

Nuclear Data

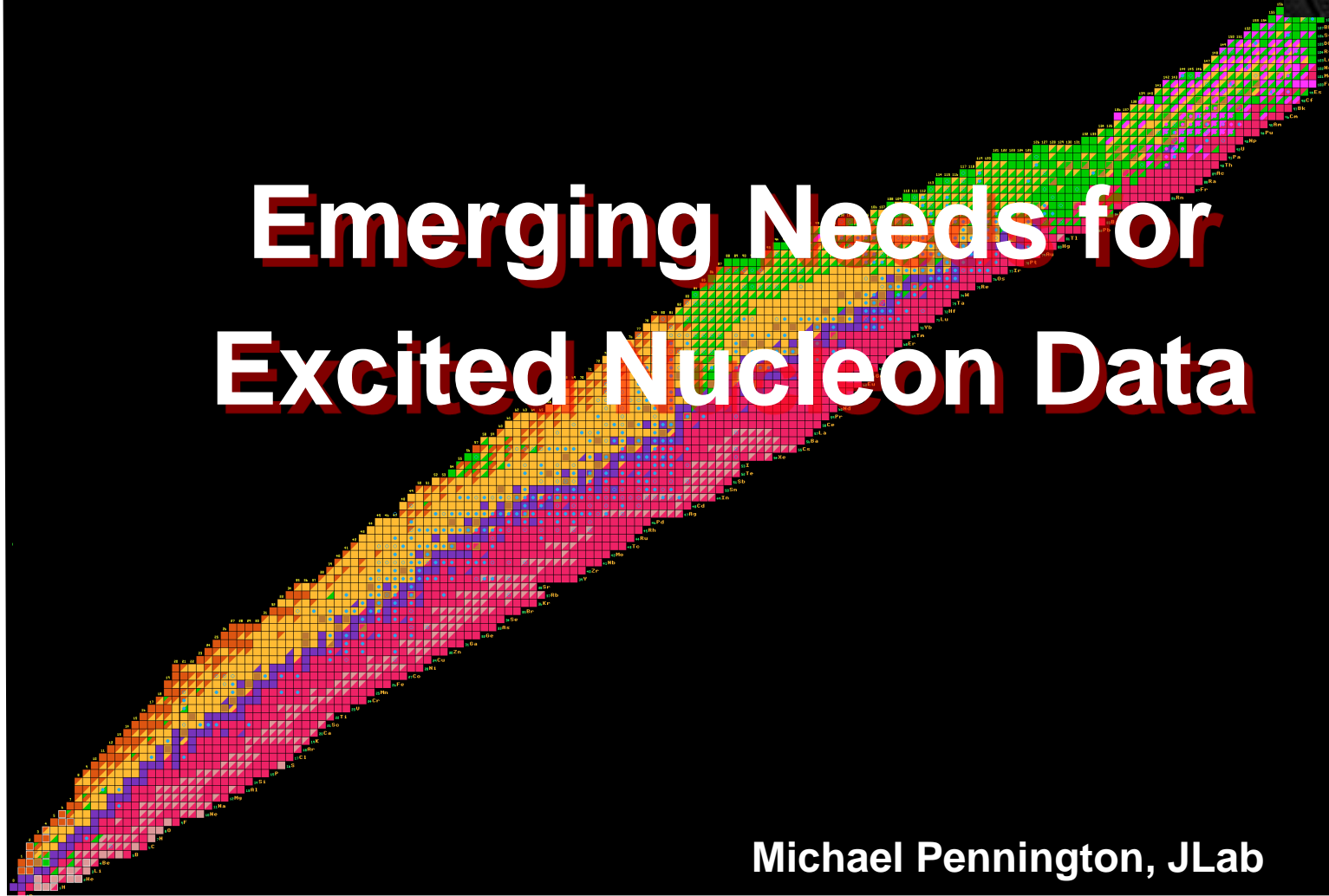


Emerging Needs for Excited Nucleon Data

Michael Pennington, JLab

N

Z



Nuclear Data

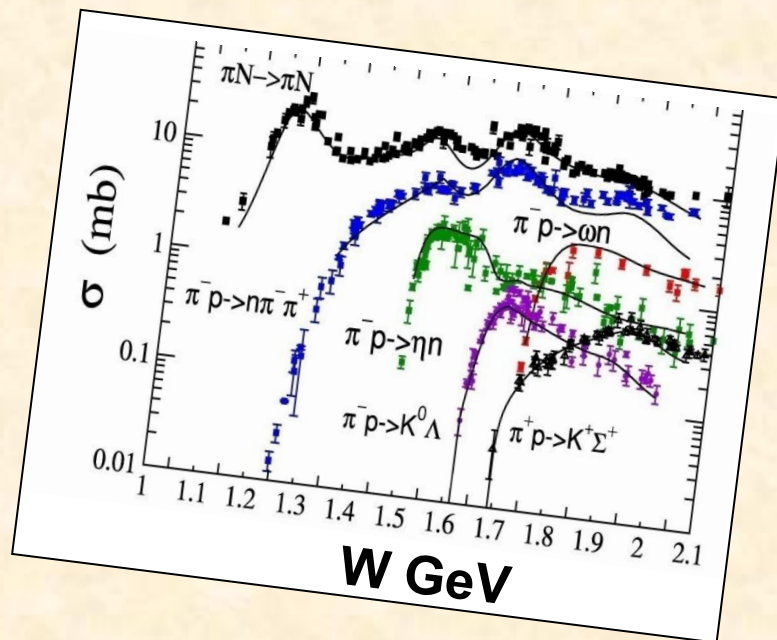
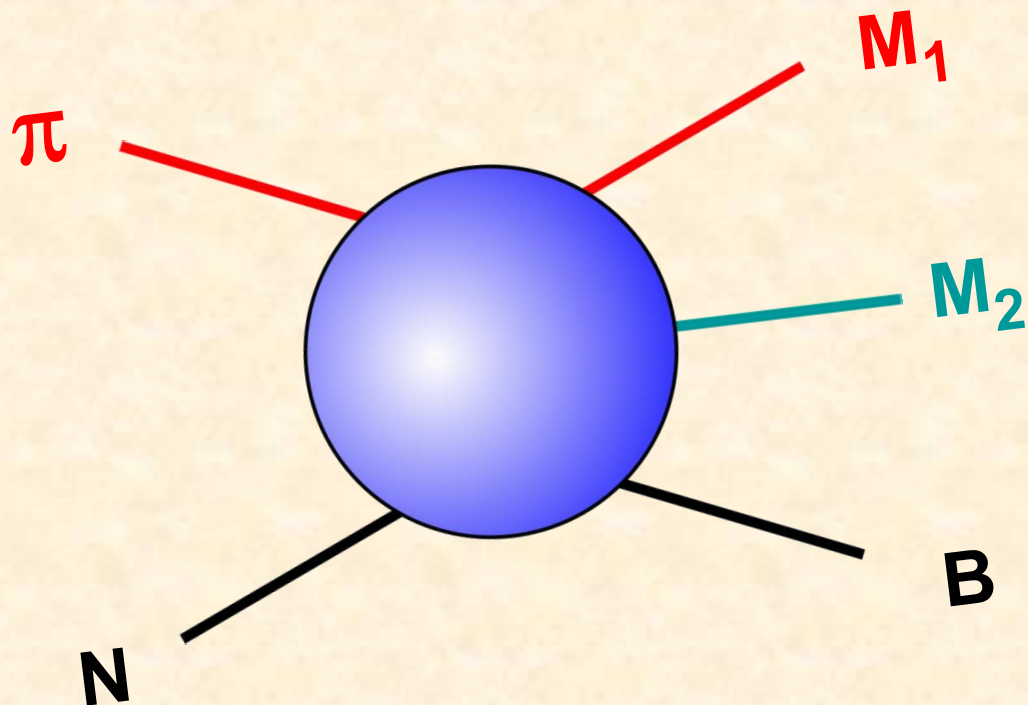


