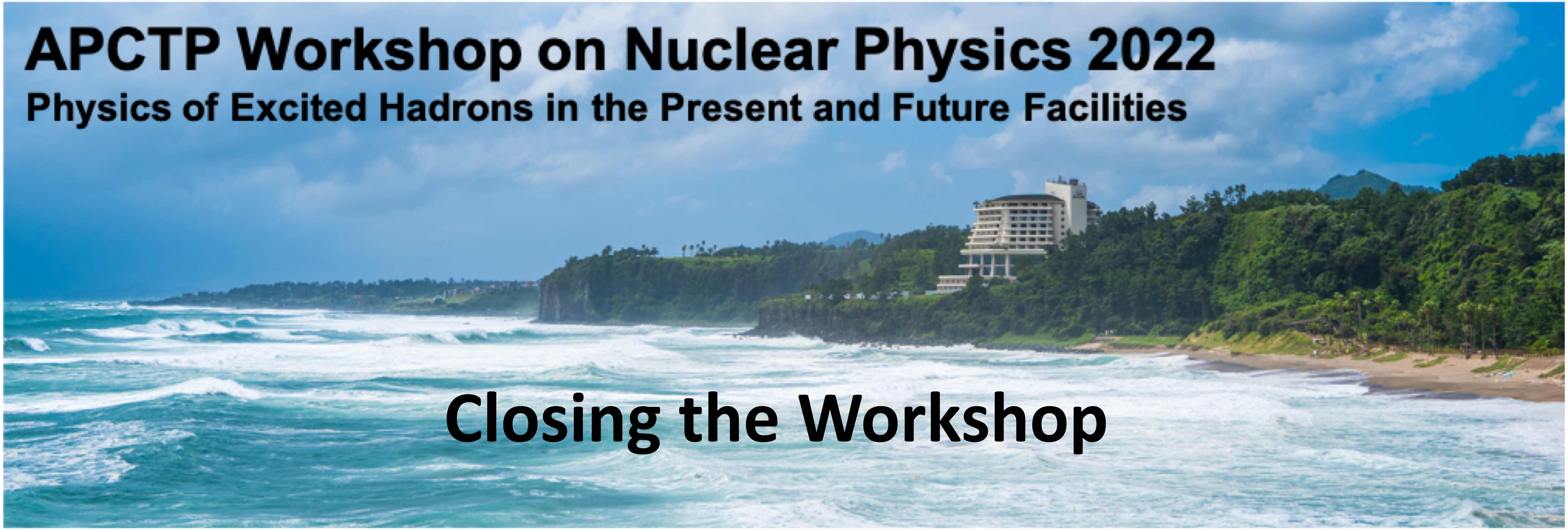


2022 also marks the 70th anniversary of discovery of the Δ^{++}**(1232)**
in $\pi^{+}p$ scattering, E. Fermi et al., Phys. Rev. 85 (1952) 936.


APCTP Workshop on Nuclear Physics 2022
Physics of Excited Hadrons in the Present and Future Facilities
July 11 - 16 / Jeju Suites Hotel / Sponsors: apctp , CHEP@KNU
The APCTP is supported by the Korean Government through the Science and Technology Promotion Fund and Lottery Fund and strives to maximise social value through its various activities.
아시아태평양 이론물리센터는 정부의 과학기술진흥기금 및 복권기금 지원으로 사회적 가치 제고에 힘쓰고 있습니다.

General comments

- The first all in-person international workshop on hadron physics many of us attended after the covid-19 pandemic.
- Great venue, superior organization, excellent talks and discussions, delicious meals, and much fun at the excursion on the yacht.

Thank you to Jiyoung for all the great work!

Jiyoung Ha

Balanced distribution of talks – thank you to the organizing committee

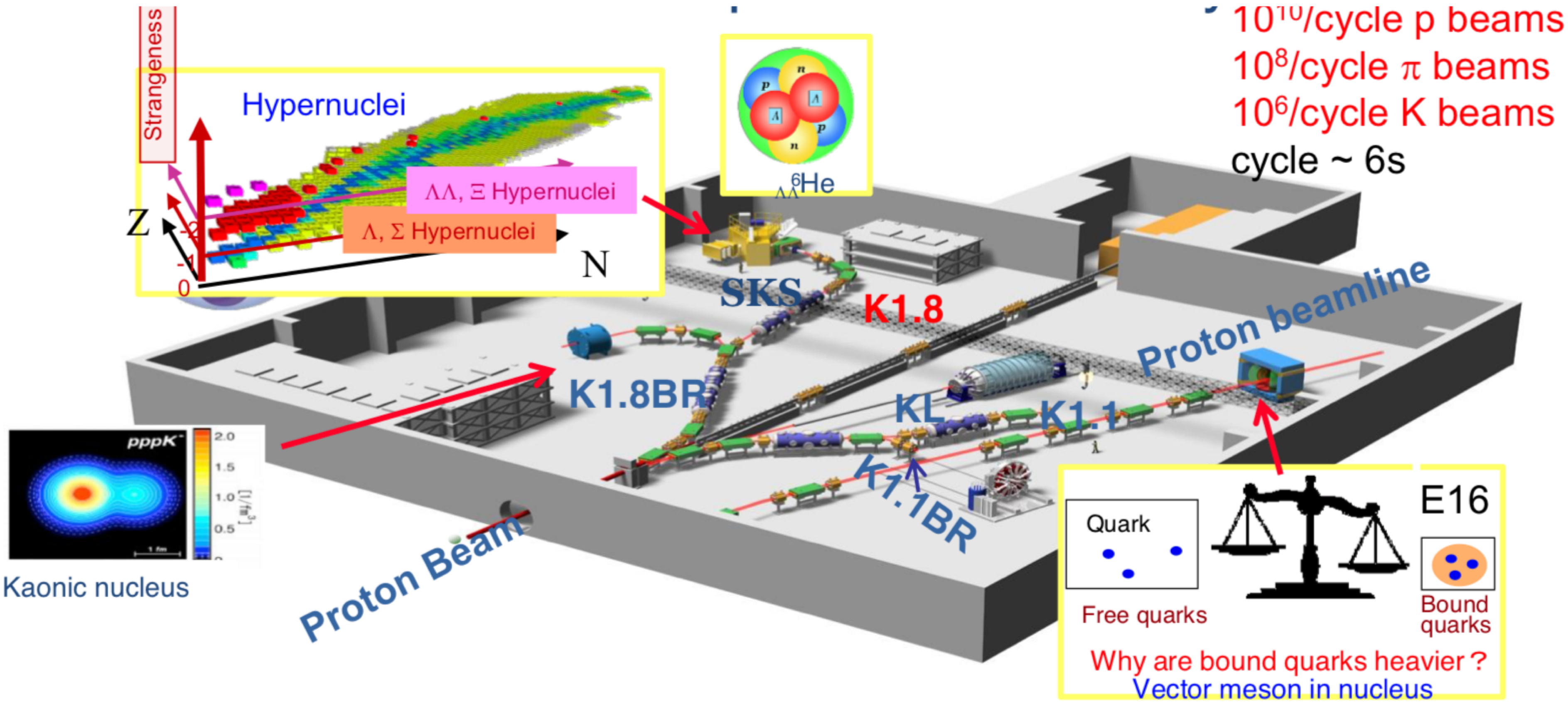
- Experimental talks: 16
- Theory talks: 18
- A good percentage of young people – good for the field
- Gender breakdown: male 33, female 1 - let us make an effort to change that **

- Facility talks: J-PARC, JLAB, MAMI-MESA, HADES, ELSA/BGOOD, ...
- Many talks showing strong involvement of theorists/phenomenologists in interpretation of data - heeding Harry Lee's message from the first day.

