of the tunnel to the next for up to five orbits
- **Experimental Halls**: where the electron beam is delivered for simultaneous research by three teams of physicists

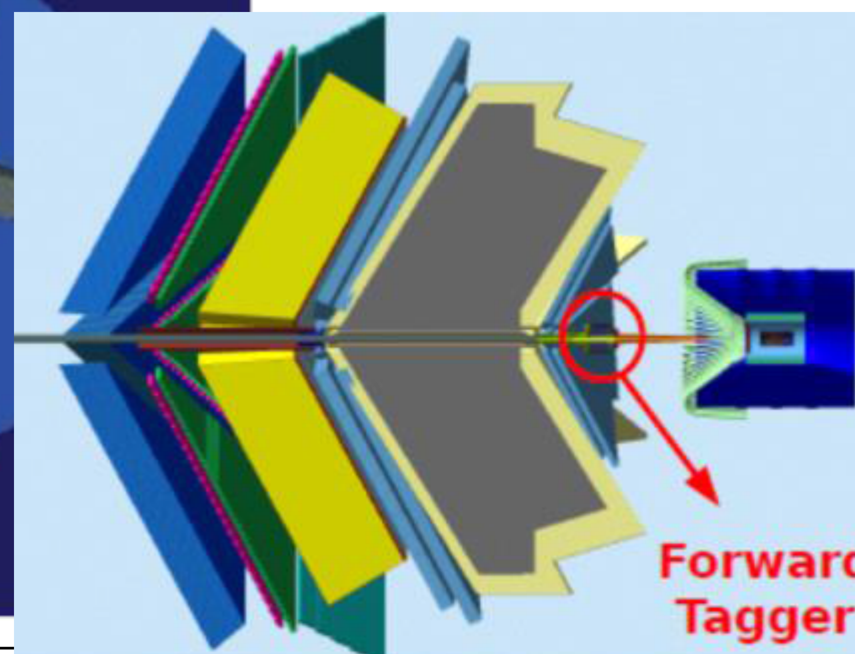
Experimental setup: CLAS12



Experimental Setup: Forward Tagger (FT)



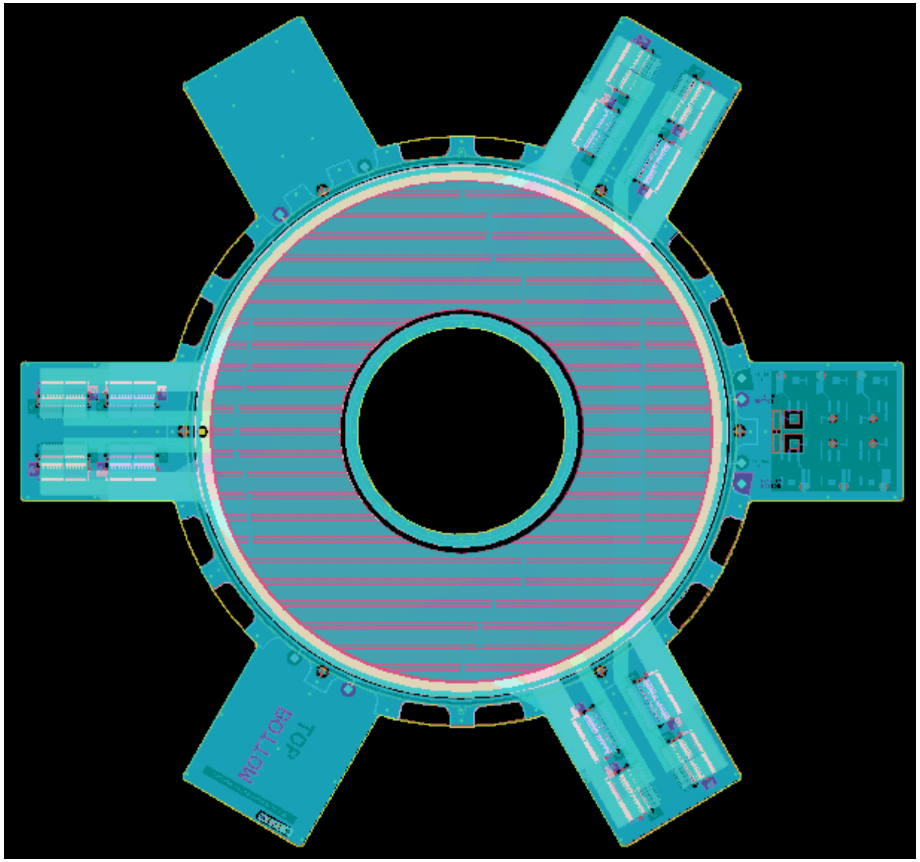




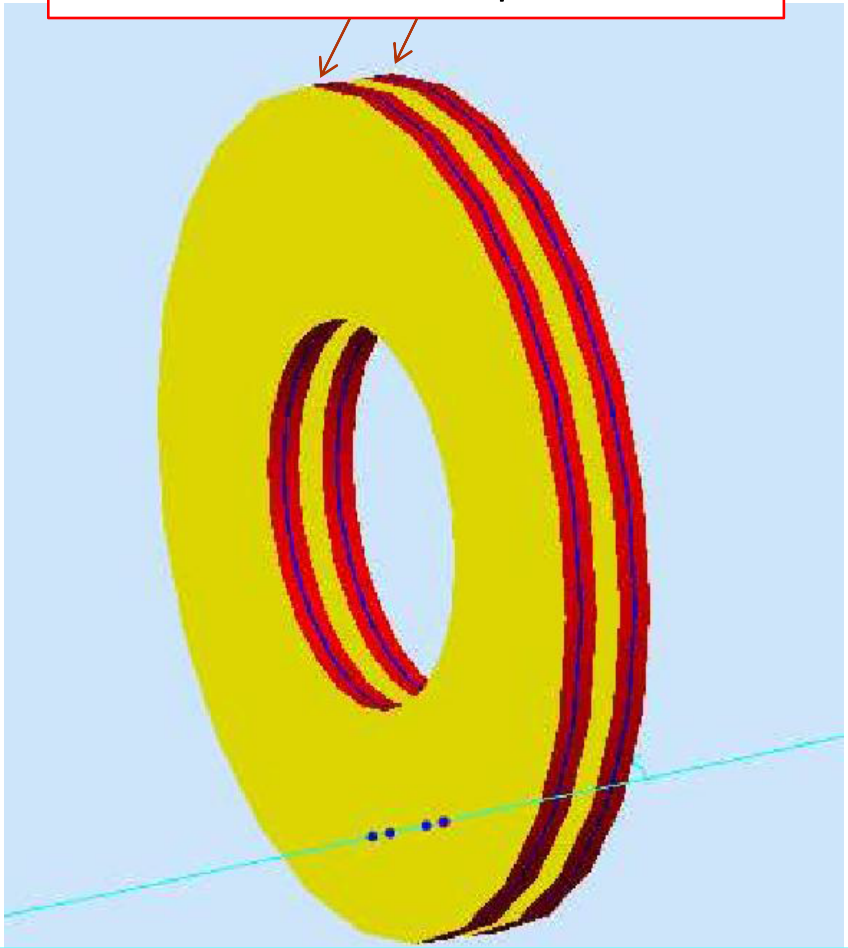
The Tracker (FT-Trck)

Micromegas detectors exploit the gas ionization process with charged particles to:

- Reconstruct the electron point of impact and path



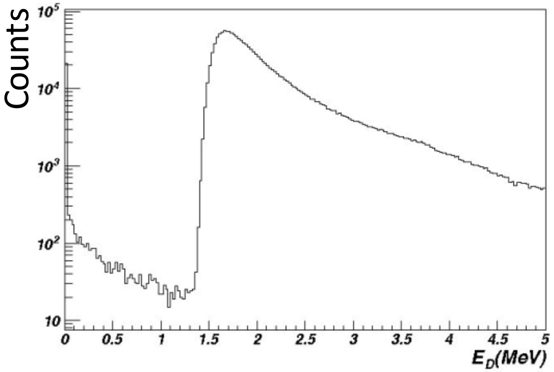
Two layers of pairs of Micromegas detectors with strip readout



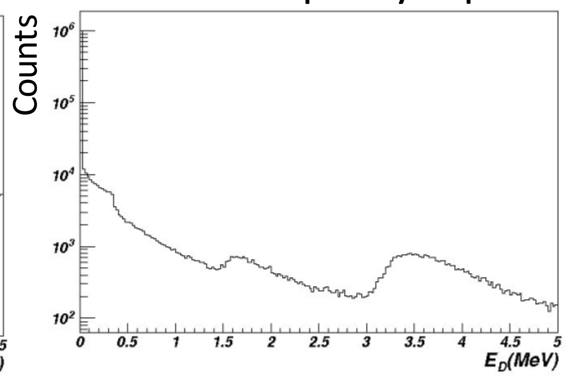
The strips of two different Micromegas in the same layer are orthogonal to produce a (x,y) couple

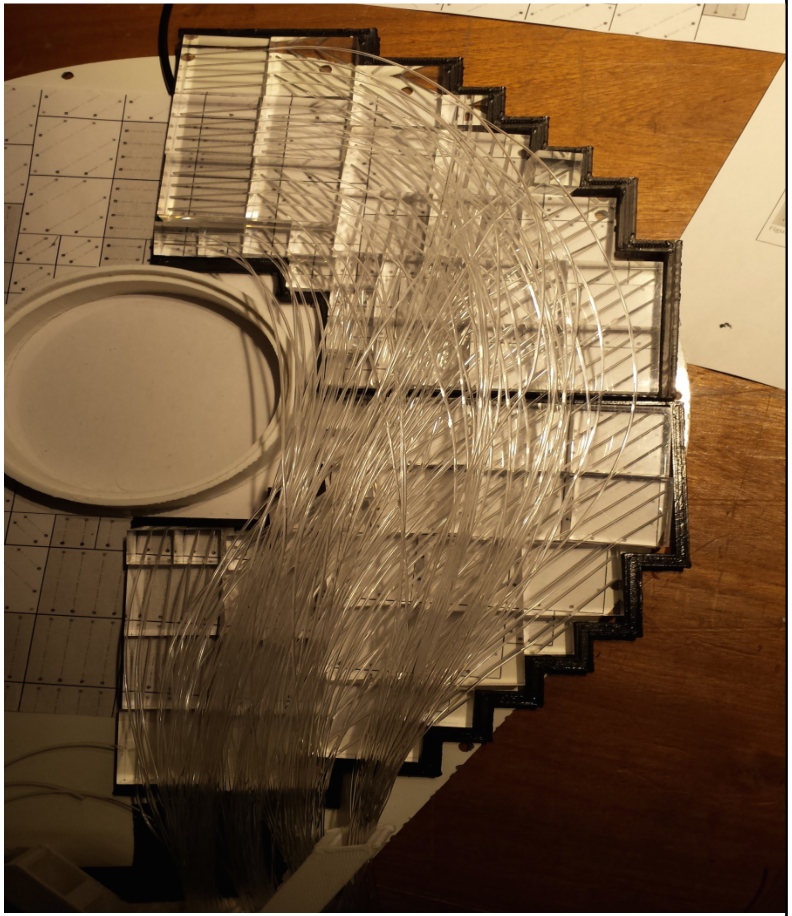
The Hodoscope (FT-Hodo)