**Emerging Needs for
Excited Hadron Data**

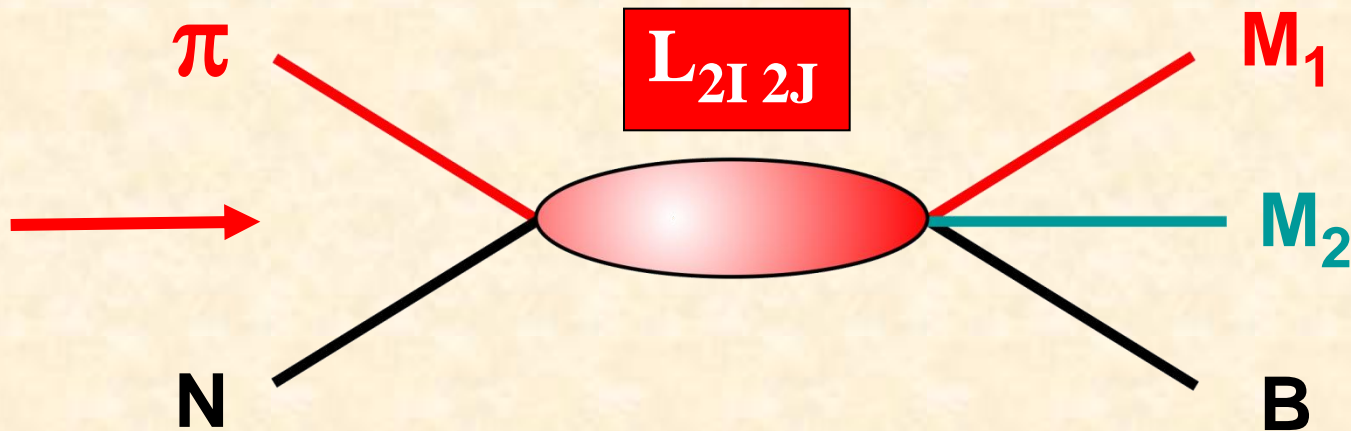
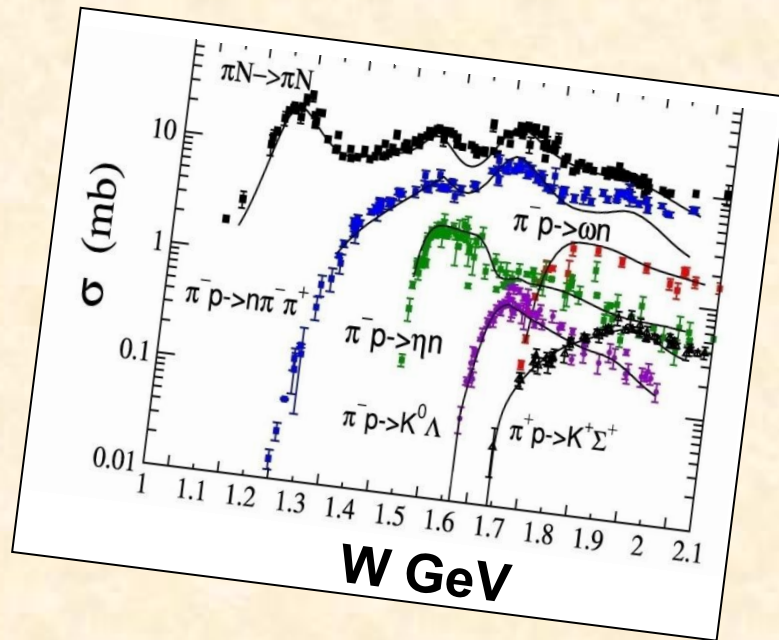
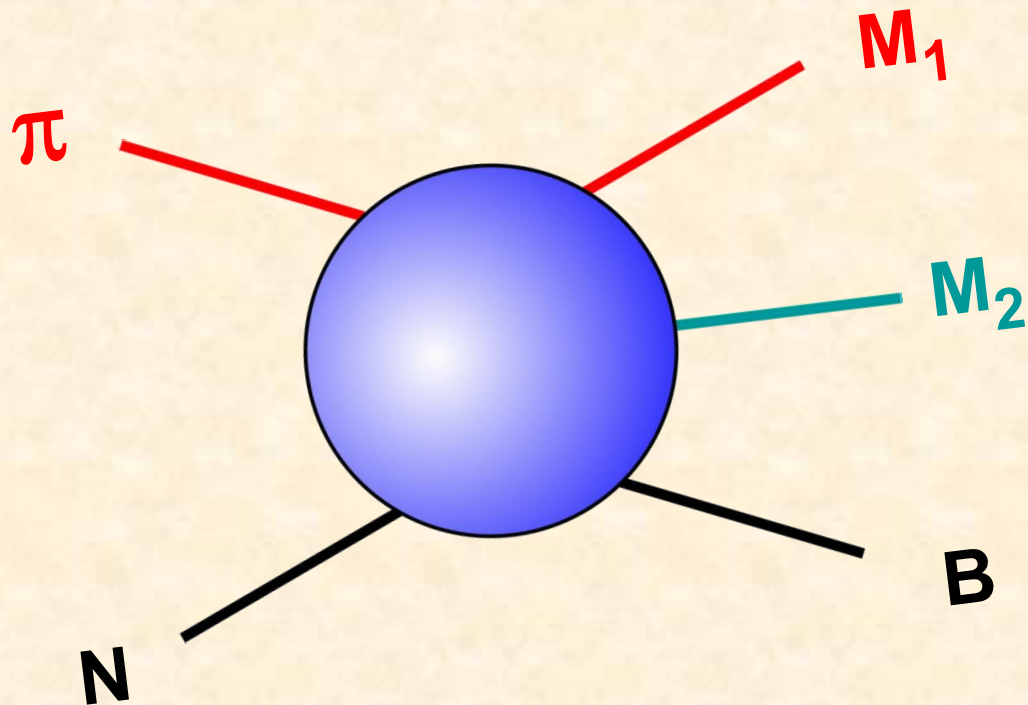