** The QNP2022 conference on quarks and nuclei has a lineup of 22 all-female plenary speakers.

J-PARC Hadron Experimental Facility

Hiroyuki Sako Baryon Spectroscopy – search for new N* and Δ* states,

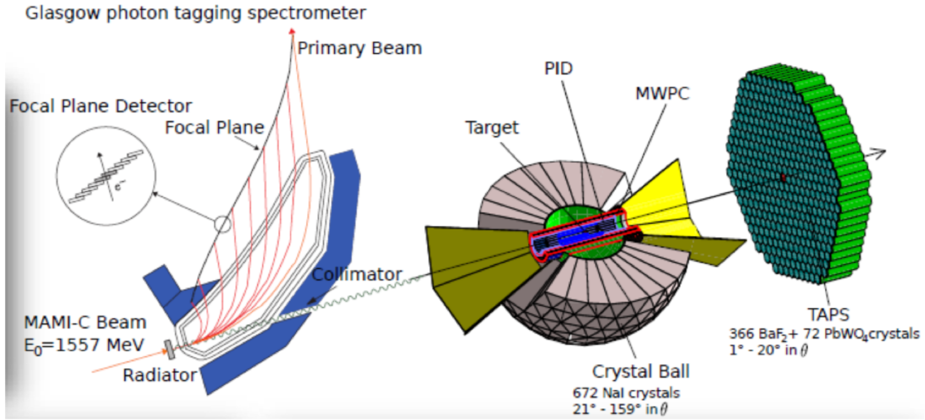


Hiroyuki Noumi Extension plan to study excited baryons with heavy flavor

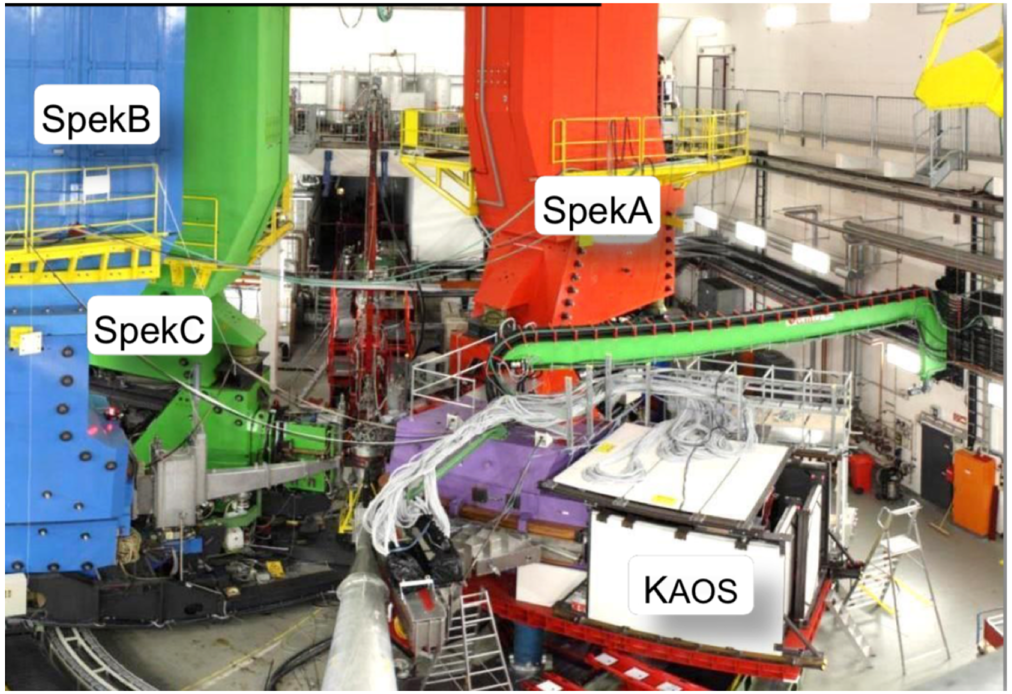
Physics Highlights and Perspectives with Electron Beams at Mainz

P. Achenbach

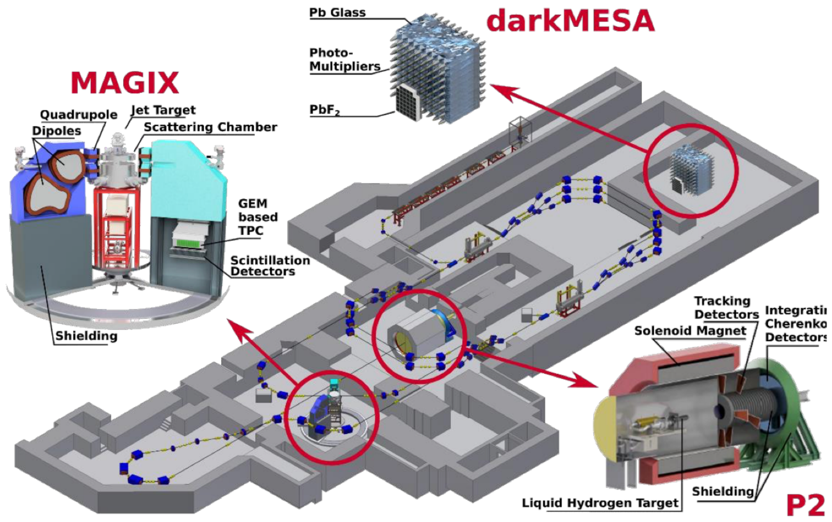
Physics with energy-tagged photon beam and crystal detectors



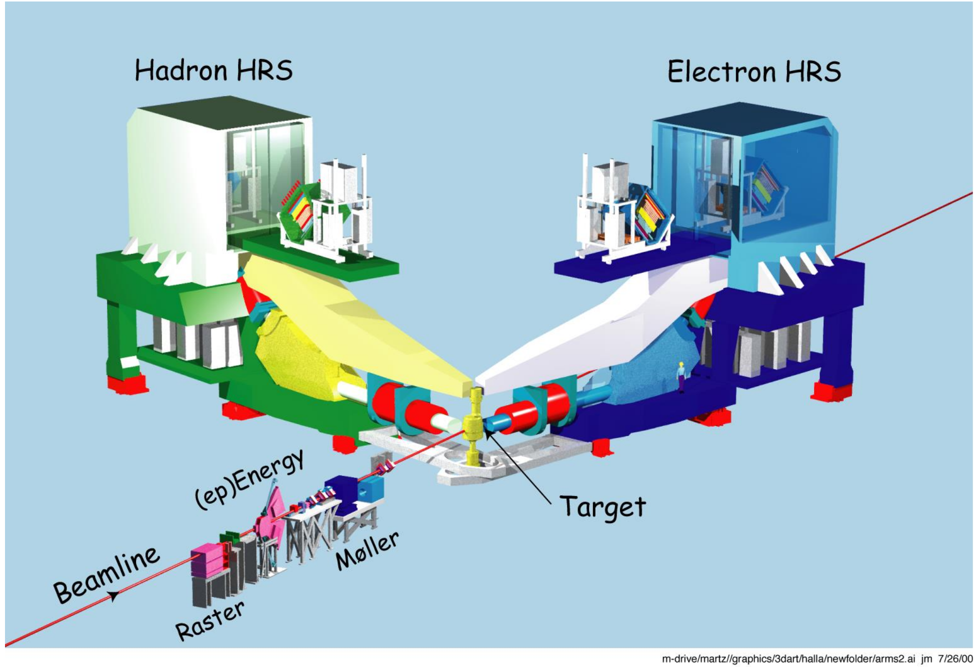
Precision electron scattering with **high resolution** focusing spectrometers. Many exciting high impact results at energy < 1.6 GeV in various stages of microtron