E released in the hodoscope by an e^-



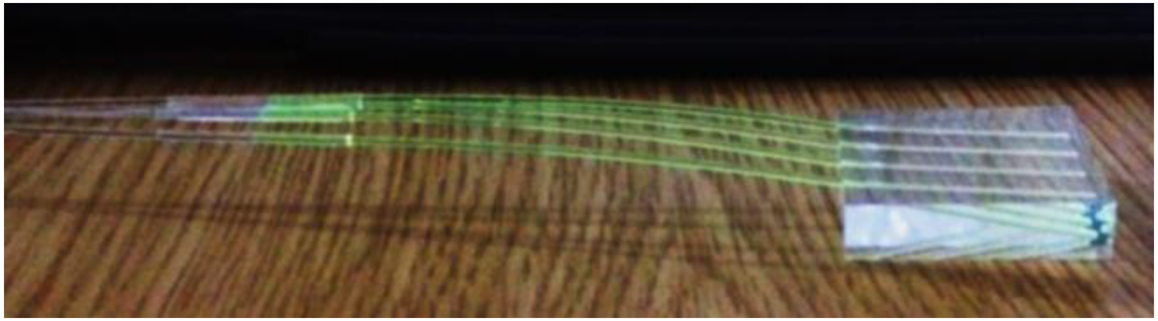
E released in the hodoscope by a γ





232 scintillator tiles, 752 fibers in total

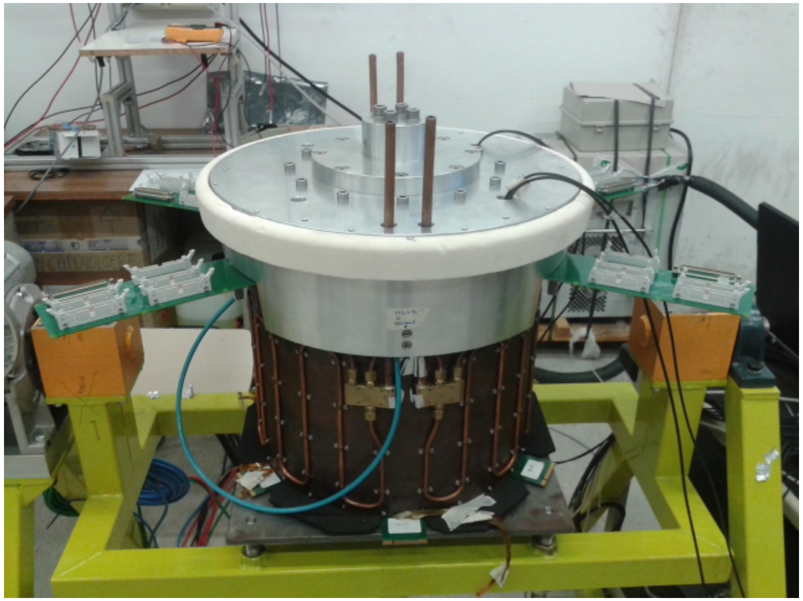
Wavelength shifting (WLS) fibres

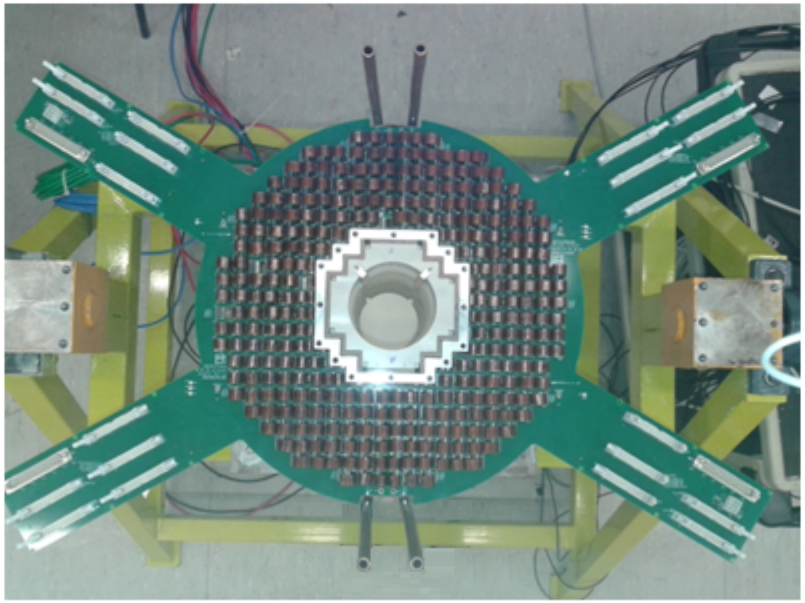


Two layers of plastic **scintillator tiles**

The Electromagnetic Calorimeter (FT-Cal)

Requirements:
- High radiation hardness
- High light yield
- Small radiation length and Moliere radius
- Fast recovery time
- Good energy and time resolution





Modules of $PbWO_4$ scintillating crystals

Pros	Contra
•High density (8.28 g/cm^3) •Small radiation lenght (0.9 cm) •Very fast decay time (6.5 ns) •Very high radiation hardness	•Poor LY (fraction of % of the NaI one) (100-200 γ/MeV) •Temperature must be controlled to avoid variations in gain and noise

Simulation and fast mc reconstruction of $K^{+}\Lambda$ electro-production events in CLAS12 using the Gent RPR-2011 model

- Develop realistic event generator
- Simulation of *quasi-data* events including simplified experimental effects with FASTMC for channel

$$e + p \rightarrow e' + K^{+} + \Lambda$$

- Selection of trigger conditions
- Production of events with different run conditions to extract the better configuration.
- Conclusions

Available data on “Strange Calc” web site

StrangeCalc

Reaction type: Electroproduction ▼

Reaction: ◉ $p(e,e'K^+)\Lambda$ ○ $p(e,e'\pi^+)n$

○ $p(e,e'K^+)\Sigma^0$ ○ $n(e,e'\pi^-)p$

○ $p(e,e'K^0)\Sigma^+$

Non-interference cross sections: ☐ $d\sigma_U$ ☐ $d\sigma_L$ ☐ $d\sigma_T$

Interference cross sections: ☐ $d\sigma_{LT}$ ☐ $d\sigma_{TT}$ ☐ $d\sigma_{LT'}$ ☐ $d\sigma_{TT'}$

Induced recoil polarization: ☐ $P^0_{y''}$

☐ P^0_n

Transferred recoil polarization: ☐ $P'_{x''}$ ☐ $P'_{z''}$

☐ P'_l ☐ P'_t

Clear

$x''y''z''$-frame: The z''-axis is along the virtual photon's three-momentum, the $x''z''$-plane is the electron plane, and the x''-axis' direction is such that the final electron's x''-component is positive.

ntl-frame: The l-axis is along the final baryon's three-momentum, the tl-plane is the hadron plane, and the t-axis' direction is such that the virtual photon's t-component is positive.

Energy variable: ◉ W ○ s ○ $E_{\gamma,\mathrm{c.m.}}$ ○ $E_{\gamma,\mathrm{lab}}$

◉ Fixed ○ Range ○ List

GeV

For the options 'Fixed' and 'Range', unphysical entries will be corrected if the variable's minimum/maximum value is not fixed. E.g.: $W = 0$ GeV will be corrected to $W = W_0$, with W_0 being the threshold energy, and $-t = 0$ GeV² will be corrected to $-t = -t_0$, with $-t_0$ being the minimum value of $-t$.

Angular variable: ◉ $\cos\theta_{\mathrm{c.m.}}$ ○ $-t$ ○ $-u$

◉ Fixed ○ Range ○ List

Photon virtuality (Q^2): ◉ Fixed ○ Range ○ List

GeV²

StrangeCalc data have been used for the Event Generator.
From the collaboration with the Ghent group we also obtained the RPR amplitudes.

Model: ◉ RPR-2011

○ RPR-2007

○ VR

☐ No resonance contributions

RPR-2011 model: Phys. Rev. C **86**, 015212 (2012)
RPR-2007 model: Phys. Rev. C **73**, 045207 (2006) and Phys. Rev. C **75**, 045204 (2007)
VR model: Phys. Rev. C **89**, 025203 (2014) and Phys. Rev. C **89**, 065202 (2014)

Calculate

Trigger and run conditions

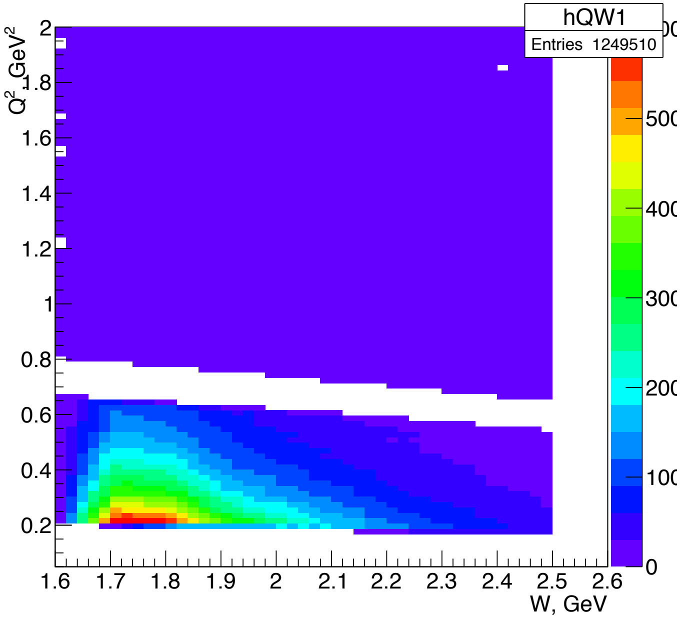
Selection of trigger conditions for fastmc event generator

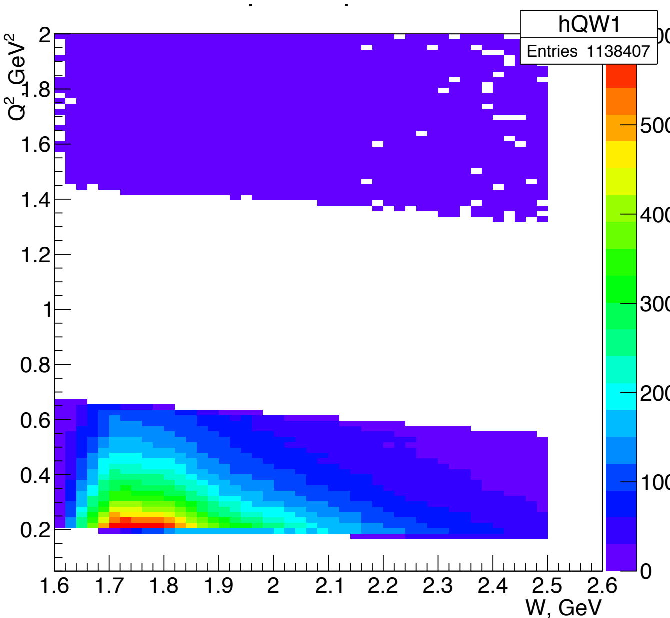
Selection of better run conditions for the experiment considering:

- E_{beam}= 6.6 GeV, 8.8 GeV, 11 GeV
- Torus current = ±1500 A, ±2950 A, ±3370 A

Magnetic field: inbending or outbending?