N

πN scattering

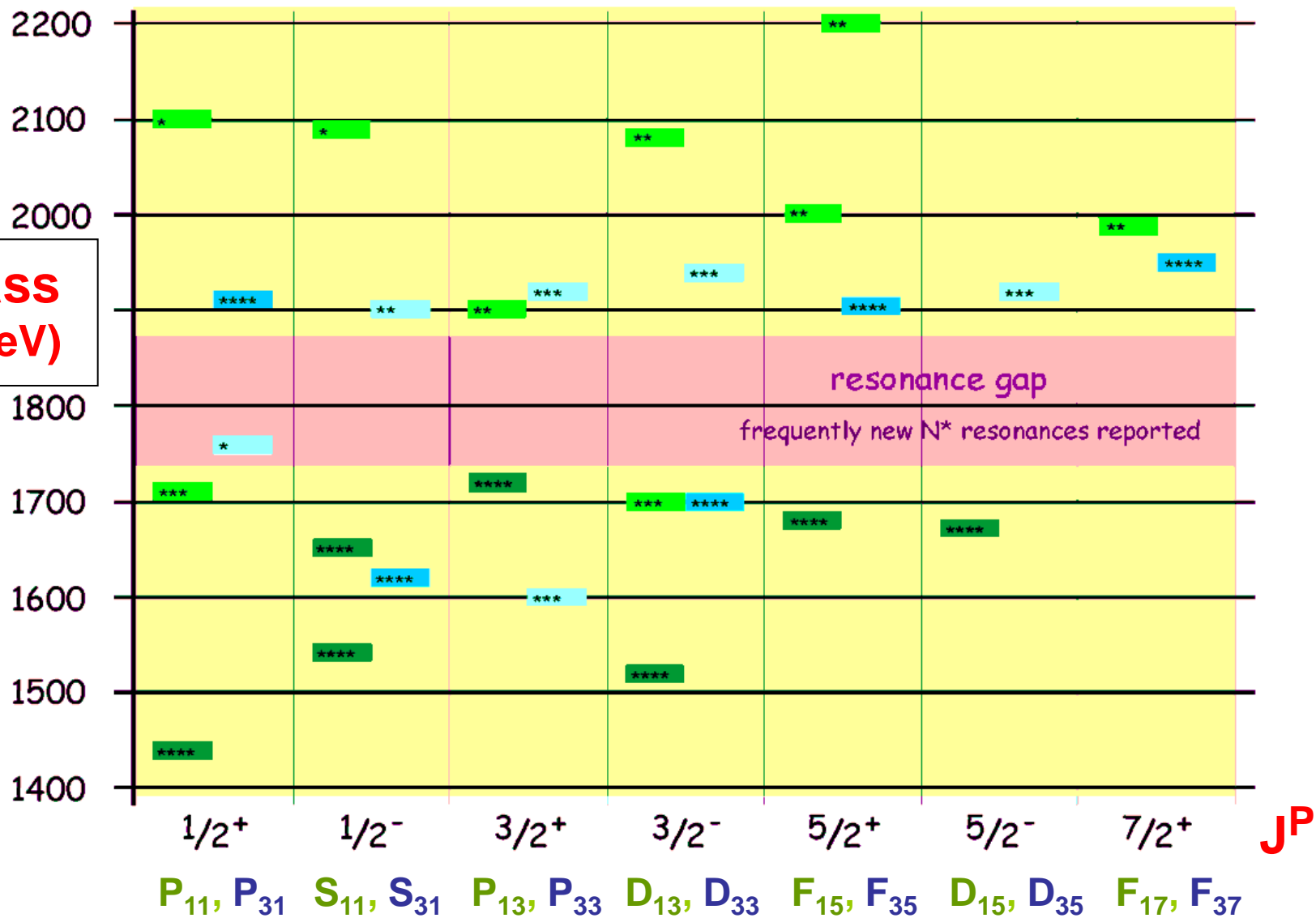


πN scattering

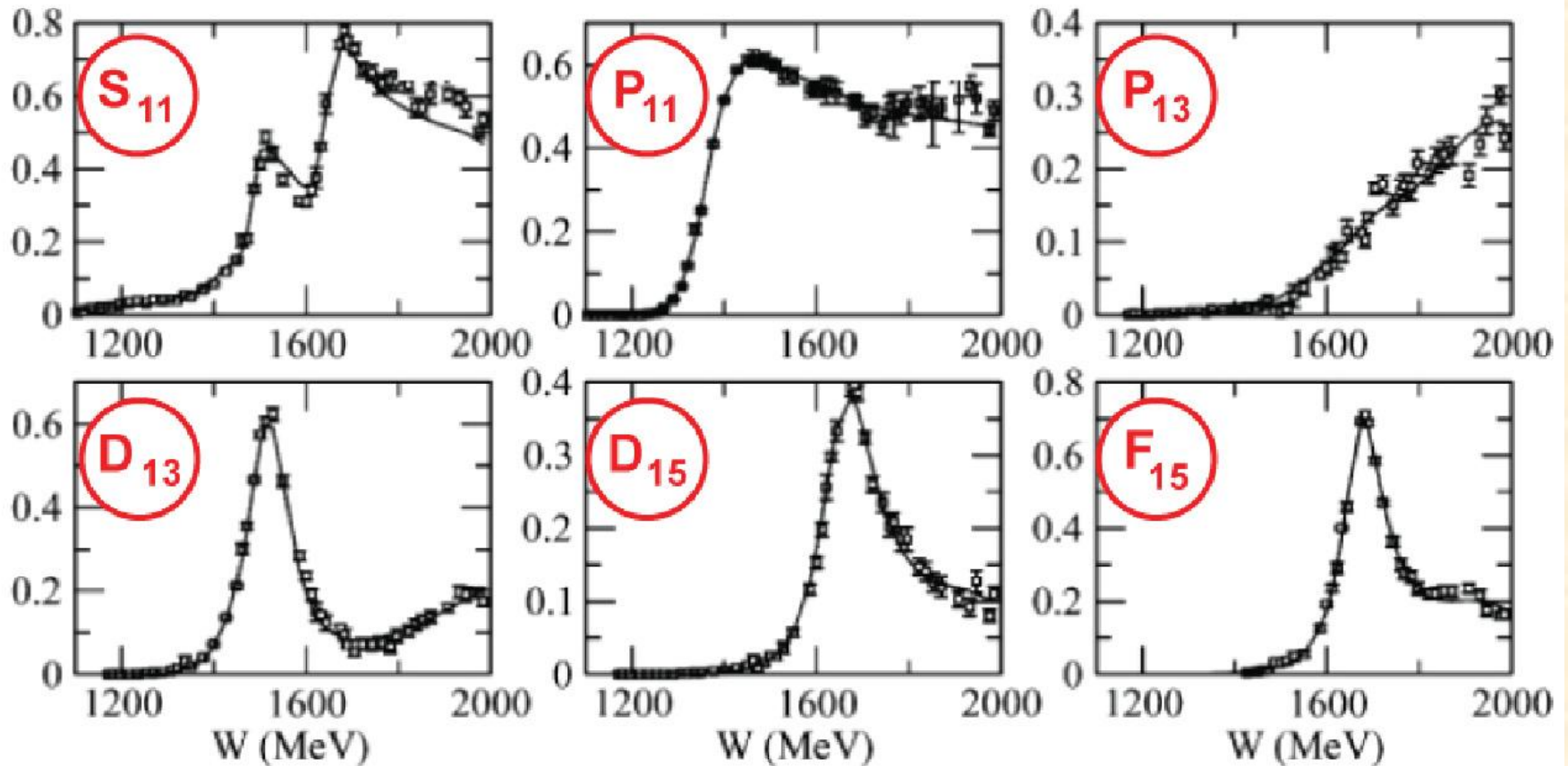


Excited Nucleon & Δ States

**Mass
(MeV)**



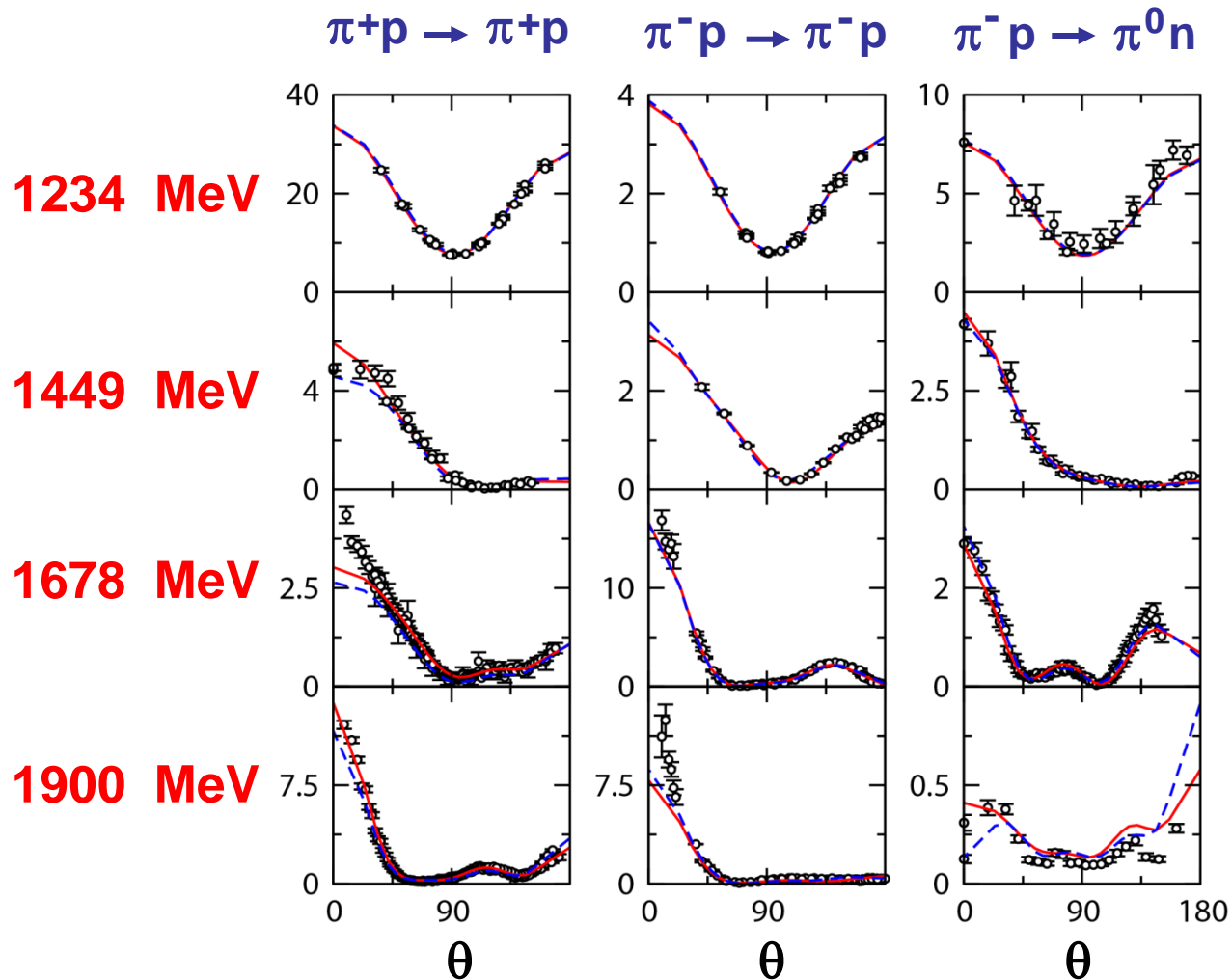
πN amplitudes



Isospin 1/2
Imaginary T