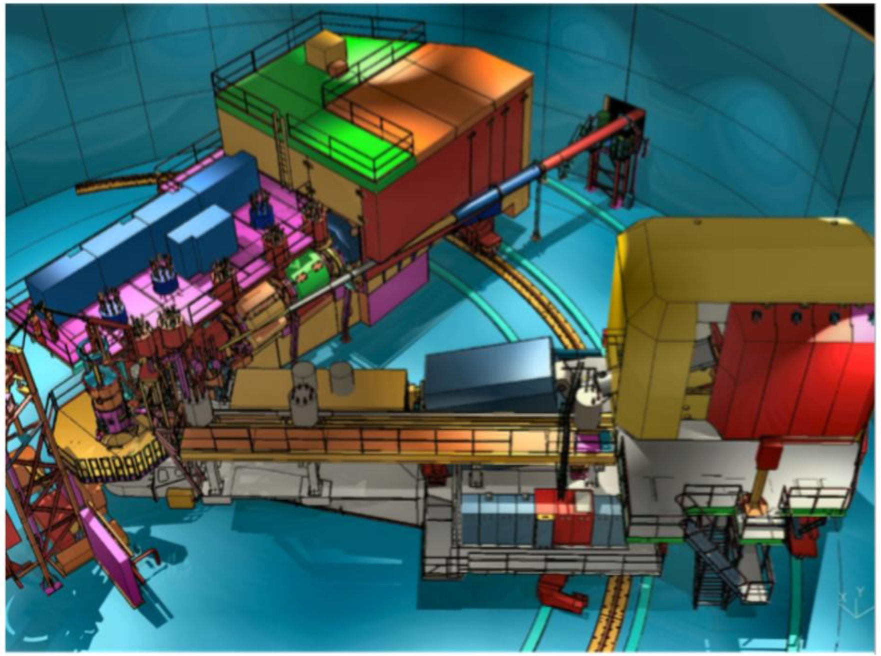


New project: **MESA** – Ultra-high current e-beam 15mA luminosity, energy below pion threshold < 155 MeV



JLab Hall A & C spectrometers + large acceptance



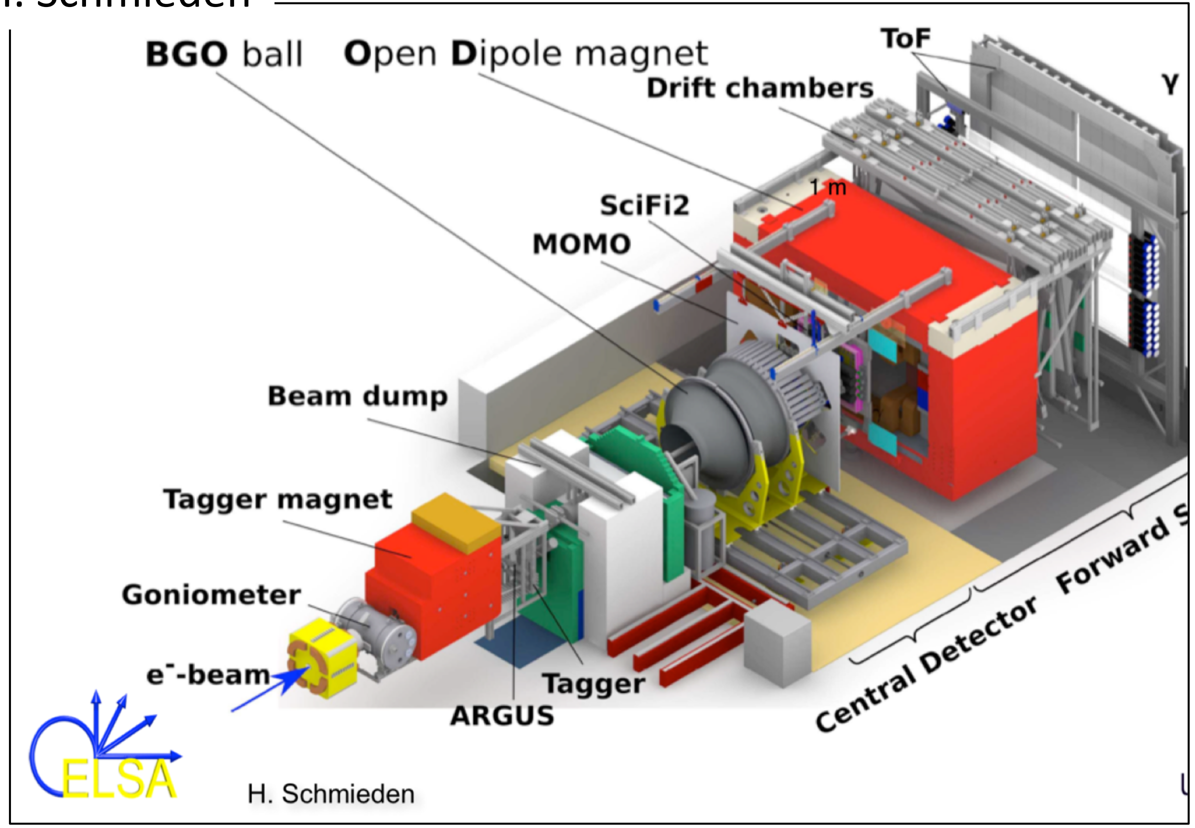


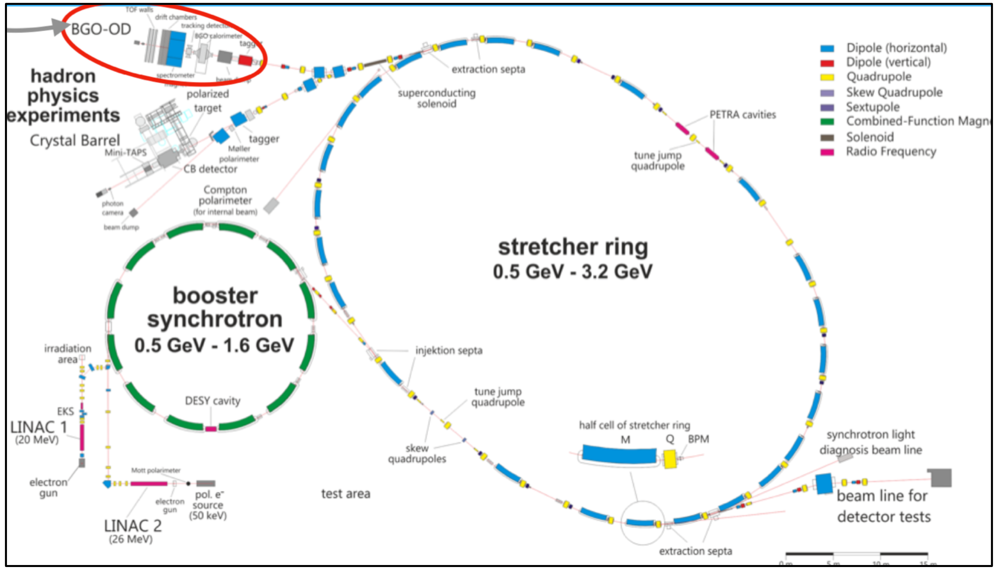
A. Cansomme

- Hall A and C high luminosity halls luminosity ranging from 10^{36} up to 5.10^{38} cm-2s-1
- Few simple measurements using small acceptance spectrometers
- Larger acceptance detectors available such as Super Big Bite
- Large acceptance detector like SoLID striving to keep running at highest luminosity
  - Approved experiments SIDIS and J/Psi
  - Future possible experiment DDVCS
- Focus on deep inelastic but could have dedicated experiment in resonance region