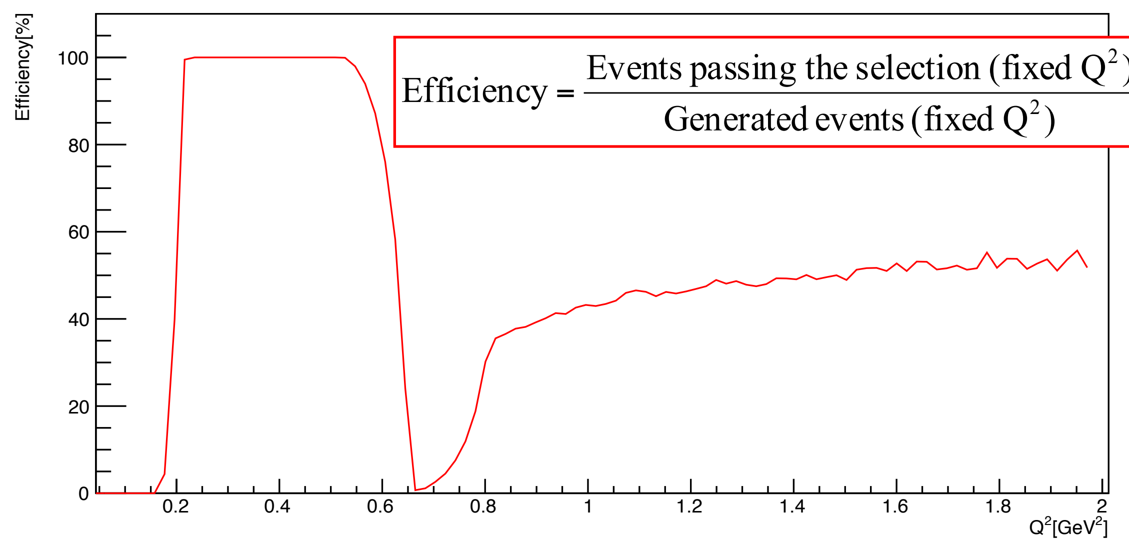
Q^2 vs W





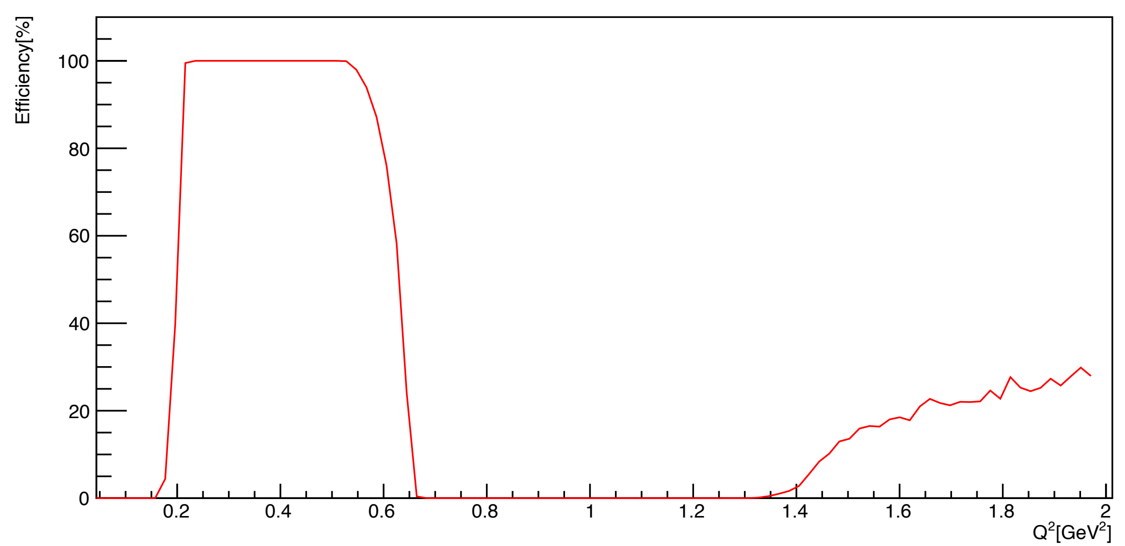
Efficiency curve

Single electron geometrical detection efficiency E = 11 GeV

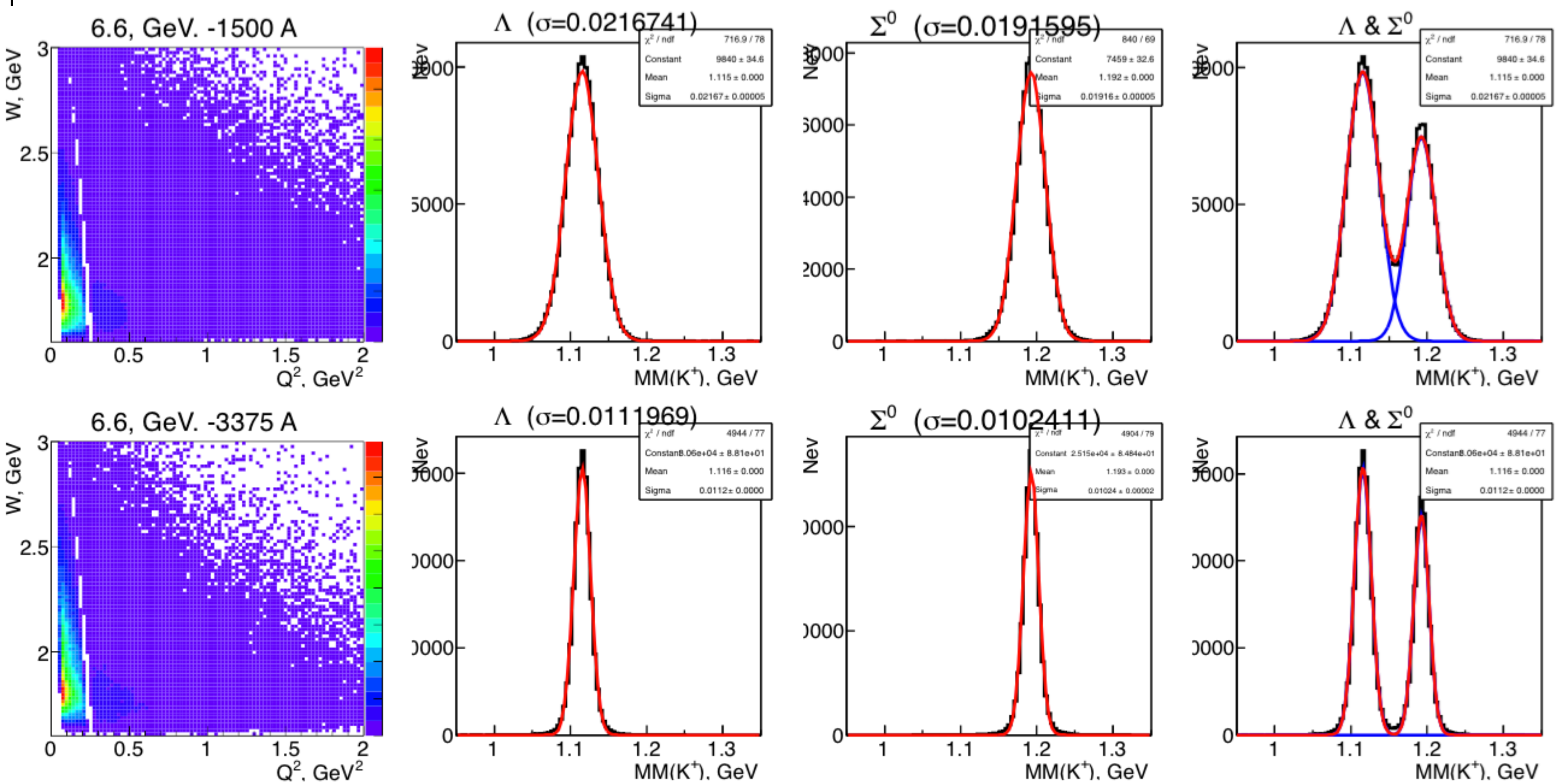


$$\text{Efficiency} = \frac{\text{Events passing the selection (fixed } Q^2)}{\text{Generated events (fixed } Q^2)}$$

Single electron geometrical detection efficiency E = 11 GeV



Strenght of Torus current



e′K$^+$ missing mass to reconstruct Λ

e′K$^+$ missing mass to reconstruct Σ^0

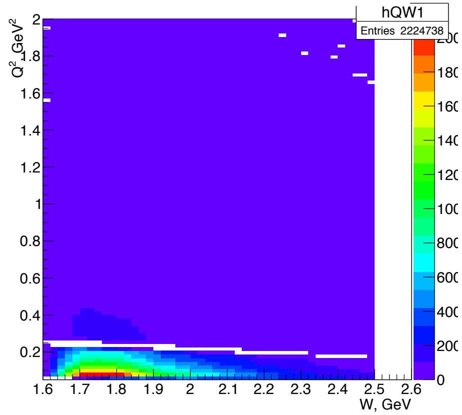
K$^+$Λ and K$^+$Σ^0 overlap histograms
↓
Advantage of high CLAS12 torus currents