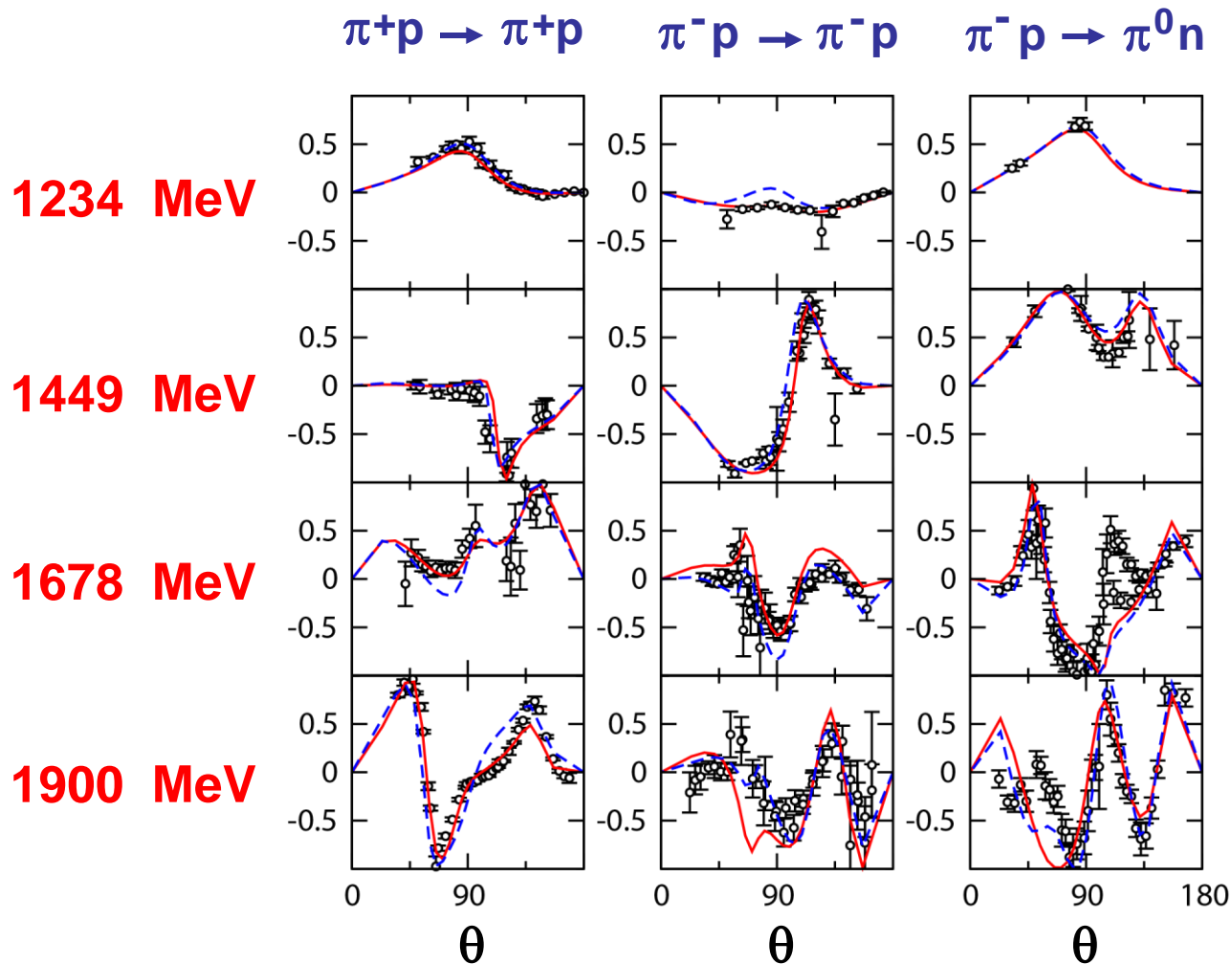
$\pi N \rightarrow \pi N$ scattering

$d\sigma/d\Omega$

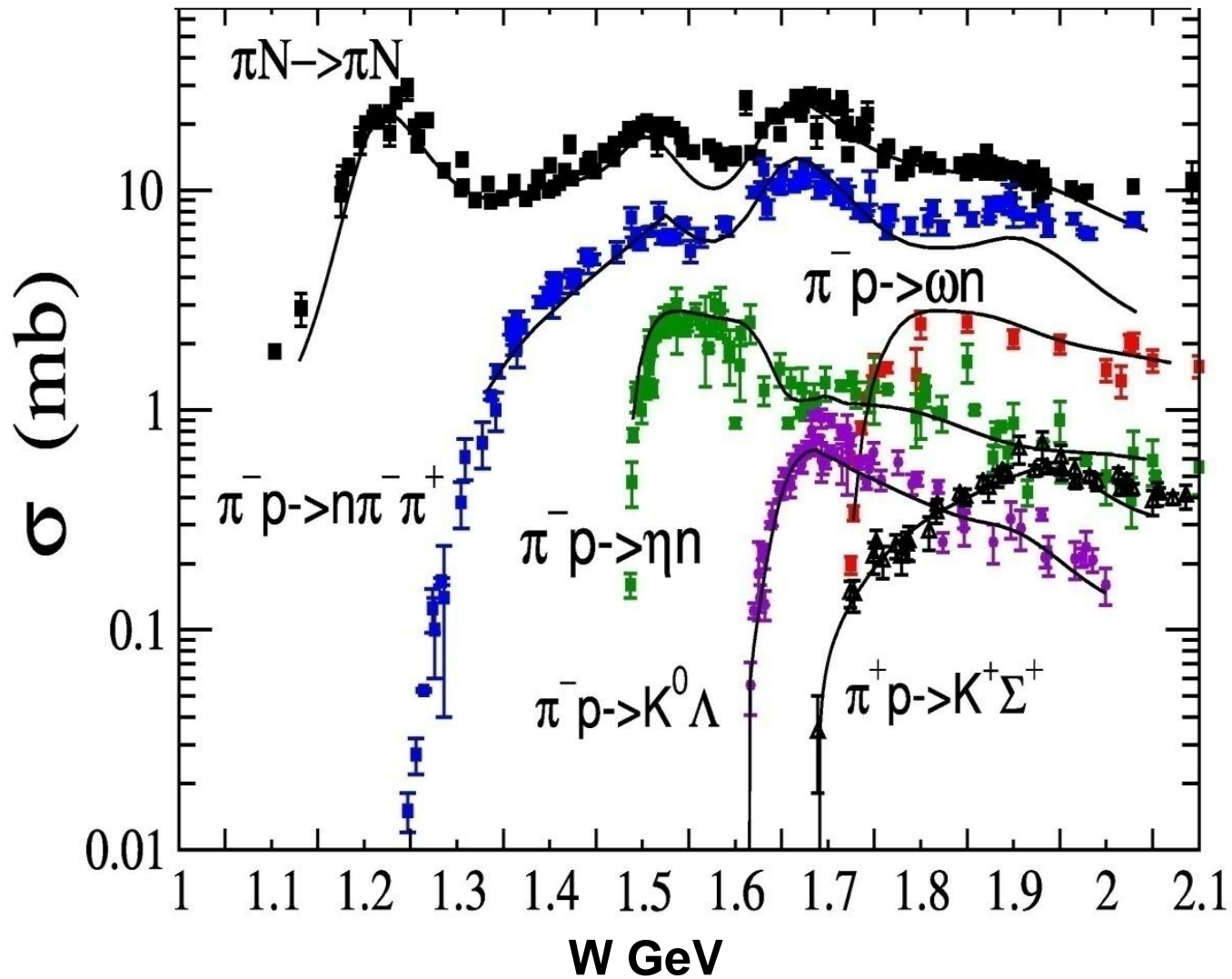


$\pi N \rightarrow \pi N$ scattering

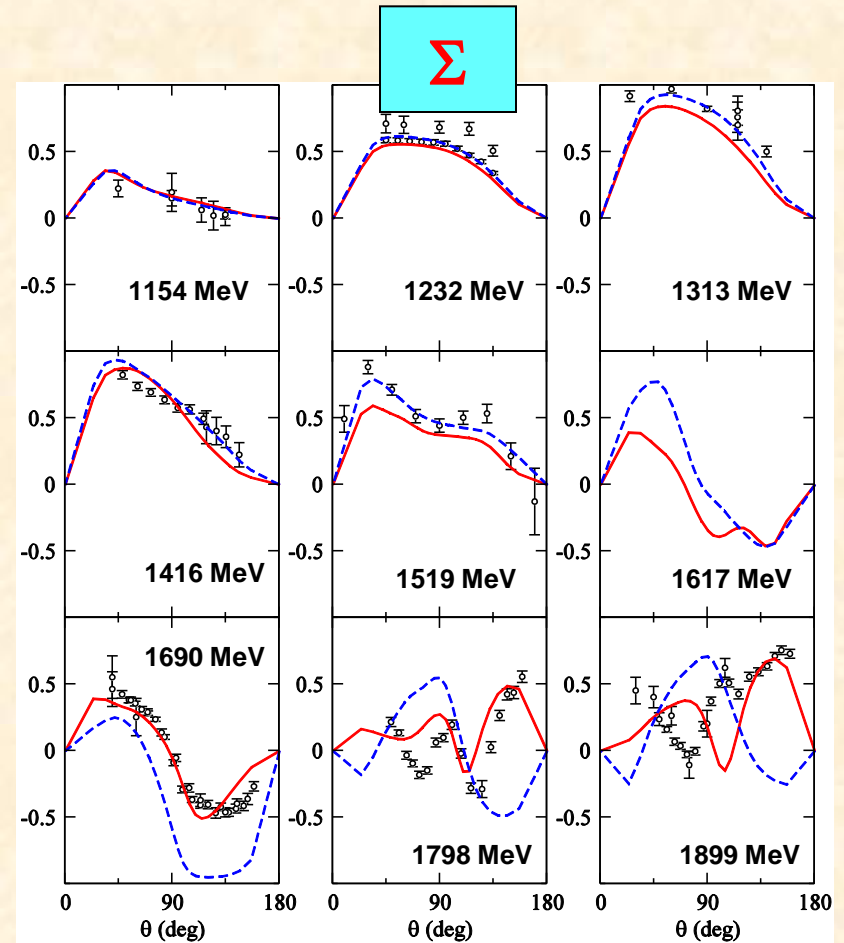
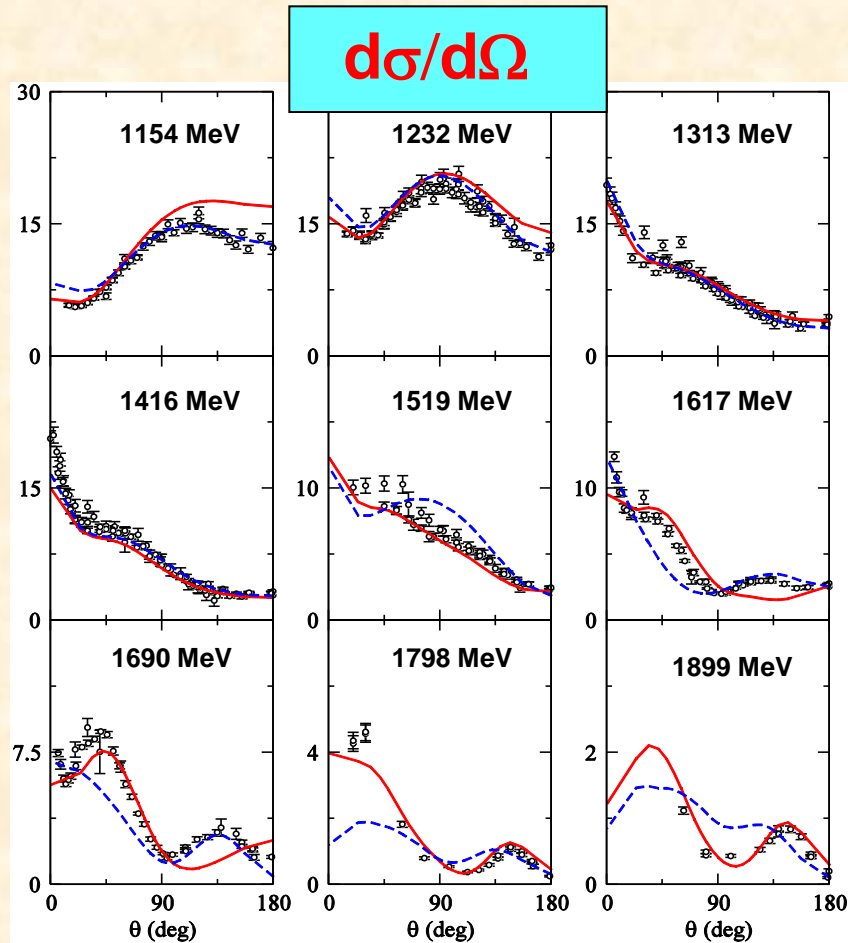
P