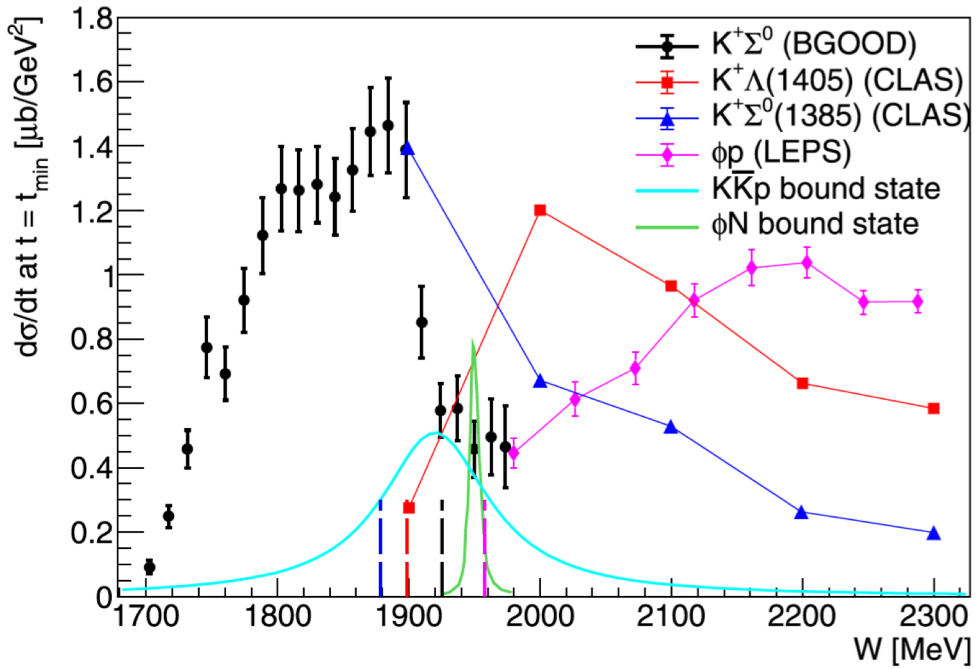
ELSA – BGOOD Experiment

H. Schmieden



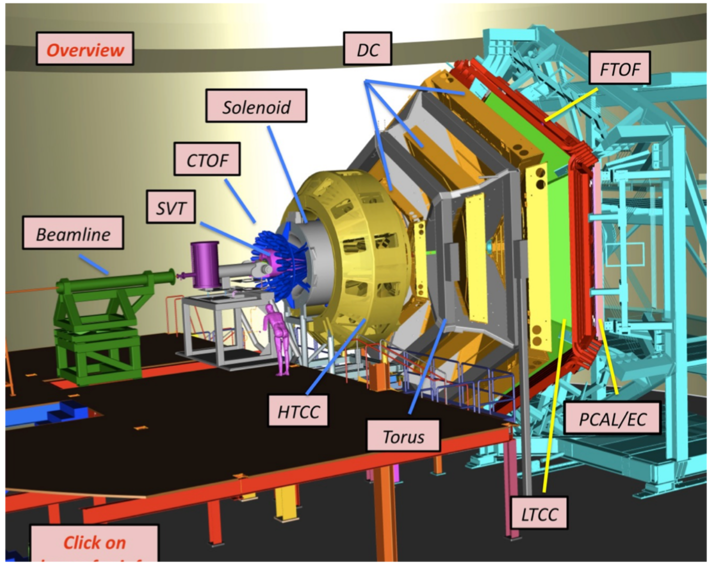


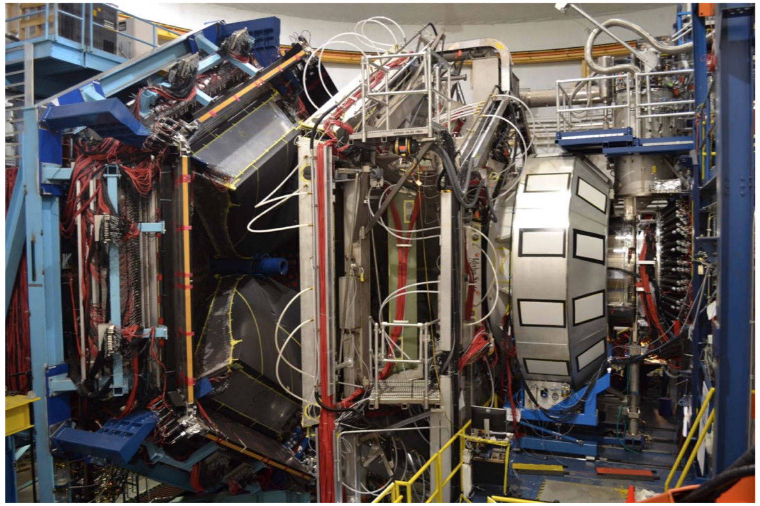
BGOOD tuned for threshold physics in uds sector