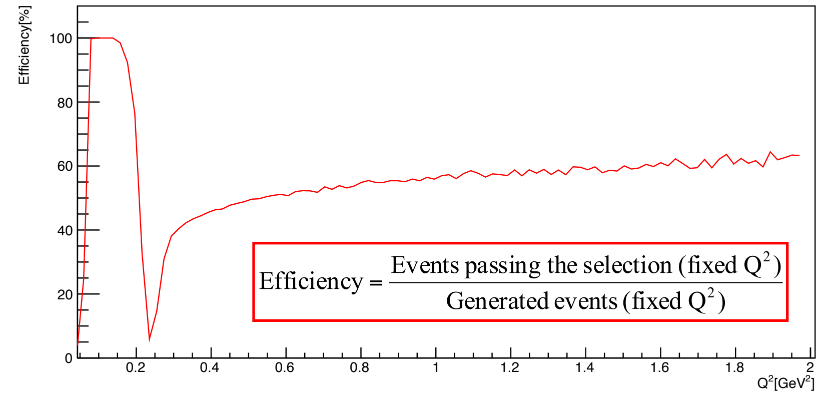
Covering the whole Q^2 range

Q² vs W

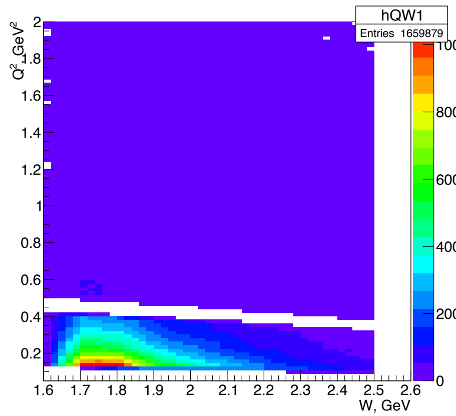
Efficiency curve

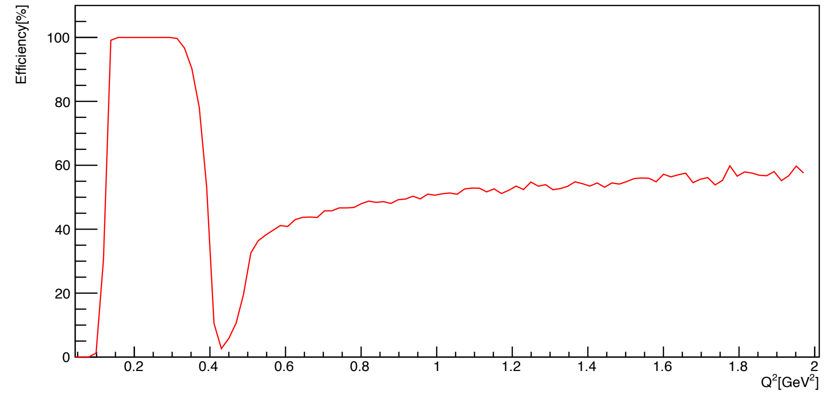
E =
6.6 GeV
TorCur= -
3375 A



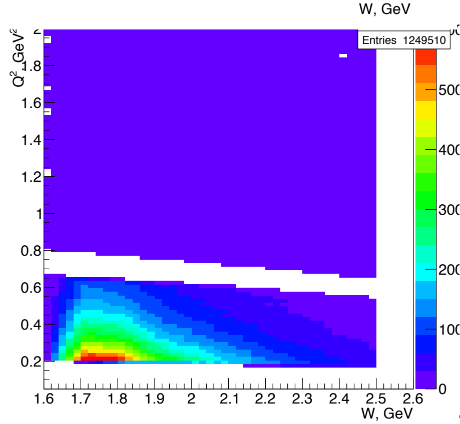


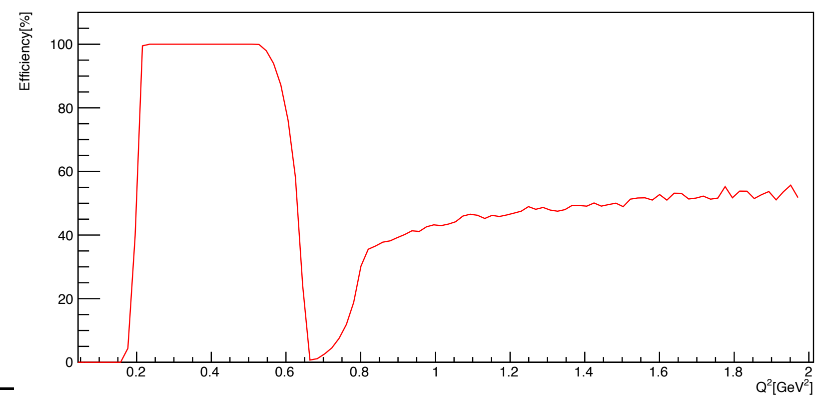
E =
8.8 GeV
TorCur=
-3375 A





E =
11 GeV
TorCur=
-3375 A



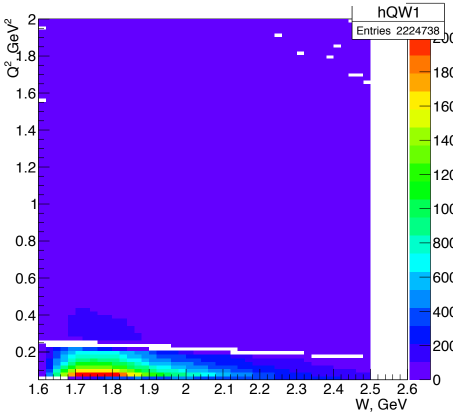


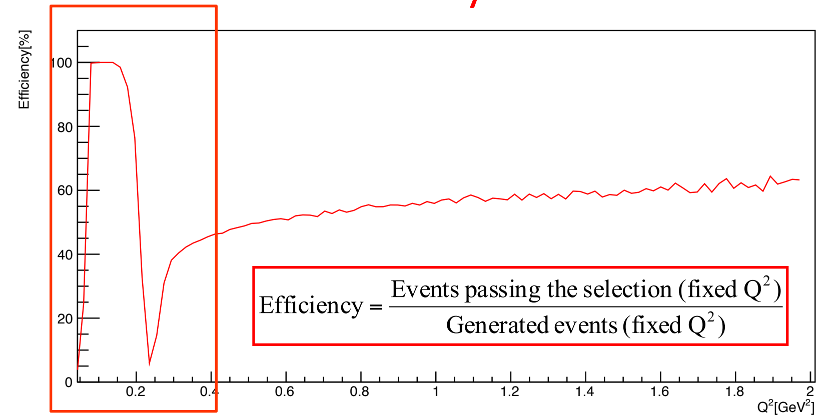
Covering the whole Q^2 range

Q^2 vs W

Efficiency curve

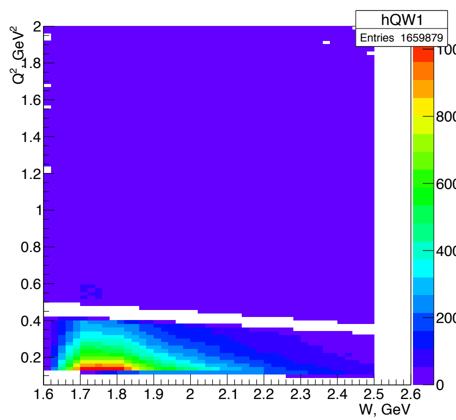
E = 6.6 GeV TorCur= -3375 A

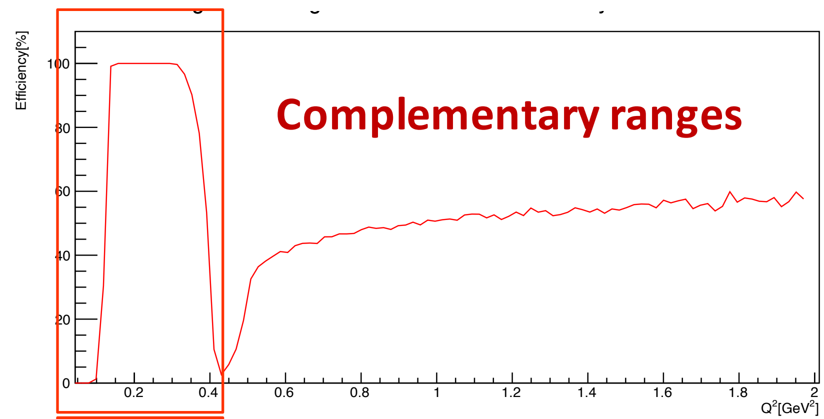




$$\text{Efficiency} = \frac{\text{Events passing the selection (fixed } Q^2)}{\text{Generated events (fixed } Q^2)}$$