πN exclusive channels



pion photoproduction: $\gamma p \rightarrow \pi^+ n$



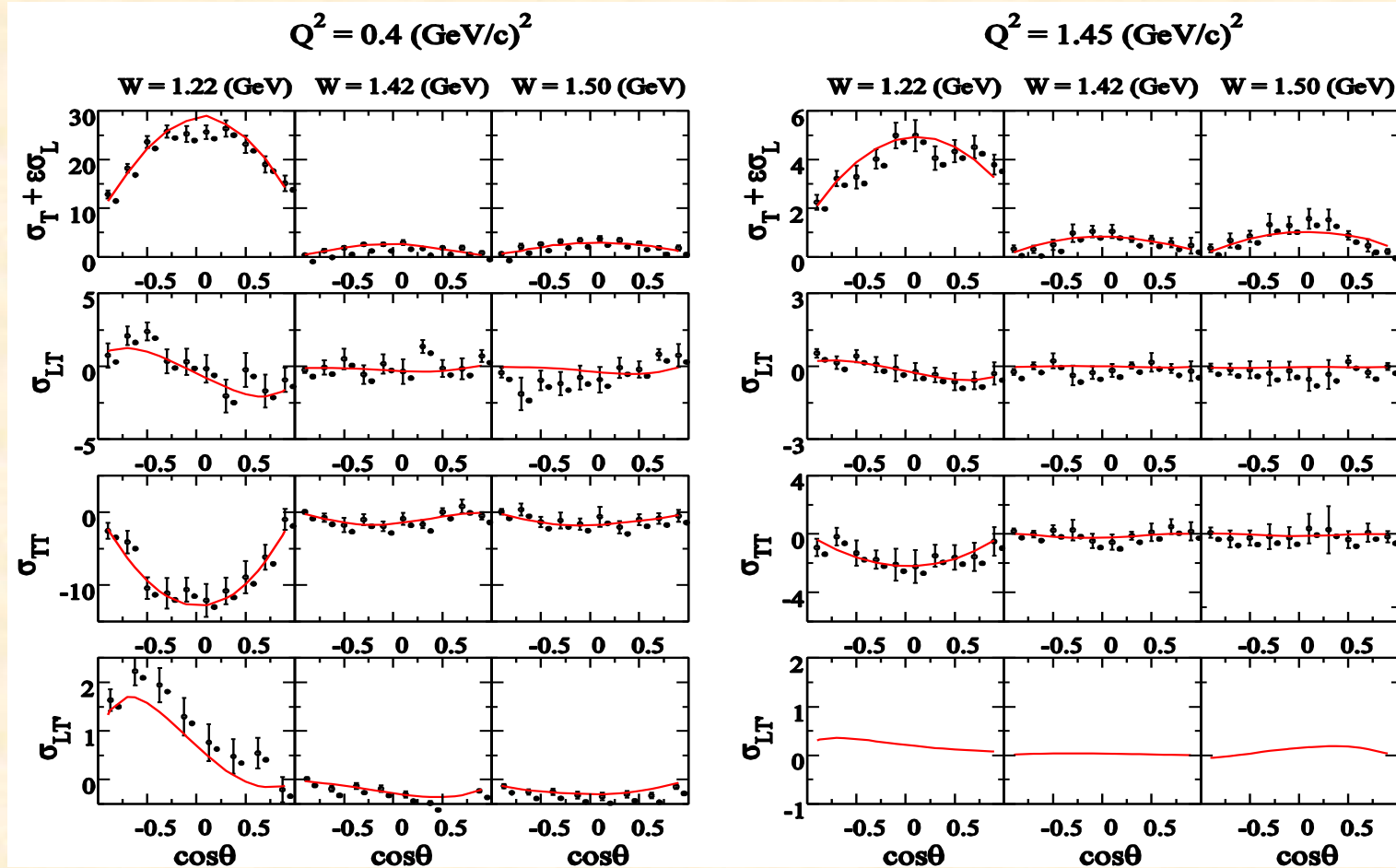
— Current model
(full combined analysis)

- - - Previous model (fitted to $\gamma N \rightarrow \pi N$ data **up to 1.6 GeV**)