Current focus on missing strange baryons

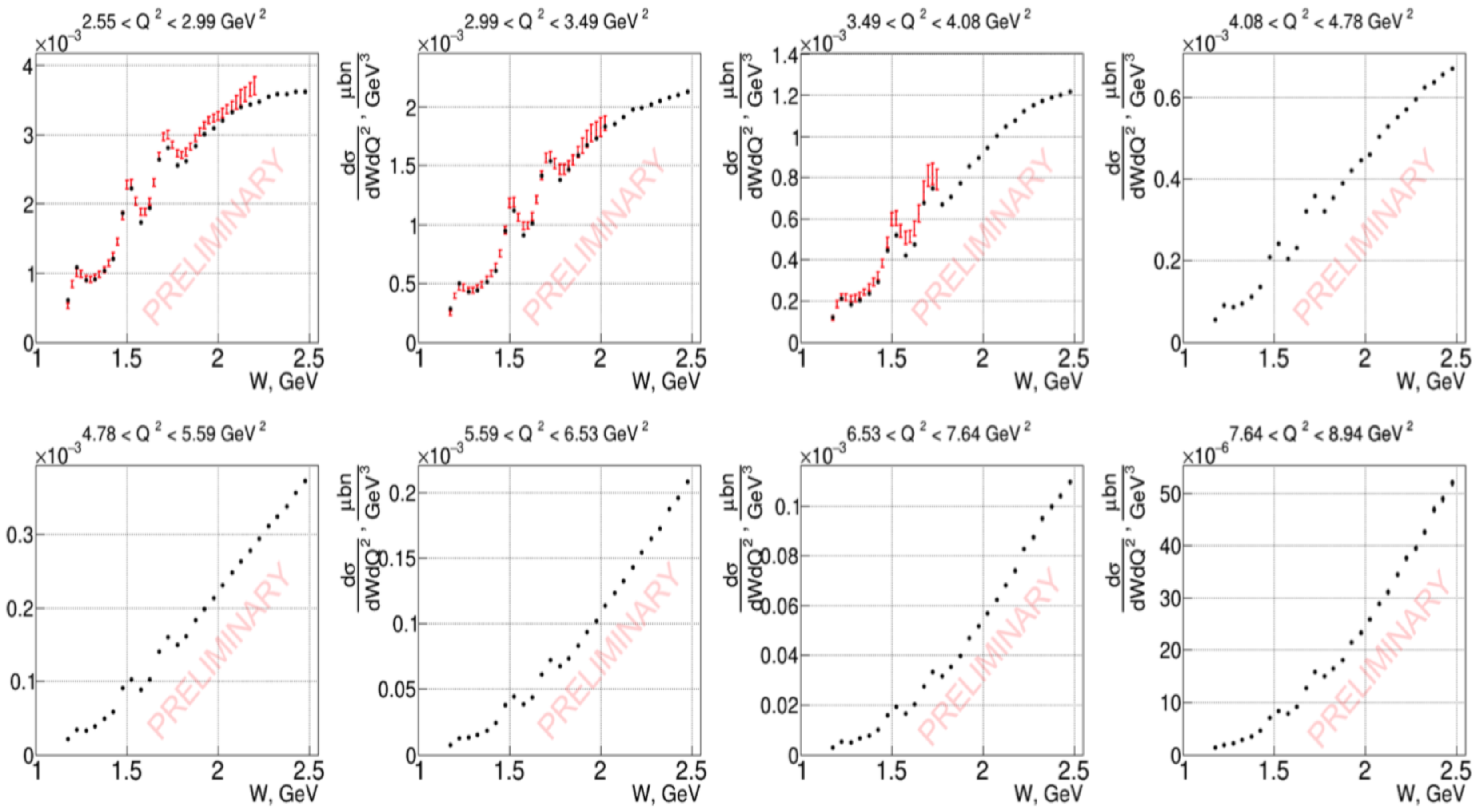
JLab CLAS12 spectrometer





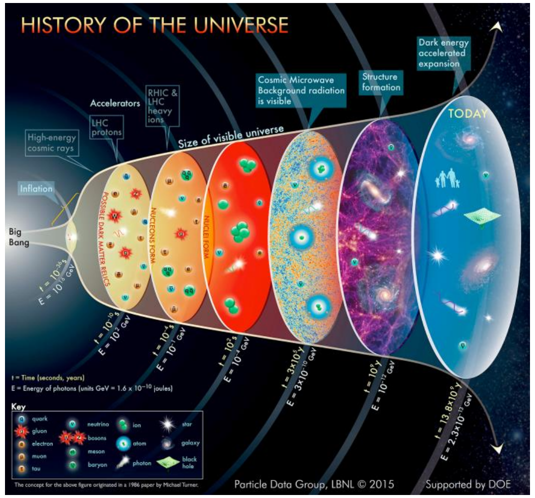
Timothy Hayward, Valerii Klimenko

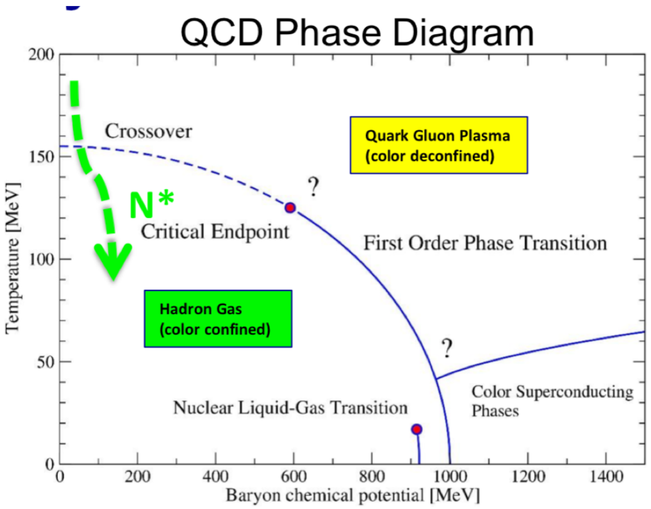
The first absolute inclusive cross section to reconstruction efficiencies.



Experiment – phenomenology- and theory - together

Hiroyuki Sako



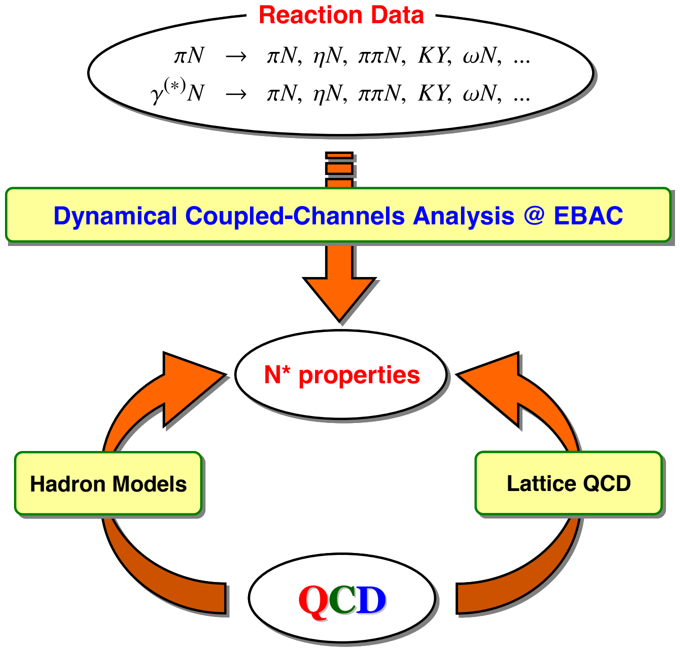


The history of the universe tells us how mass was generated in the transition from quark-gluon plasma of non-interaction quarks and gluons to confinement of hadrons. It involves all excited baryon resonances.

We are trying to reconstruct from todays data what happened in the process that took place 14 x 10^9 years ago at temperatures above 10^{12}K (100 MeV). Experiments at GeV levels are perfectly matched to probing resonances generated in during this transition in "isolation".

T.S. Harry Lee

Study of N → N* over a broad range of Q^2 will reveal how the **nucleon mass is dynamically generated from massless quarks of PQCD** and provide information on the effects of the meson-baryon cloud.



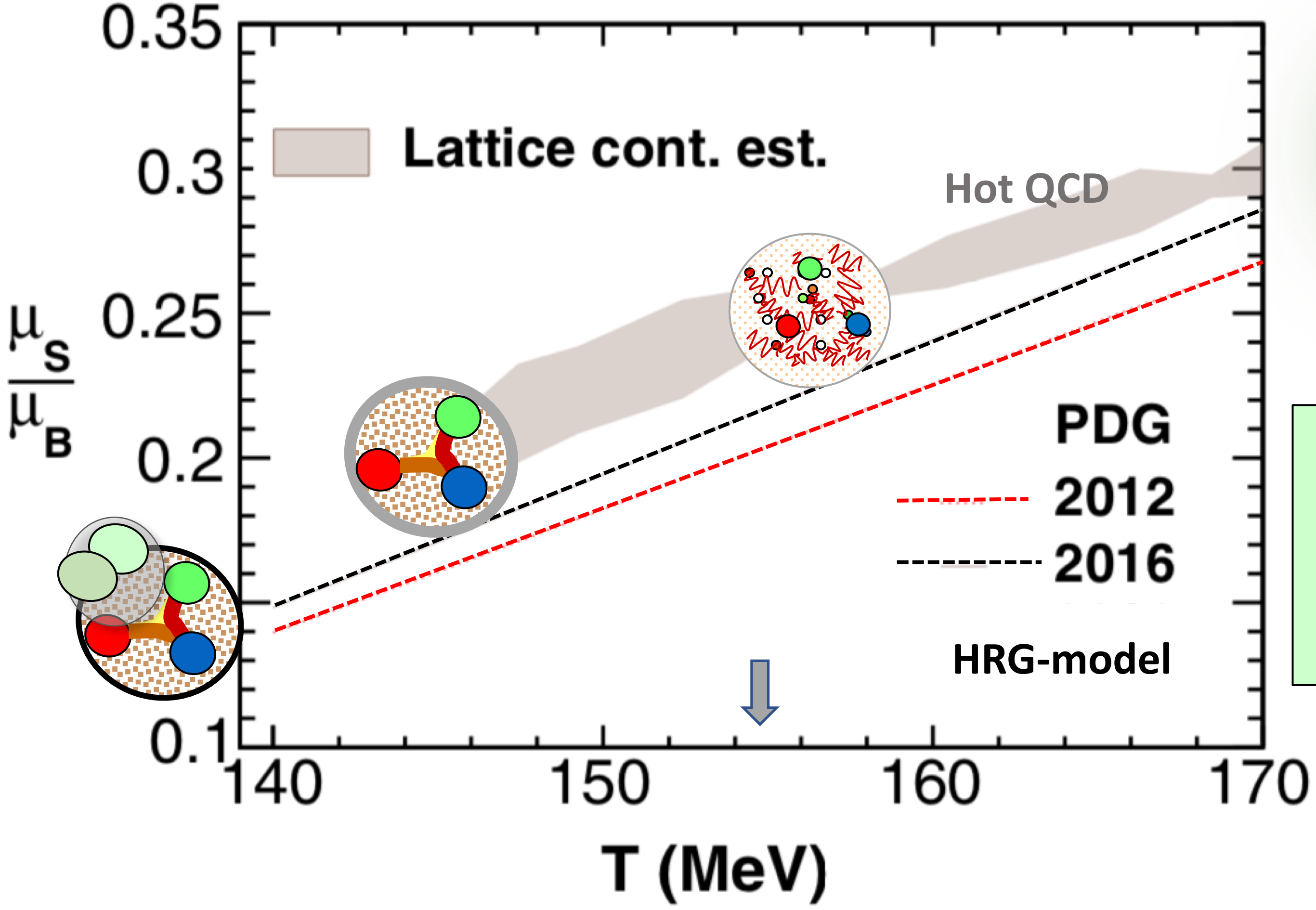
1. Need extensive data of meson production reactions
2. Need theoretical models to extract the N* from the data
3. Need to understand the structure of N*