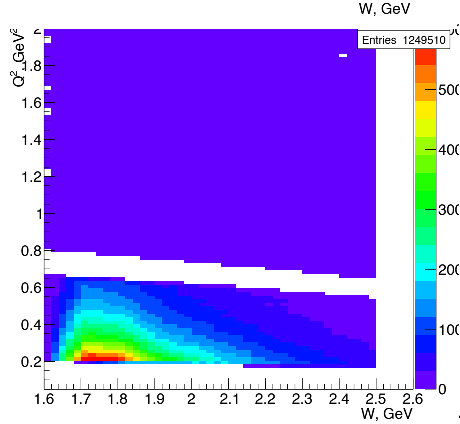
E = 8.8 GeV TorCur= -3375 A

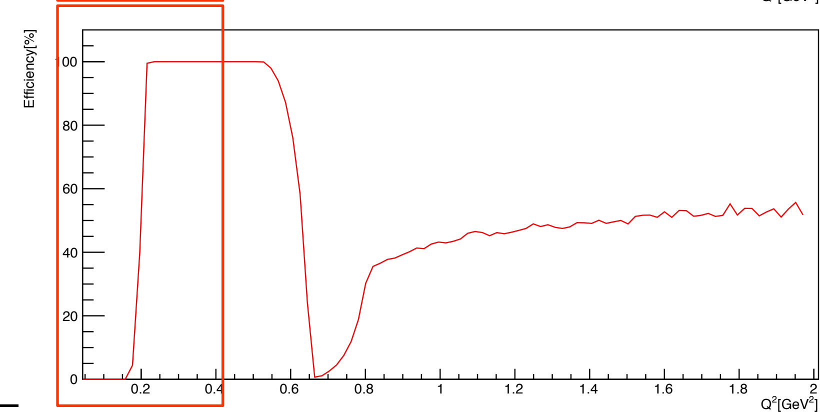




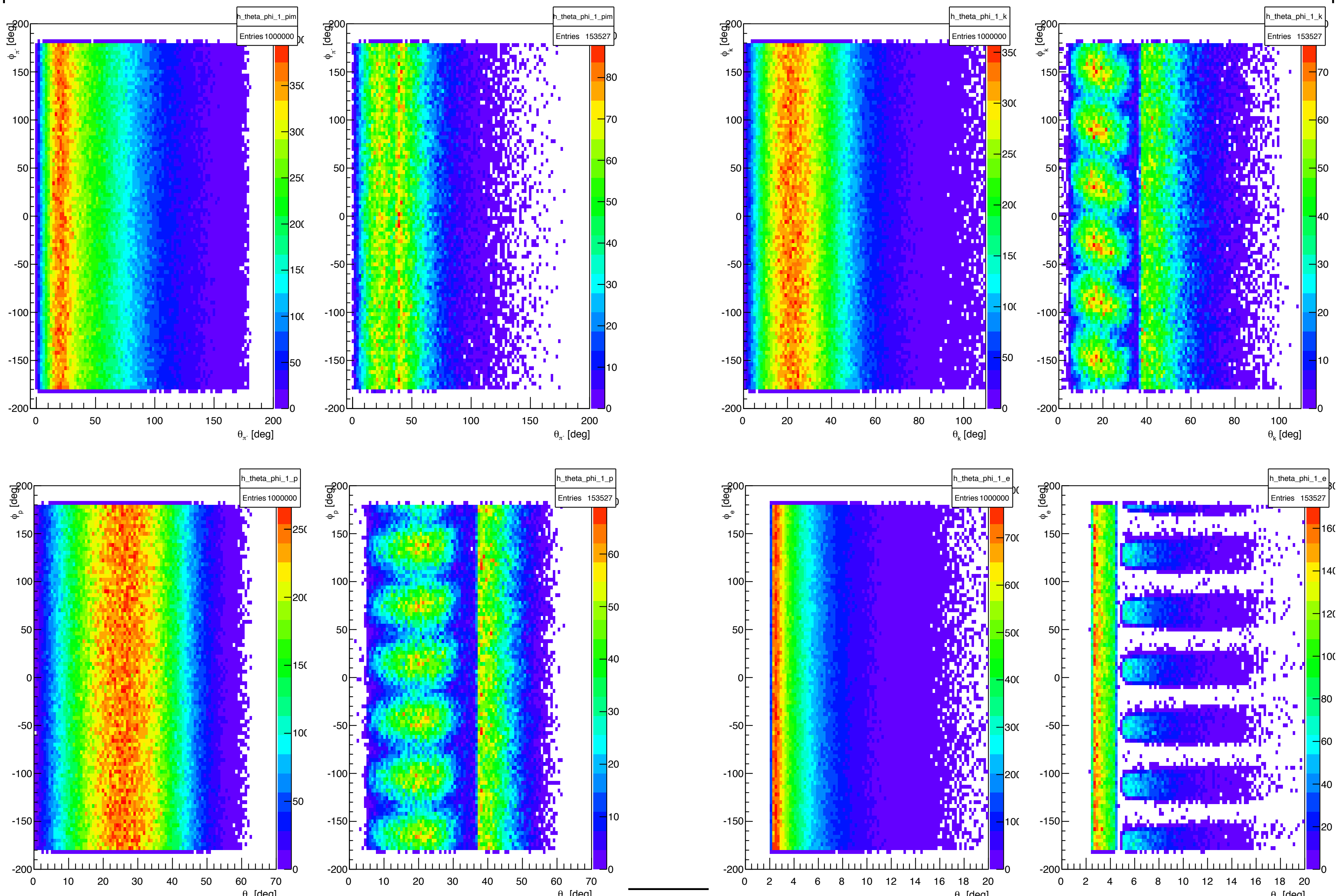
Complementary ranges

E = 11 GeV TorCur= -3375 A





Results for run conditions: E_{beam}=6.6 GeV TorCur=-3750 A



Simulation of RPR-2011 model + hybrid contribution

- Breit-Wigner ansatz for the hybrid amplitude:

$$M_{\lambda_\gamma}^{\lambda_p \lambda_Y} = \langle \lambda_f | T_r | \lambda_\gamma \lambda_p \rangle = \frac{\langle \lambda_f | T_{dec} | \lambda_R \rangle \langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle}{M_r^2 - W^2 - i\Gamma_r M_r}$$

λ, λ_N, λ_Y = elicities of photon, nucleon and yperon

Dependence on the electrocouplings

$$\langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle = \frac{W}{M_r} \sqrt{\frac{8 M_N M_r q_{\gamma_r}}{4\pi\alpha}} \sqrt{\frac{q_{\gamma_r}}{q_\gamma}} A_{1/2,3/2}(Q^2) \quad \text{with} \quad |\lambda_\gamma - \lambda_p| = \frac{1}{2}, \frac{3}{2} \text{ for transverse photons,}$$

$$\langle \lambda_R | T_{em} | \lambda_\gamma \lambda_p \rangle = \frac{W}{M_r} \sqrt{\frac{16 M_N M_r q_{\gamma_r}}{4\pi\alpha}} \sqrt{\frac{q_{\gamma_r}}{q_\gamma}} S_{1/2}(Q^2) \text{ for longitudinal photons}$$

- Add the hybrid contribution to the RPR-2011 at amplitude level:

$$\mathcal{M}_{\lambda}^{\lambda_N \lambda_Y} = M_{\lambda}^{\lambda_N \lambda_Y} + \mathscr{M}_{\lambda}^{\lambda_N \lambda_Y} \qquad \mathcal{H}_{\lambda\lambda'} = \sum_{\lambda_N, \lambda_Y} \mathcal{M}_{\lambda}^{\lambda_N \lambda_Y} \left(\mathcal{M}_{\lambda'}^{\lambda_N \lambda_Y} \right)^\dagger$$

Study of sensitivity

•Add the hybrid contribution at **amplitude level** and study the sensitivity of our system to the presence of a hybrid resonance:

$$\mathcal{M}_{\lambda}^{\lambda_N \lambda_Y} = M_{\lambda}^{\lambda_N \lambda_Y} + \mathscr{M}_{\lambda}^{\lambda_N \lambda_Y} \qquad \mathcal{H}_{\lambda\lambda'} = \sum_{\lambda_N, \lambda_Y} \mathcal{M}_{\lambda}^{\lambda_N \lambda_Y} \left(\mathcal{M}_{\lambda'}^{\lambda_N \lambda_Y} \right)^{\dagger}$$

$\lambda, \lambda_N, \lambda_Y$ = elicities of photon, nucleon and yperon

•Using the relationships:

$$\frac{d\sigma_T}{d\Omega_K^*} = \chi \frac{1}{(4\pi)^2} (\mathcal{H}_{1,1} + \mathcal{H}_{-1,-1}) \qquad \frac{d\sigma_{TT}}{d\Omega_K^*} = -\chi \frac{1}{(4\pi)^2} (\mathcal{H}_{1,-1} + \mathcal{H}_{-1,1})$$

$$\frac{d\sigma_L}{d\Omega_K^*} = 2\chi \frac{1}{(4\pi)^2} \mathcal{H}_{0,0} \qquad \frac{d\sigma_{LT}}{d\Omega_K^*} = -\chi \frac{1}{(4\pi)^2} (\mathcal{H}_{0,1} + \mathcal{H}_{1,0} - \mathcal{H}_{-1,0} - \mathcal{H}_{0,-1})$$

$$\frac{d^5\sigma}{d\epsilon_2^{lab} d\Omega_2^{lab} d\Omega_K^*} = \Gamma' \left(\frac{d\sigma_T}{d\Omega_K^*} + \epsilon \frac{d\sigma_L}{d\Omega_K^*} + \epsilon \frac{d\sigma_{LT}}{d\Omega_K^*} cos(2\phi_K^*) + \sqrt{\epsilon(\epsilon+1)} \frac{d\sigma_{TT}}{d\Omega_K^*} cos(\phi_K^*) \right)$$

With

$$\chi = \frac{1}{16 W m_P} \frac{|\boldsymbol{p}_K^*|}{K_H} \qquad K_H = \omega_{\text{lab}} - \frac{Q^2}{2m_P}$$

$$\epsilon = \frac{4EE' - Q^2}{2(E^2 + E'^2) + Q^2} \qquad \Gamma' = \frac{\alpha}{2\pi^2} \frac{\epsilon_2^{lab}}{\epsilon_1^{lab}} \frac{(\omega_{lab} - \frac{Q^2}{2m_N})}{Q^2} \frac{1}{1-\epsilon}$$

Study of sensitivity: Legendre moments

Expansion in terms of Legendre moments: a way to probe the sensitivity to a hybrid baryon contribution

$$P_m = \frac{2m+1}{2}\int_{-1}^{1} L_m(x) f(x) dx$$

$$L_m(x) = \sum_{j=0}^{m} a_{mj} x^j \qquad a_{mj} = (-1)^{(m-j)/2} \frac{1}{2^m} \frac{(m+j)!}{\left(\frac{(m-j)}{2}\right)! \left(\frac{(m+j)}{2}\right)! \, j!} \qquad m - j = even$$