pion electroproduction: $ep \rightarrow e'\pi^0 p$

Fit to the structure function data (~ 20000) from CLAS

$$Q^2 > 0$$



$\pi N \rightarrow K \Lambda$

$d\sigma/d\Omega$

P

$\pi^+ p \rightarrow K^+ \Sigma^+$

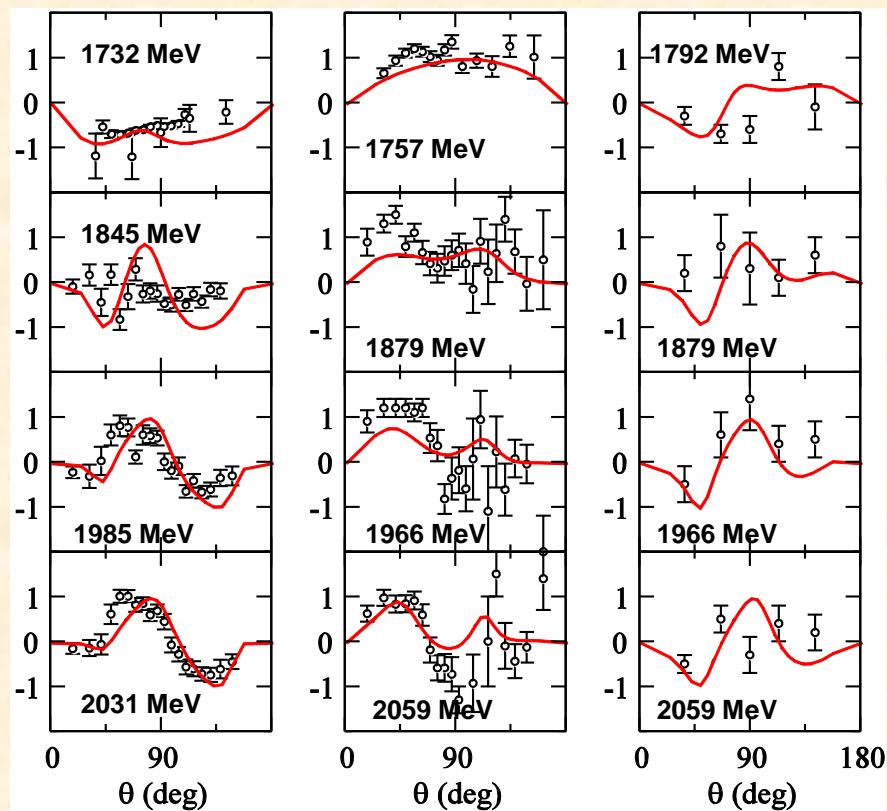
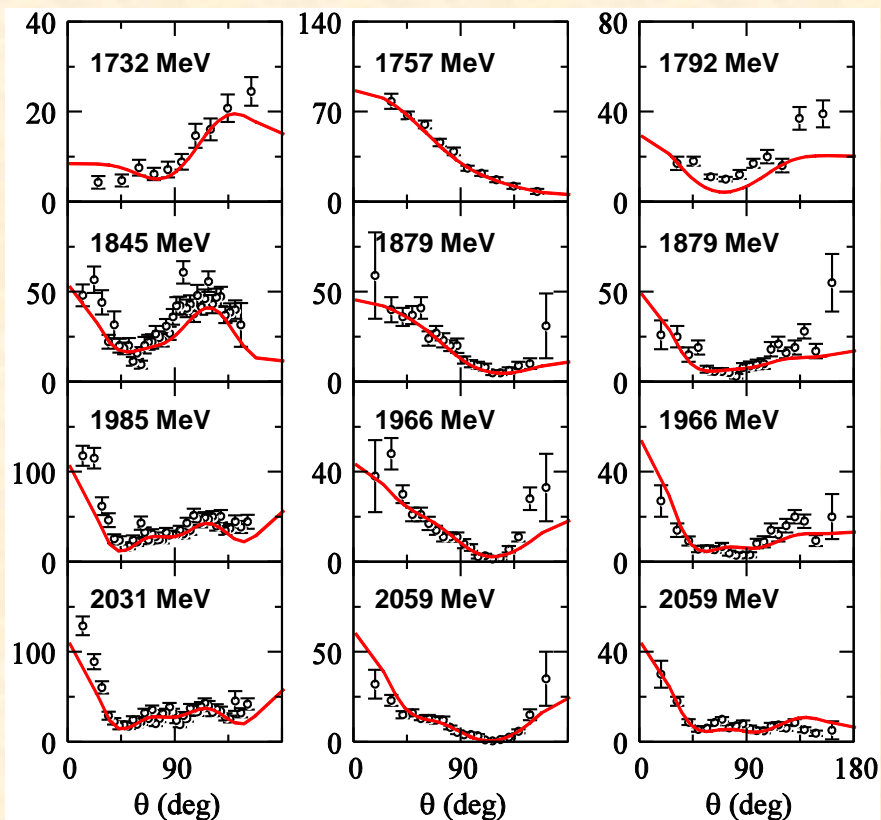
$\pi^- p \rightarrow K^0 \Lambda^0$

$\pi^- p \rightarrow K^0 \Sigma^0$

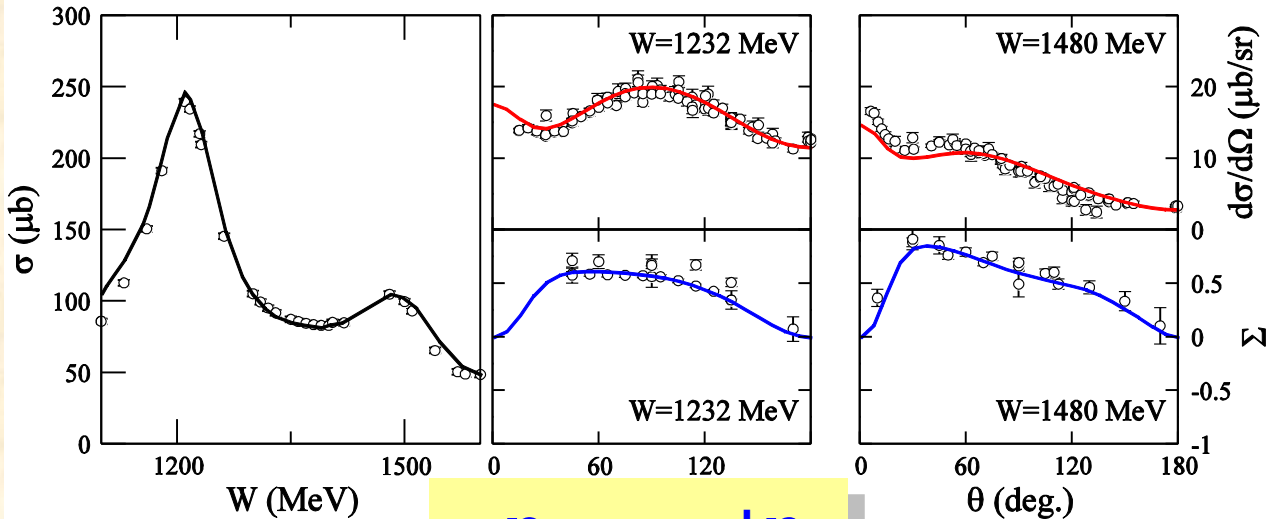
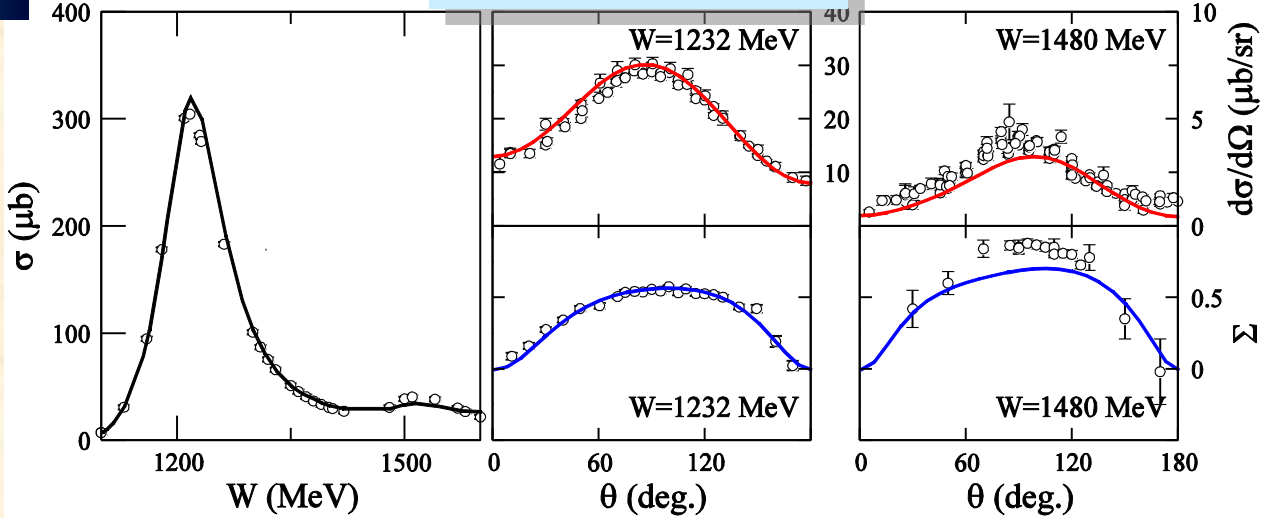
$\pi^+ p \rightarrow K^+ \Sigma^+$

$\pi^- p \rightarrow K^0 \Lambda^0$

$\pi^- p \rightarrow K^0 \Sigma^0$



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



$\gamma p \rightarrow \pi^+ n$

EBAC-DCC
(preliminary)