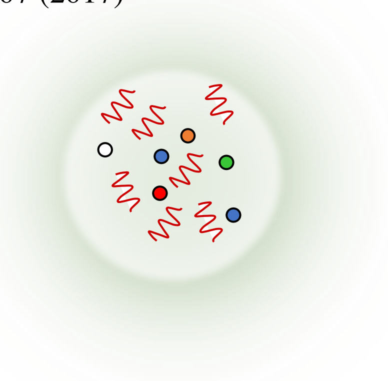
The ultimate case for the missing excited baryons

Understanding the history of our universe

strangeness / baryon chemical potential

Sandeep Chatterjee et al; PRC **96**, 054907 (2017)





We do not describe the transition near the cross over temperature without accounting for the full complement of quark model baryon resonances.

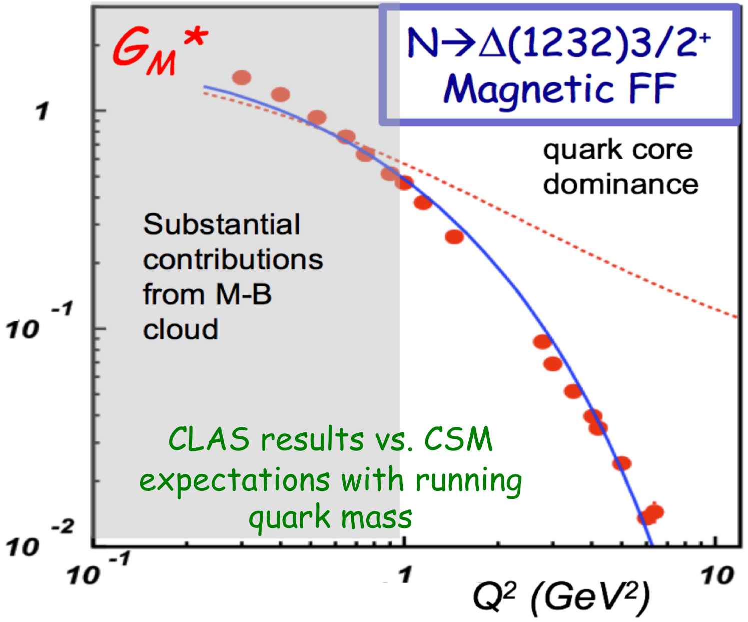
PDG 2016 with *, **

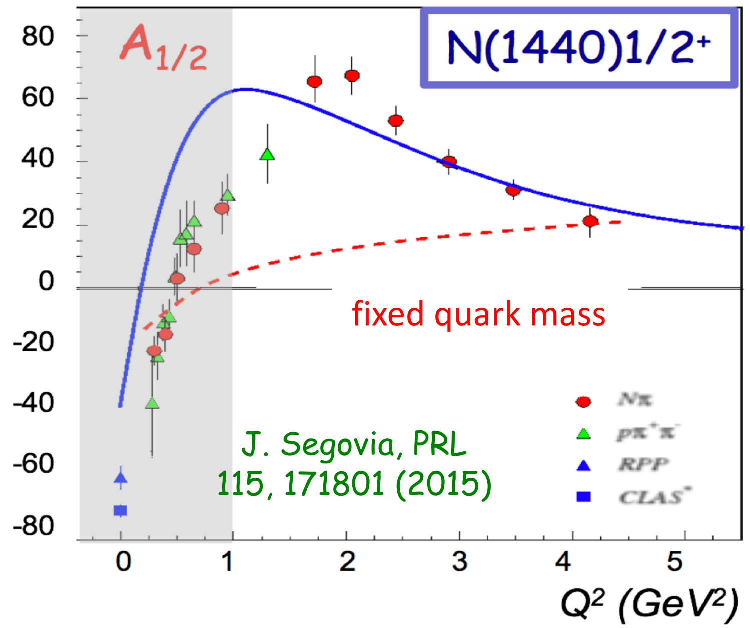
N(1860)	N(1880)
N(1895)	N(1895)
N(2000)	N(2040)
N(2060)	N(2100)
N(2120)	N(2300)
N(2570)	N(2700)
Δ(1750)	Δ(1900)
Δ(1940)	Δ(2000)
Δ(2150)	Δ(2200)
Δ(2300)	Δ(2350)
Δ(2390)	Δ(2400)
Δ(2750)	Δ(2950)
N(1875)	

PDG 2018 with ***, ****

Electroexcitation of N* key to learn about EHM?

Measurements of transition form factors on N* states need to be extended to higher Q^2 to probe the transition where quarks have lost most of the dressing Q^2 >

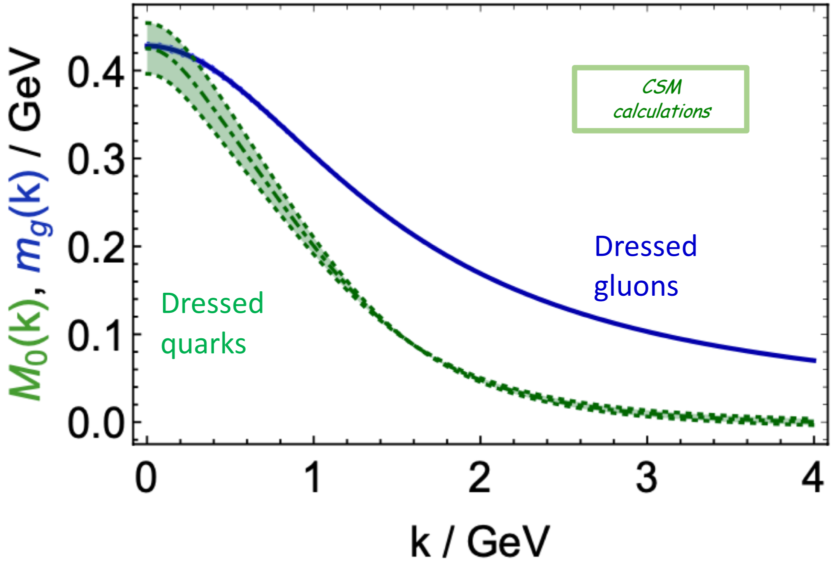




Importance of the pion cloud at small Q, not included in computation.