$$L_0 = 1$$

$$L_1 = cos\vartheta$$

$$L_2 = \frac{1}{2}(3cos\vartheta^2 - 1)$$

$$L_3 = \frac{1}{2}(5cos\vartheta^3 - 3cos\vartheta)$$

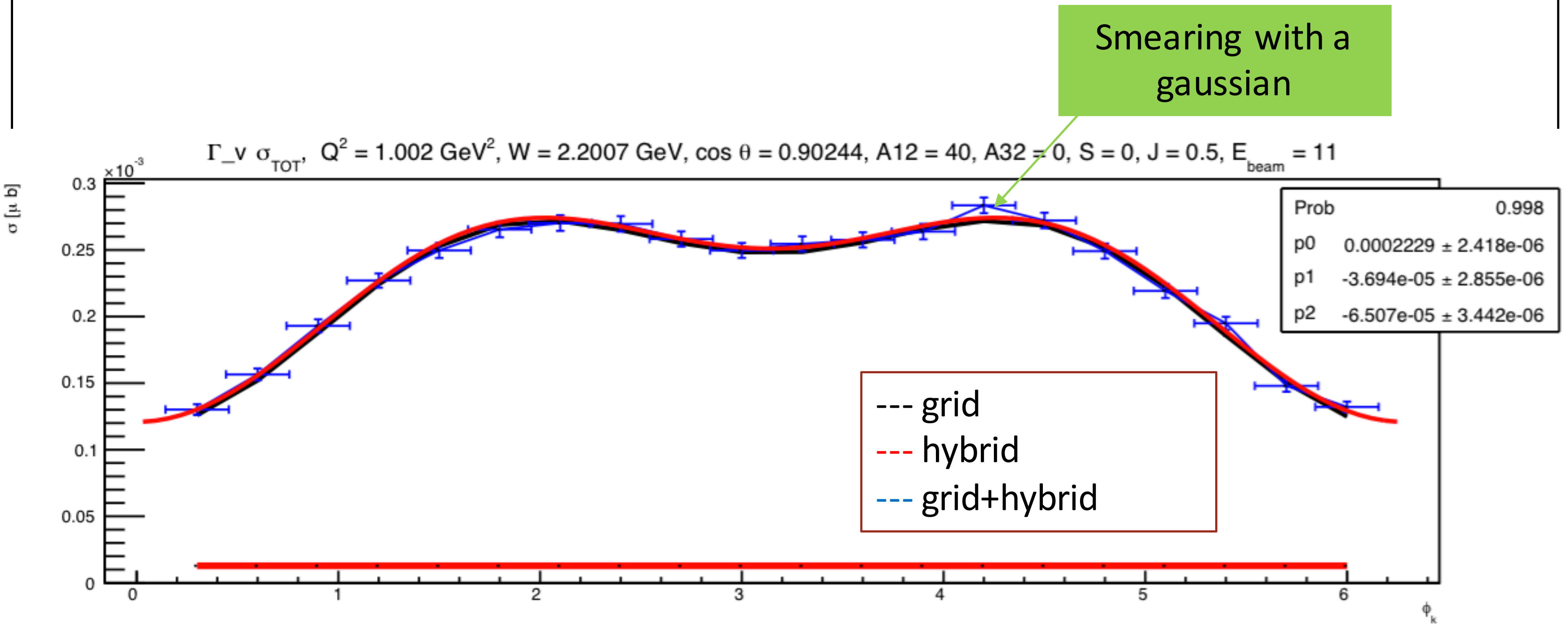
$$L_4 = \frac{1}{8}(35cos\vartheta^4 - 30cos\vartheta^2 + 3)$$

$$L_5 = \frac{1}{8}(63cos\vartheta^5 - 70cos\vartheta^3 + 15cos\vartheta)$$

$$L_6 = \frac{1}{16}(231cos\vartheta^6 - 315cos\vartheta^4 + 105cos\vartheta - 5)$$

The appearance of a structure in a single Legendre moment at the same value of W for each Q^2 point is likely a signal from a resonance contribution.

Estimation of errors



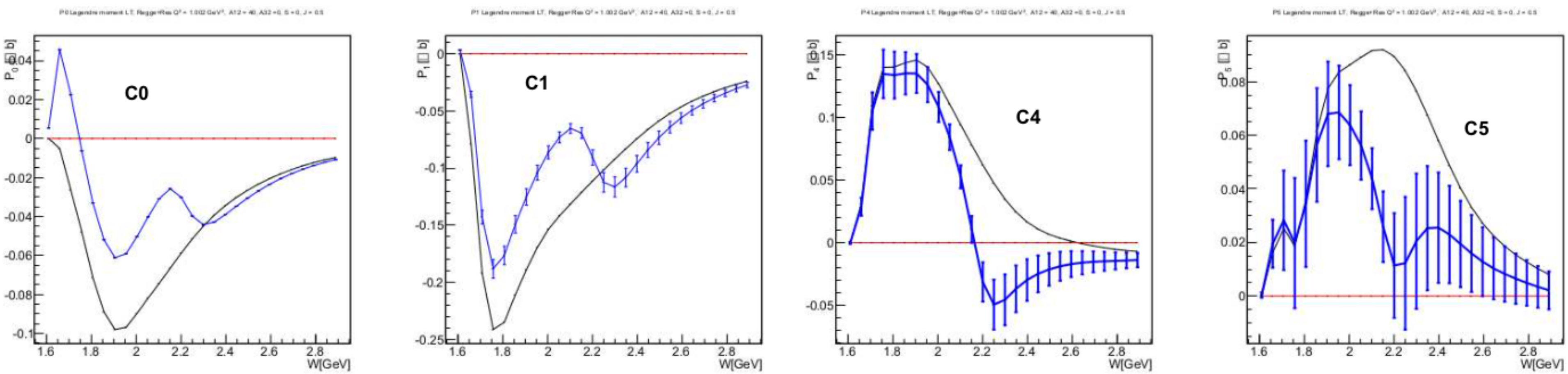
- J = 1/2
- Grid: Regge + Res.
- Q^2 = 1.002 GeV^2
- $A_{1/2}$ = 40
- W = 2.2007 GeV
- cos ϑ= 0.90244

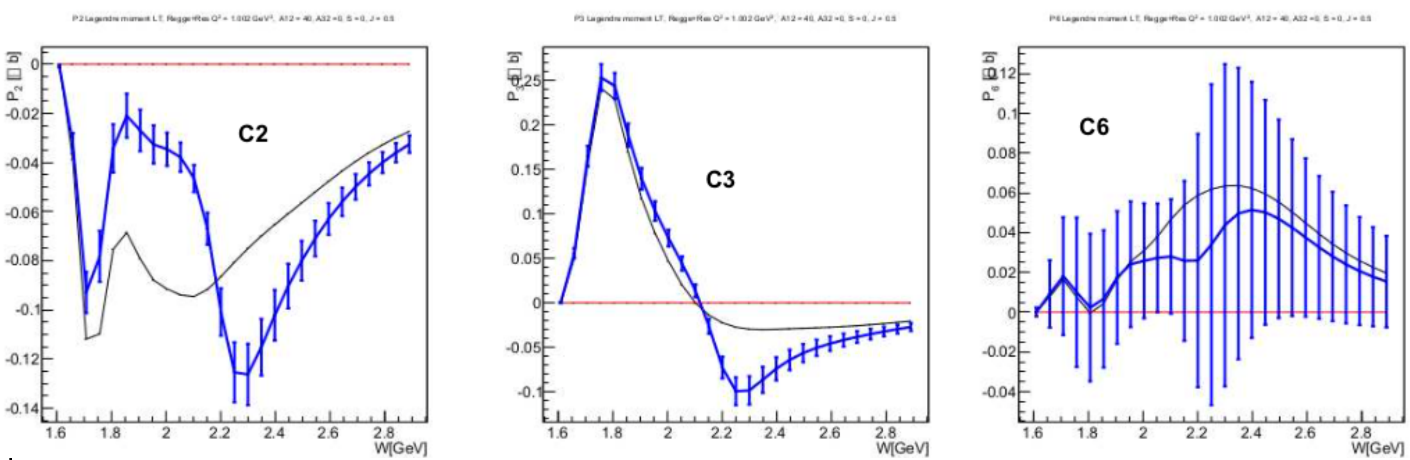
Extraction of cross sections with a fit:

$$\frac{d^4\sigma}{dWdQ^2d\Omega_k} = \Gamma_v[\underbrace{\boxed{\sigma_T + \varepsilon\sigma_L}}_{p_0 + err(p_0)} + \underbrace{\boxed{\varepsilon\sigma_{TT}}}_{p_1 + err(p_1)} cos2\varphi_k + \underbrace{\boxed{\sqrt{\varepsilon(\varepsilon+1)}\sigma_{LT}}}_{p_2 + err(p_2)} cos\varphi_k]$$

LT: Legendre moments analysis

Significant structures appear in most of the Legendre moments at the value of W = 2.2 GeV, corresponding to the mass of the added hybrid baryon



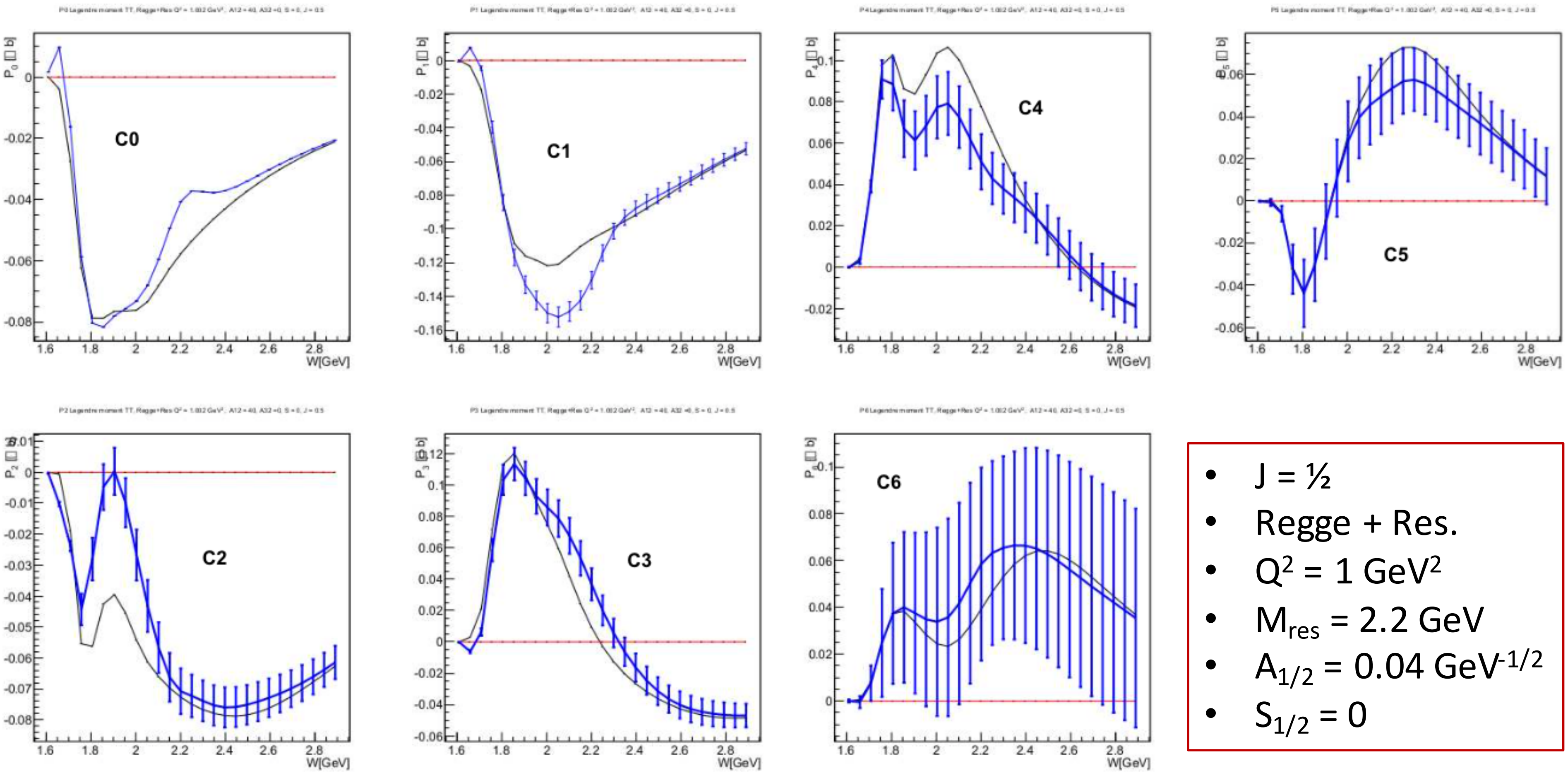


- J = ½
- Regge + Res.
- Q^2 = 1 GeV^2
- M_{res} = 2.2 GeV
- $A_{1/2}$ = 0.04 $GeV^{-1/2}$
- $S_{1/2}$ = 0