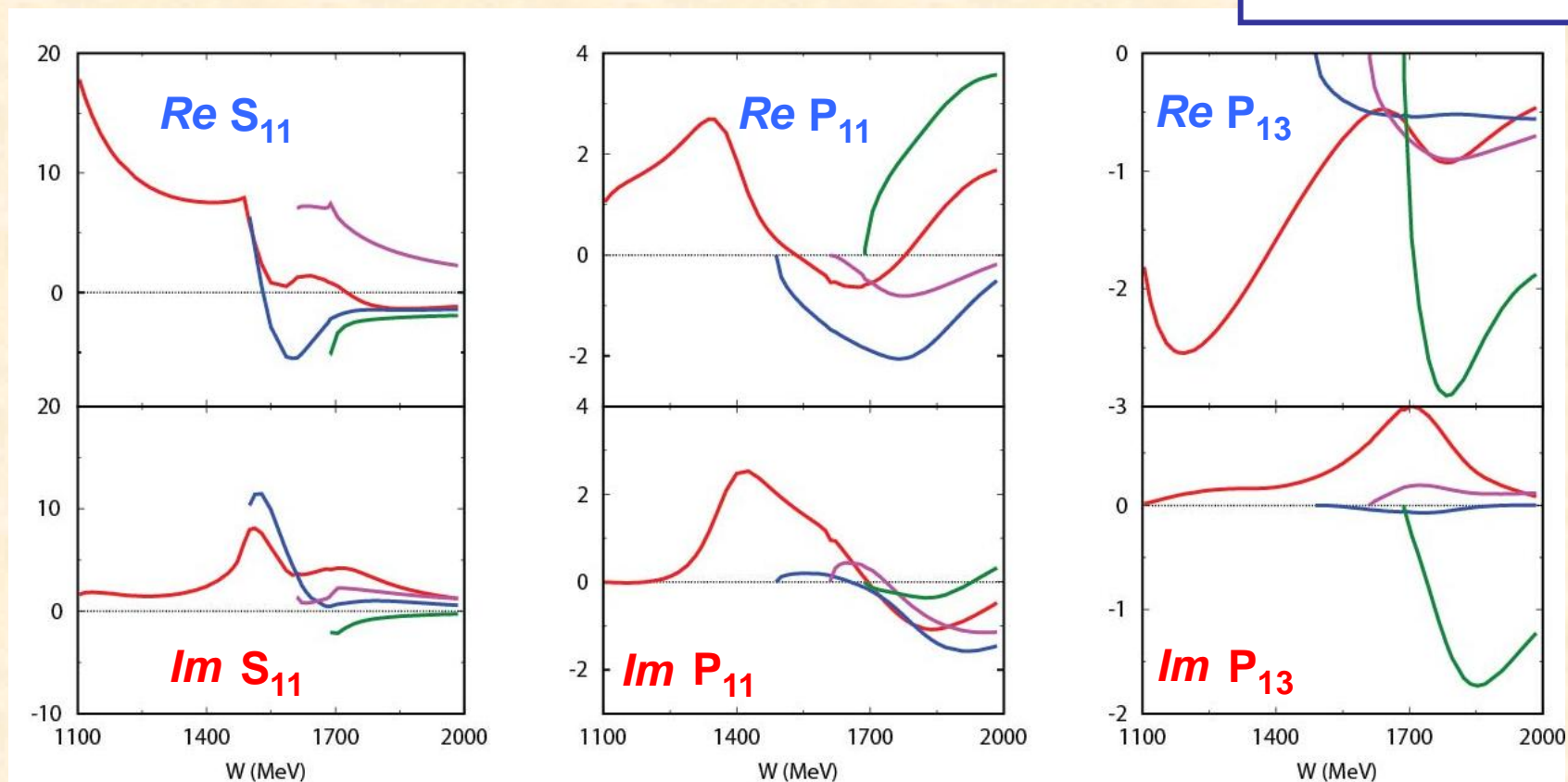
γN amplitudes

$\gamma p \rightarrow \pi N$

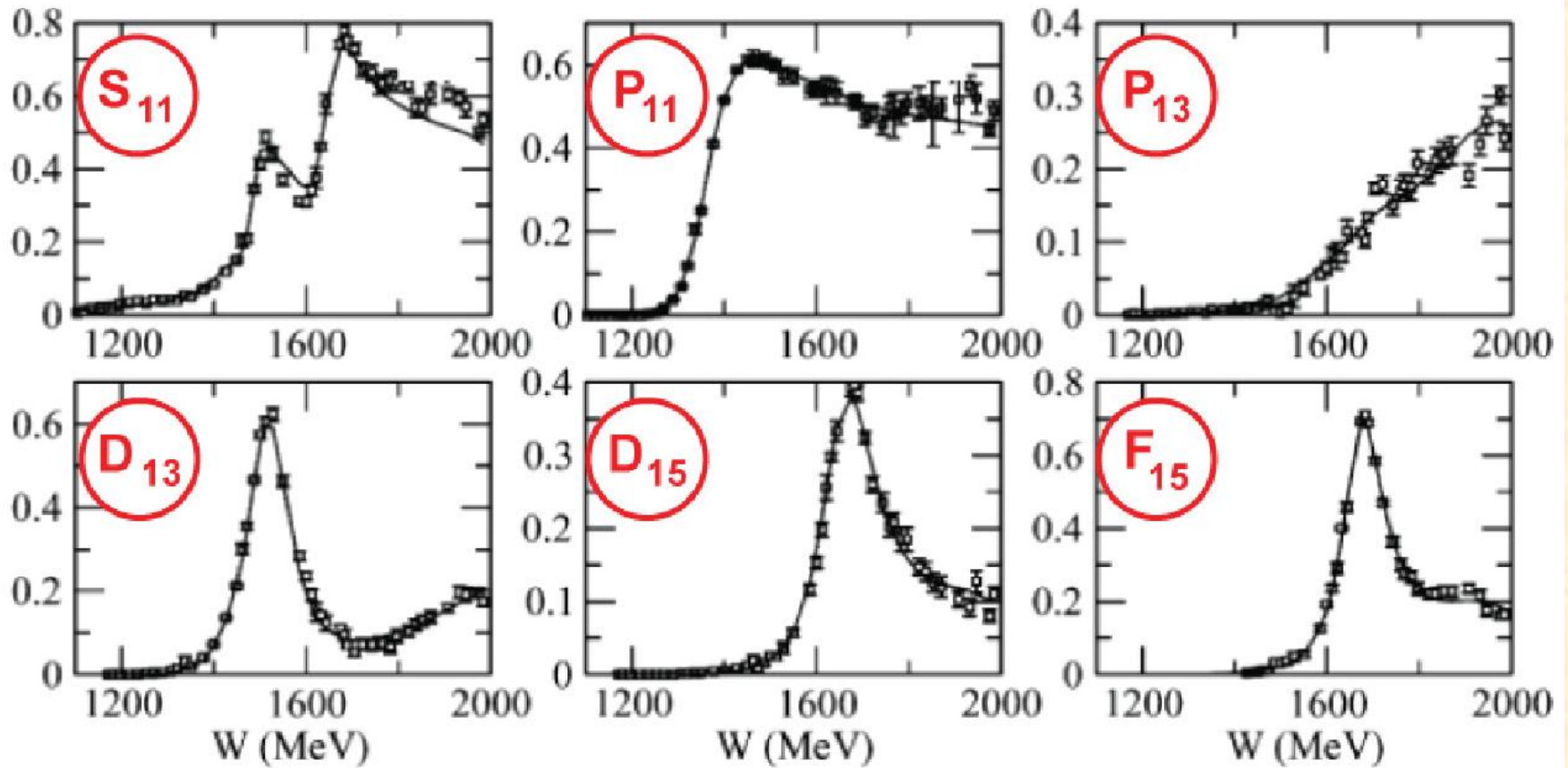
$\gamma p \rightarrow \eta N$

$\gamma p \rightarrow K\Lambda$

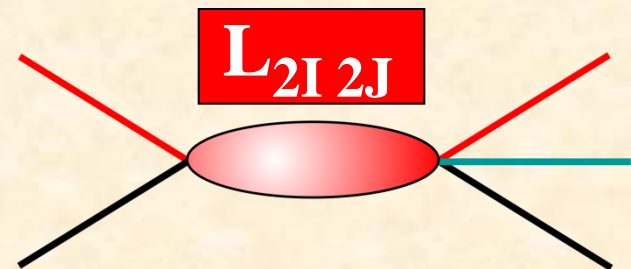
$\gamma p \rightarrow K\Sigma$



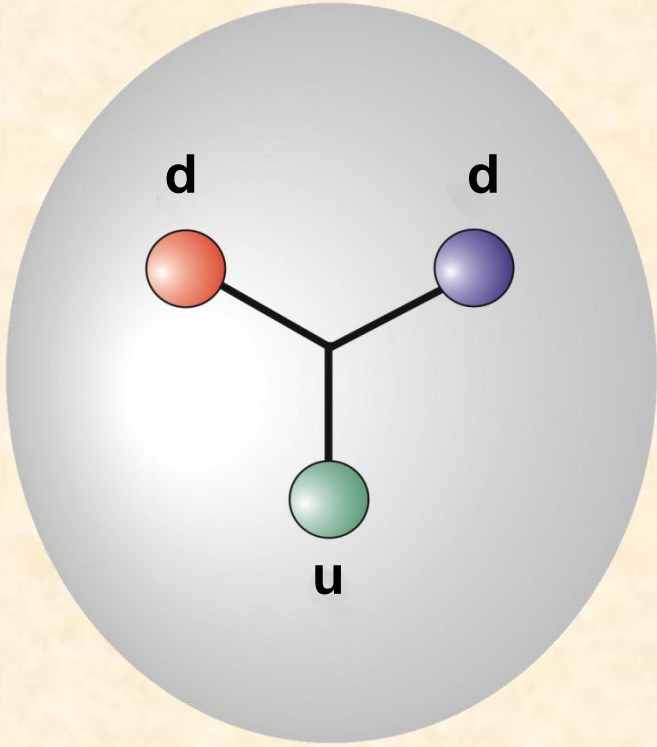
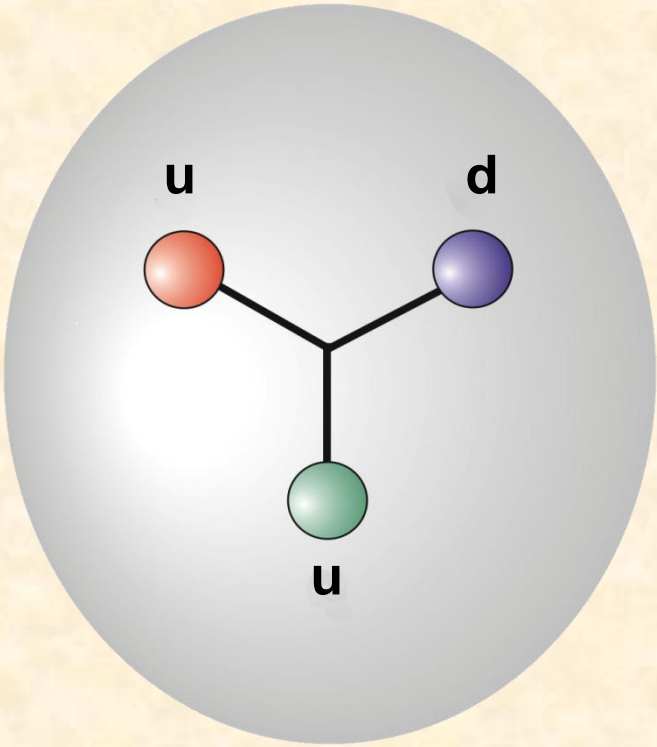
πN amplitudes