Victor Mokeev

Continuous QCD calculation



Defining the "complete experiment" problem

Y. Wunderlich

Finale: the 'coupled-channels complete experiment'

Consider *channel-space* $\{|\pi N\rangle, |\gamma N\rangle, |\pi\pi N\rangle\}$, i.e.:

$$(\mathcal{T}_{fi}) = \begin{bmatrix} \mathcal{T}_{\pi N,\pi N} & \mathcal{T}_{\pi N,\gamma N} & \mathcal{T}_{\pi N,\pi\pi N} \\ \mathcal{T}_{\gamma N,\pi N} & \mathcal{T}_{\gamma N,\gamma N} \simeq 0 & \mathcal{T}_{\gamma N,\pi\pi N} \\ \mathcal{T}_{\pi\pi N,\pi N} & \mathcal{T}_{\pi\pi N,\gamma N} & \mathcal{T}_{\pi\pi N,\pi\pi N} \end{bmatrix}.$$

$\hookrightarrow$ Measure individual complete experiments with perfect *phase-space coverage and overlap* among individual reactions (complete exp.'s determinable using *graphs*):

Reaction	Example complete experiment (yields $\lvert b_i \rvert$ & ϕ_{ij})
$\pi N \rightarrow \pi N$ ($N_{\mathcal{A}} = 2$)	$\sigma_0, \hat{P}, \hat{R}, \hat{A}$
$\pi N \rightarrow \pi\pi N$ ($N_{\mathcal{A}} = 4$)	$\sigma_0, \check{P}_y, \check{P}_z, \check{P}_{x'}, \check{P}_{y'}, \check{\mathcal{O}}_{yy'}, \check{\mathcal{O}}_{zy'}, \check{\mathcal{O}}_{yz'}$
$\gamma N \rightarrow \pi N$ ($N_{\mathcal{A}} = 4$)	$\sigma_0, \check{\Sigma}, \check{T}, \check{P}, \check{E}, \check{H}, \check{L}_{x'}, \check{T}_{x'}$
$\gamma N \rightarrow \pi\pi N$ ($N_{\mathcal{A}} = 8$)	$\sigma_0, \check{P}_y, \check{P}_{y'}, \check{\mathcal{O}}^{\odot}_{yy'}, \check{\mathcal{O}}_{yy'}, \check{P}^{\odot}_{y'}, \check{P}^{\odot}_{y}, I^{\odot}, \check{P}_x, \check{P}_z, \check{P}_{x'}, \check{P}^{s}_{x}, \check{P}^{\odot}_{x}, \check{P}^{c}_{z}, \check{P}^{\odot}_{z}, \check{P}^{\odot}_{x'}$

$\Rightarrow$ For these 4 reactions, we have $\mathcal{T}_{fi} = e^{i\phi_{fi}}\tilde{\mathcal{T}}_{fi}$, with $\tilde{\mathcal{T}}_{fi}$ fixed.

$\hookrightarrow$ Fit at least two (or more) complementary ED models (BnGa, JüBo, ...), which have to have *as good unitarity-constraints as possible*, to this database

$\Rightarrow$ Missing phase-information $e^{i\phi_{fi}}$ fixed and resonance-spectrum (hopefully) unique!

Issues:
- Can we assume perfect time-reversal inv., to relate $3 \rightarrow 2$ to $2 \rightarrow 3$ processes?
- $3 \rightarrow 3$-process $\pi\pi N \rightarrow \pi\pi N$ unmeasurable. Does this hurt the proposal?

News from the Quark Model – it is still needed!

Detailed update on **covariant spectator quark model** (CSQM) calculations of the nucleon resonance transition form factors of the lower mass states.

G. Ramalho

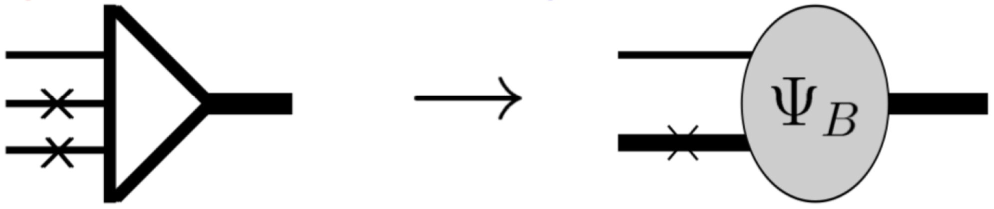
Calculations of N^* transition form factors at large Q^2

$\Delta(1232)\frac{3}{2}^+$, $N(1440)\frac{1}{2}^+$, $N(1535)\frac{1}{2}^-$, $N(1520)\frac{3}{2}^-$, $\Delta(1600)\frac{3}{2}^+$

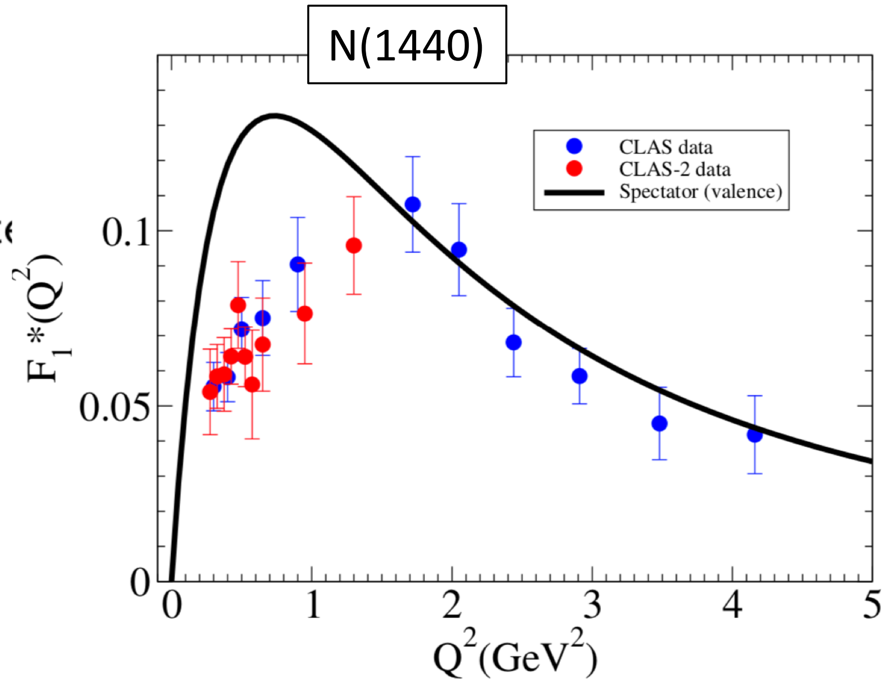
$N(1650)\frac{1}{2}^-$, $N(1700)\frac{3}{2}^-$, $\Delta(1620)\frac{1}{2}^-$, $\Delta(1700)\frac{3}{2}^-$ **[SQTM]**