--- RPR --- hybrid --- RPR+hybrid

TT: Legendre moments analysis

Significant structures appear in most of the Legendre moments at the value of W = 2.2 GeV, corresponding to the mass of the added hybrid baryon



- $J = ½$
- Regge + Res.
- $Q^2 = 1\ GeV^2$
- $M_{res} = 2.2\ GeV$
- $A_{1/2} = 0.04\ GeV^{-1/2}$
- $S_{1/2} = 0$

--- RPR --- hybrid --- RPR+hybrid

χ^2 vs $A_{1/2}$

The dependency of χ^2 calculated as

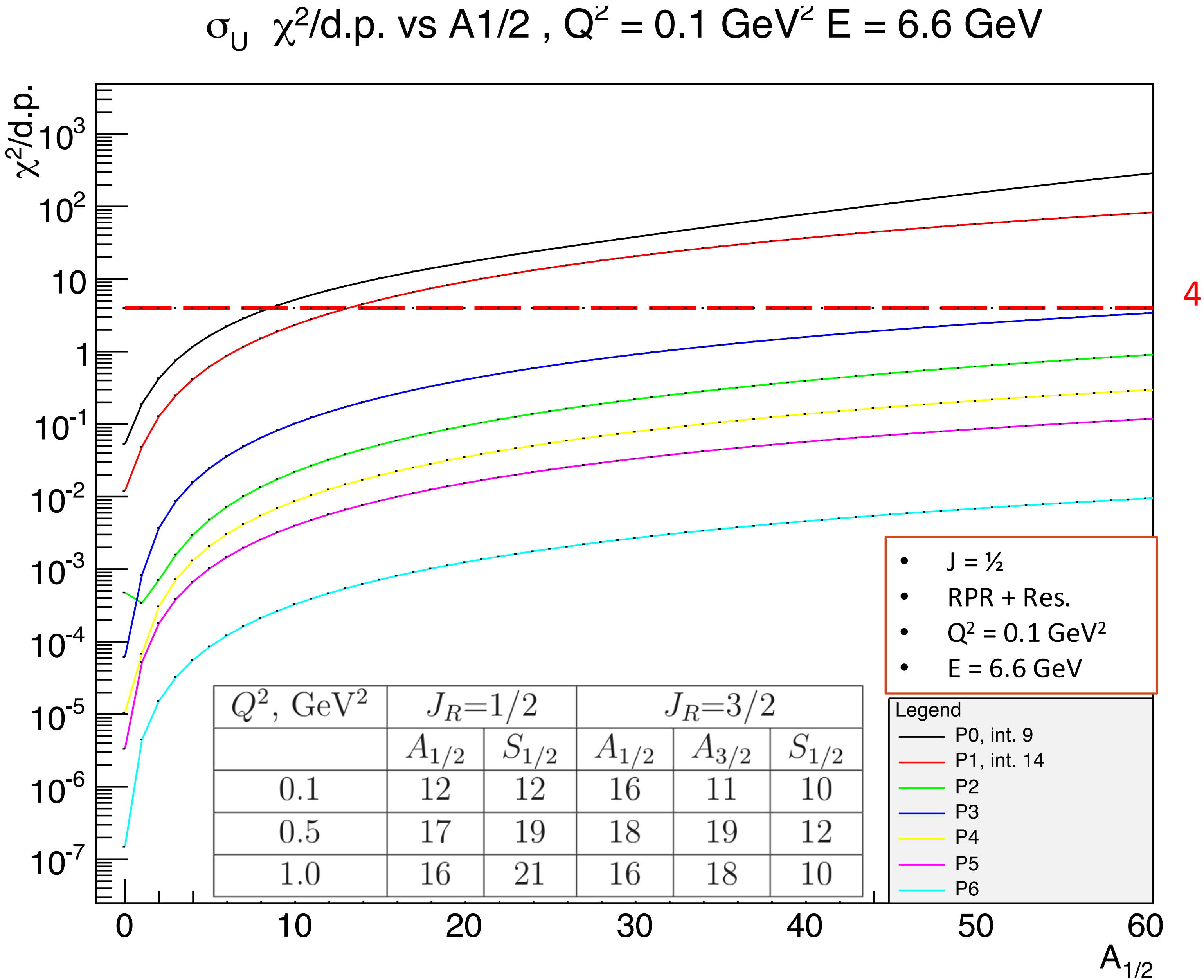
$$\chi^2 = \frac{1}{N_{d.p.}} \sum_{W} \frac{\left(P_m^{model\,+\,hybrid,\ variable\ A_{1/2}} - P_m^{model}\right)^2}{\delta^2}$$

on a variable $A_{1/2}$ has been estimated for Legendre moments $P_0,\ldots,P_6$ for different configurations:

- E_{beam} = 6.6 GeV, 8.8 GeV
- Q^2 = 0.1 GeV^2, 0.562 GeV^2, 1.002 GeV^2

For each curve the value of $A_{1/2}$ for which the χ^2 exceeds 4 has been obtained.

U Legendre moment: χ^2 vs $A_{1/2}$



Q^2, GeV^2	J_R=1/2		J_R=3/2		
	$A_{1/2}$	$S_{1/2}$	$A_{1/2}$	$A_{3/2}$	$S_{1/2}$
0.1	12	12	16	11	10
0.5	17	19	18	19	12
1.0	16	21	16	18	10

χ^2 vs M_{res}

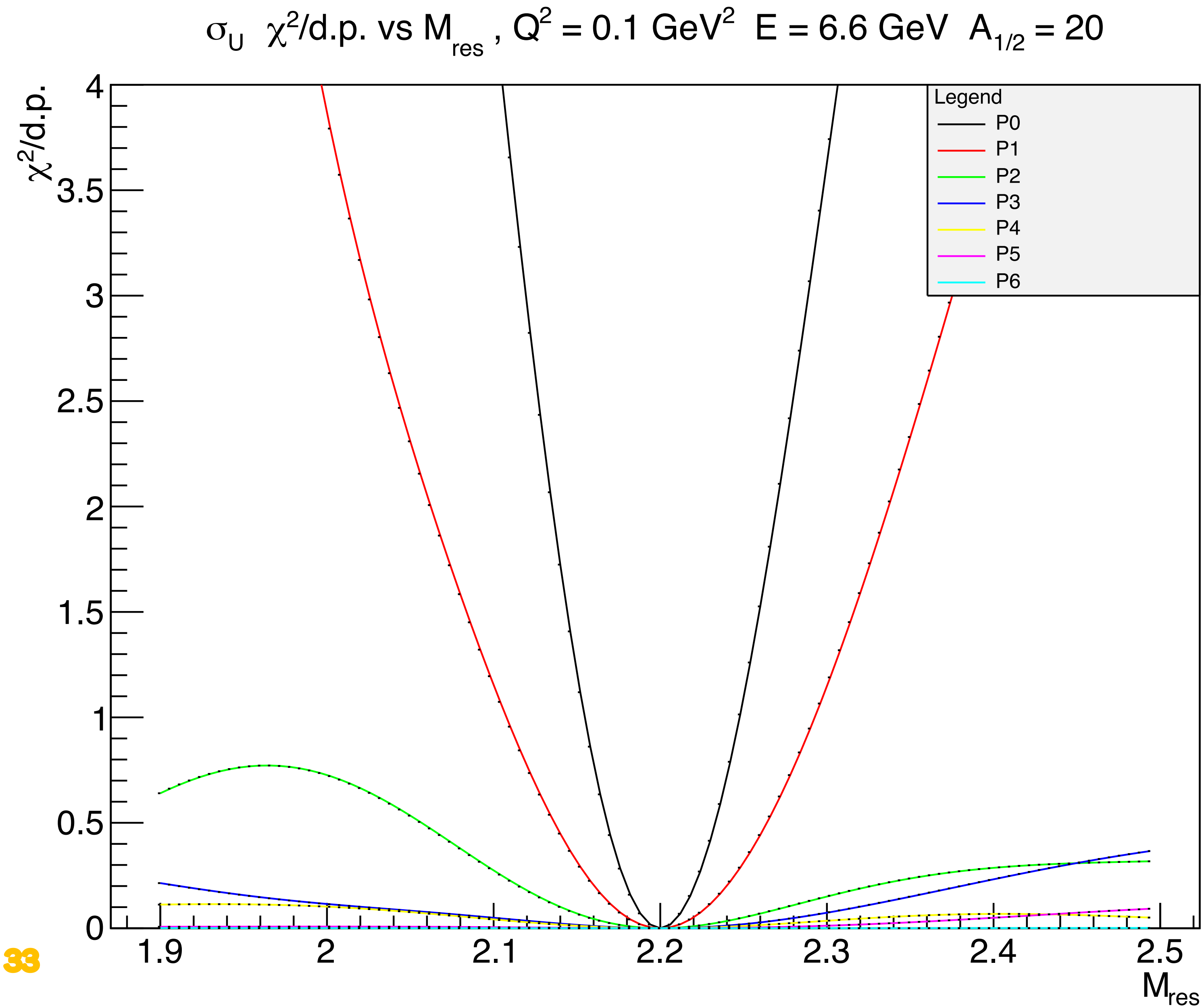
The dependency of χ^2 calculated as

$$\chi^2 = \frac{1}{N_{d.p.}} \sum_{W} \frac{(P_m^{model\, +\, hybrid\, with\, M_{res}=2.2\ GeV} - P_m^{model\, +\, hybrid\, with\, variable\, M_{res}})^2}{\delta^2}$$

on a variable M_{res} has been estimated for Legendre moments $P_0,\ldots,P_6$ for different configurations:

- E_{beam} = 6.6 GeV, 8.8 GeV
- $A_{1/2}$ = 20, 40
- Q^2 = 0.1 GeV^2, 0.562 GeV^2, 1.002 GeV^2

U Legendre moment: χ^2 vs M_{res}



- J = ½
- RPR with res.
- Q^2 = 0.1 GeV^2
- E = 6.6 GeV
- A = 20

χ^2 vs M_{res} and A

The χ^2 has been calculated as:

$$\chi^2 = \frac{1}{N_{d.p.}} \sum_{W,cos\vartheta\ \varphi} \frac{(\sigma_{fixed} - \sigma_{variable})^2}{\delta^2} = \frac{1}{N_{d.p.}} \sum_{W,cos\vartheta\ \varphi} \left(\frac{\sigma_{fixed} - \sigma_{variable}}{\sigma_{variable}}\right)^2 N_{ev}$$

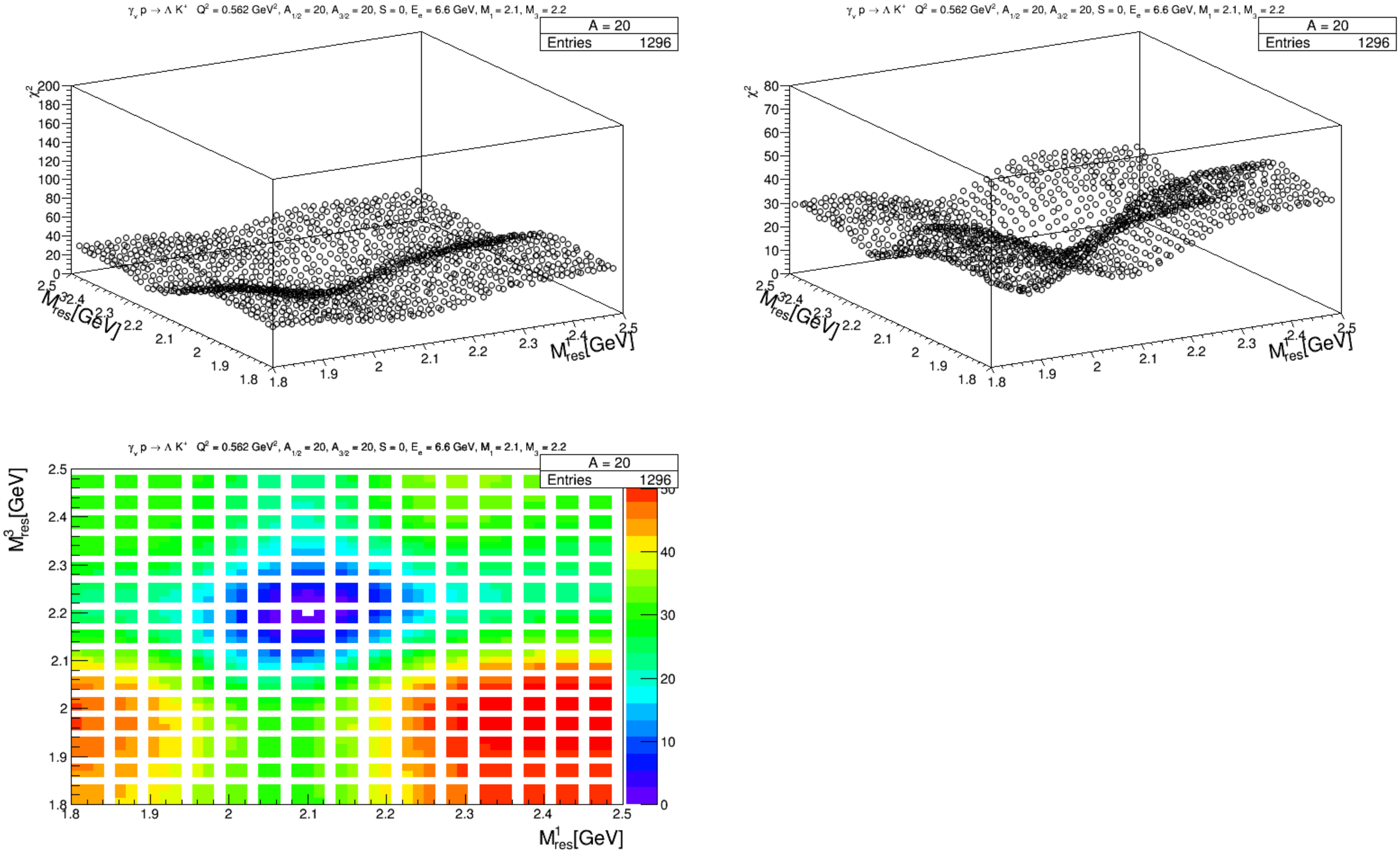
Where

- σ_{fixed}: model + hybrid, 2 resonances
  - Resonance 1: $J = \frac{1}{2}, A_{1/2} = fixed, M^1_{res} = 2.1\ GeV$
  - Resonance 2: $J = \frac{3}{2}, A_{3/2} = fixed, A_{1/2} = fixed, M^3_{res} = 2.2\ GeV$
- $\sigma_{variable}$: model + hybrid, 2 resonances
  - Resonance 1: $J = \frac{1}{2},\ A_{1/2} = variable(0 - 50, step\ 1), M^1_{res} = variable(1.8 - 2.5\ GeV, step\ 20\ MeV)$
  - Resonance 2: $J = \frac{3}{2}, A_{\frac{3}{2}} = variable\ (0 - 50, step\ 1), A_{1/2} = variable(0 - 50, step\ 1), M^3_{res} = variable\ (1.8 - 2.5\ GeV, step\ 20\ MeV)$
- N_{ev} = number of expected events in 50 days beamtime for each bin in Q^2 , $W, cos\vartheta, \varphi$

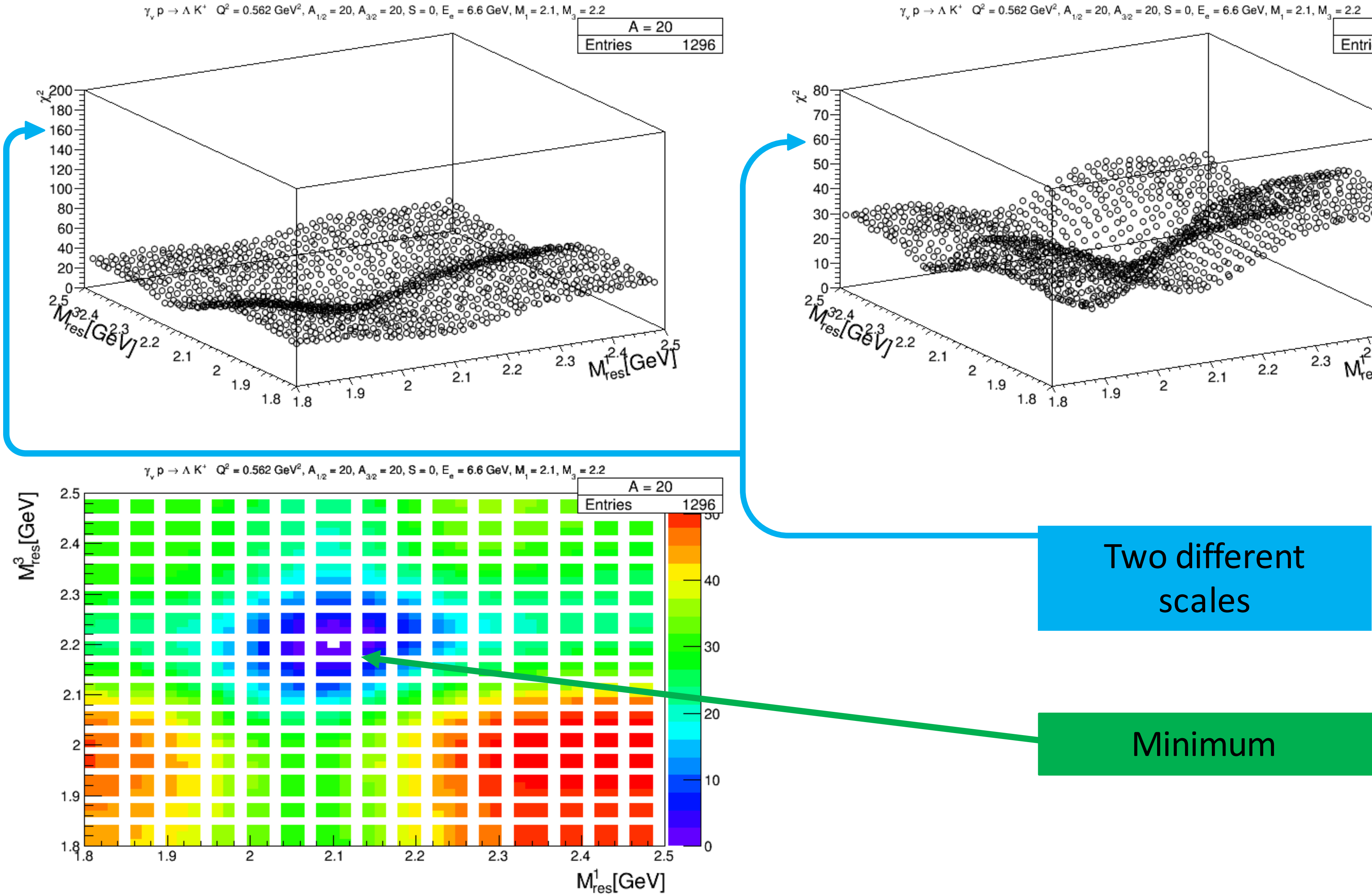
χ^2 has been estimated for variable M^1_{res} , M^3_{res} and $A_{1/2} = A_{3/2}$ for the configurations:

- ($J^+_{1/2} : A_{1/2}, J^+_{3/2} : A_{1/2}, A_{3/2}$) = (10, 10, 10), (20, 20, 20), (40, 40, 40)
- E_{beam} = 6.6 GeV
- Q^2 = 0.562 GeV^2
- Γ_{res} = 0.25 GeV

A_{fixed}=20: χ^2 vs M_{res} and A



A_{fixed}=20: χ^2 vs M_{res} and A



Conclusions

Simulation and fast mc reconstruction of $K^+\Lambda$ electro-production events in CLAS12

- Run condition: E_{beam}=6.6 GeV and Torus Current = -3750 A presents good values of efficiency
- Search of hybrid baryons in runs with standard conditions of magnet and beam energy can be integrated with dedicated runs.

Study of sensitivity

- Hybrid resonance has been added at **amplitude level** to study the sensitivity of our system to a hybrid resonance
- Legendre moments analysis has been employed as a way to identify resonances

Future Work

Next step:

- Full implementation in CLAS12 simulation and reconstruction
  - GEMC
  - CLARA framework

- Reconstruction of the interaction strength from simulated data

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- Full implementation in CLAS12 simulation and reconstruction
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Thank you

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