... some results at low-Q^2

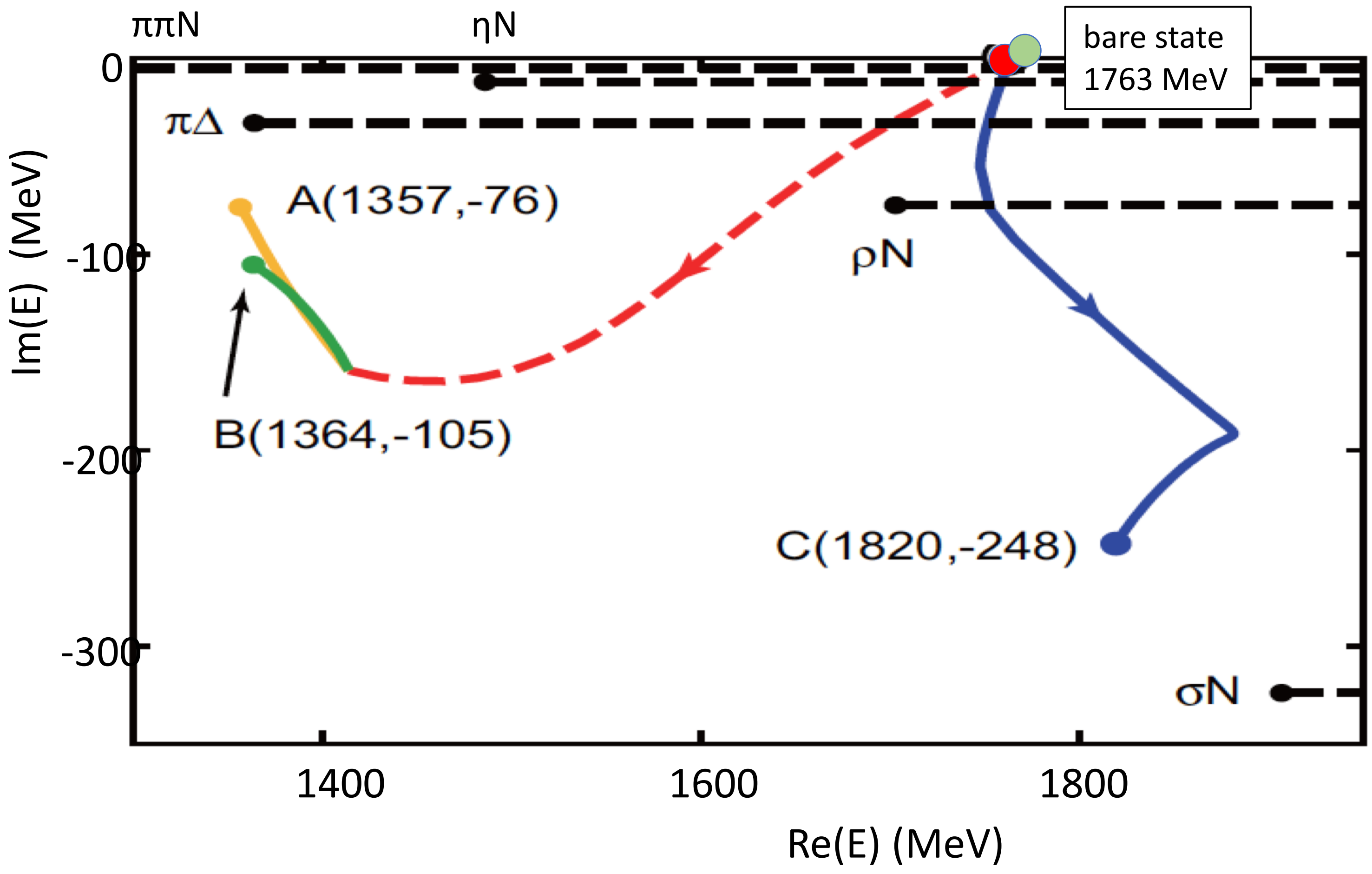
Covariant Spectator Theory: wf Ψ_B defined in terms of a 3-quark verte system with 2 on-shell quarks and an off-shell quark



$\Rightarrow$ qq pair replaced by an *effective* diquark with mass m_D



Why the mass of the Roper N(1440) mass sits below the N(1535) mass



Resonance masses (poles) can change significantly when the coupling to inelastic channels is included dynamically.

N. Suzuki, B. Julia-Diaz, H. Kamano, T.-S. H. Lee, A. Matsuyama, T. Sato, Phys.Rev.Lett.104:042302,2010

Does it apply to other “Roper-like” state that were discussed at the workshop?

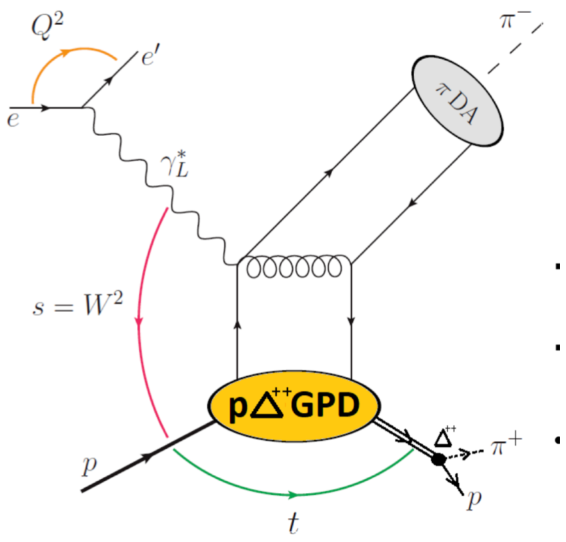
Resonance transition GPD (CFF)

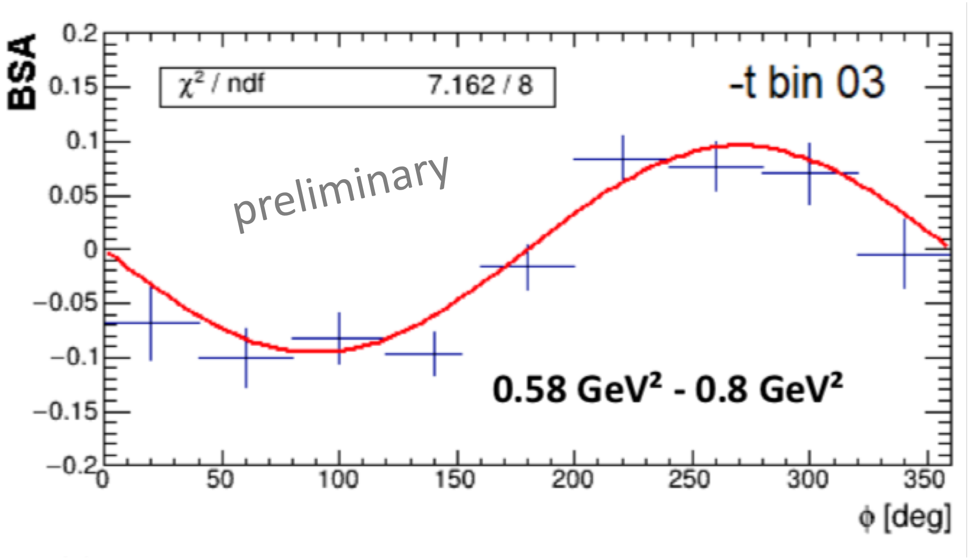
- The GPD program on the proton now well established and gravitational form factor was found to $d^q_1(t)$ make large contribution to the GPD (CFF) $\mathcal{H}(\xi,t)$ determined from DVCS data and confirmed by TCS data.

  $d_1(0)$ = -2.04 +/- 0.35 (DVCS data)

  $d_1(0)$ = -2.16 (χQSM), *H.Y. Won, et al*. (Friday cont. talk)

- Today we saw first preliminary data related to resonance transition GPD in **ep→ e$\Delta^{++}\pi^-$**





Kyungseon Joo

The Yacht trip

The sun makes an appearance as we leave this beautiful island Jeju.

16. July 2022

For a very exciting workshop

Yongseok Oh and Kyungseon Joo

THANK YOU!

감사합니다