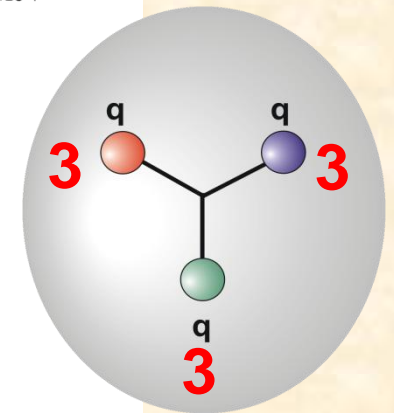
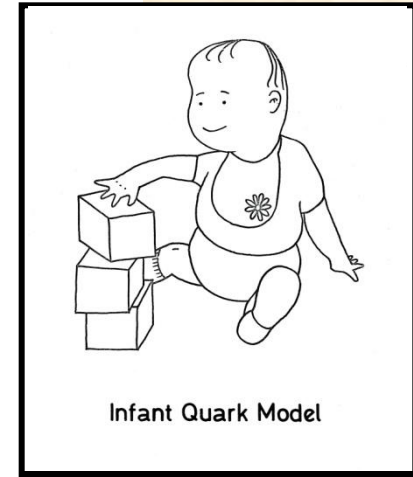
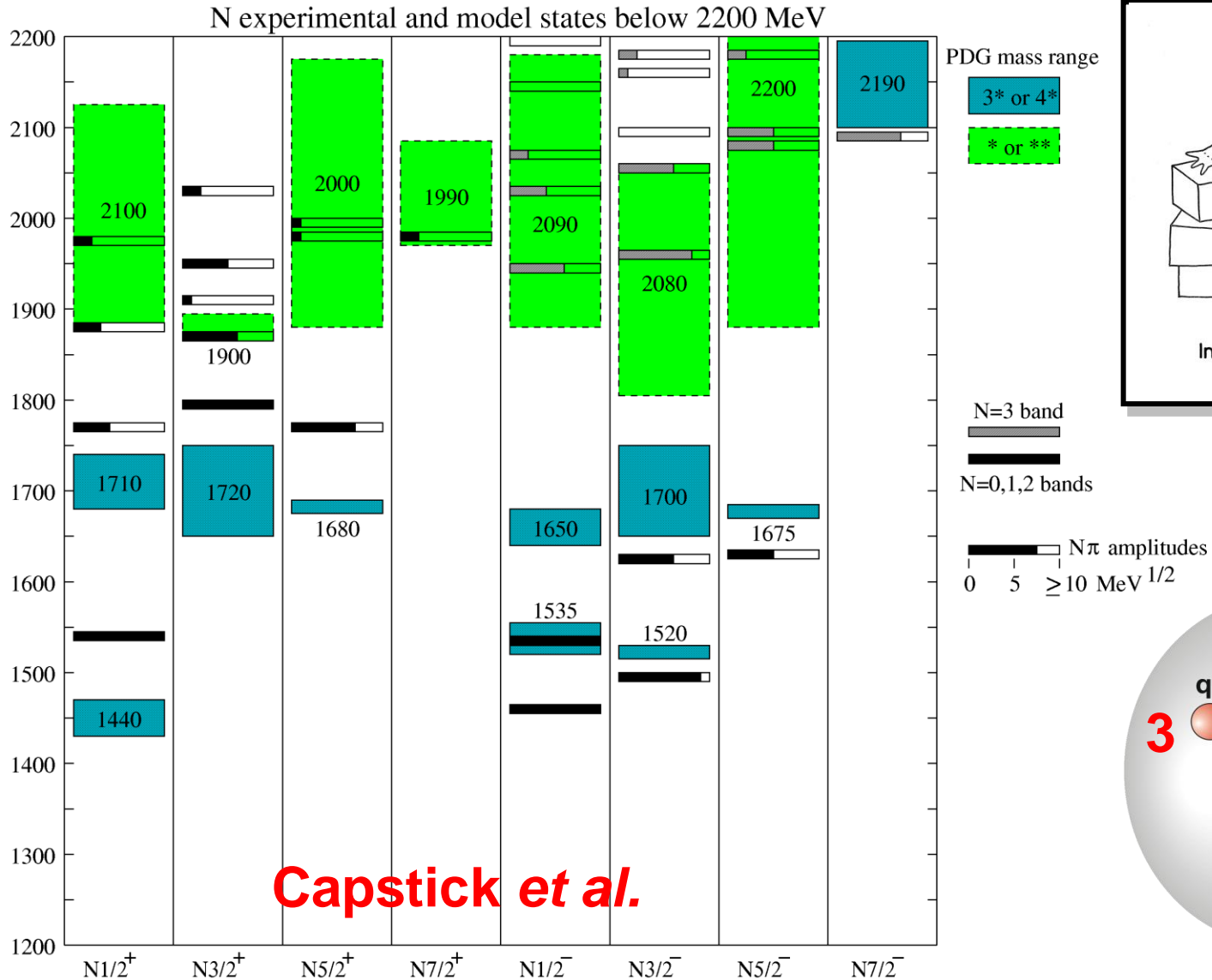
Isospin 1/2
Imaginary T



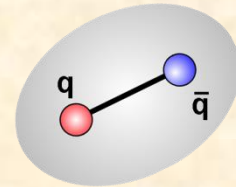
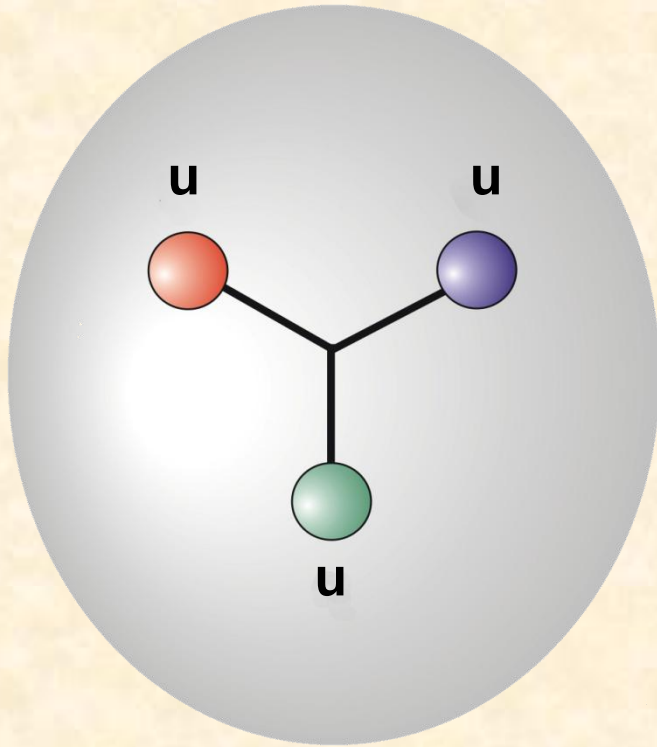
N(938)



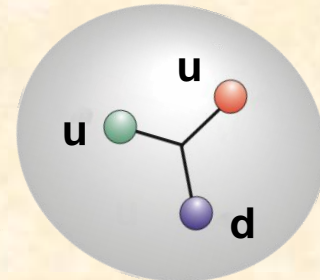
Nucleon model states (πN couplings)



$\Delta(1232)$



π^+



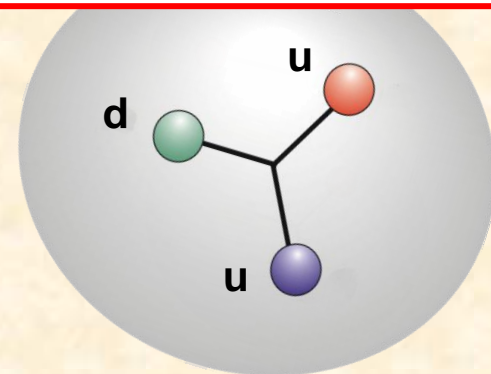
N

N*(1xxx)

$$\mathcal{L}_{\text{QCD}} = \sum_{q=u,d,s,c,b} \bar{\psi}_q (i \gamma_\mu D^\mu - m_q) \psi_q - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

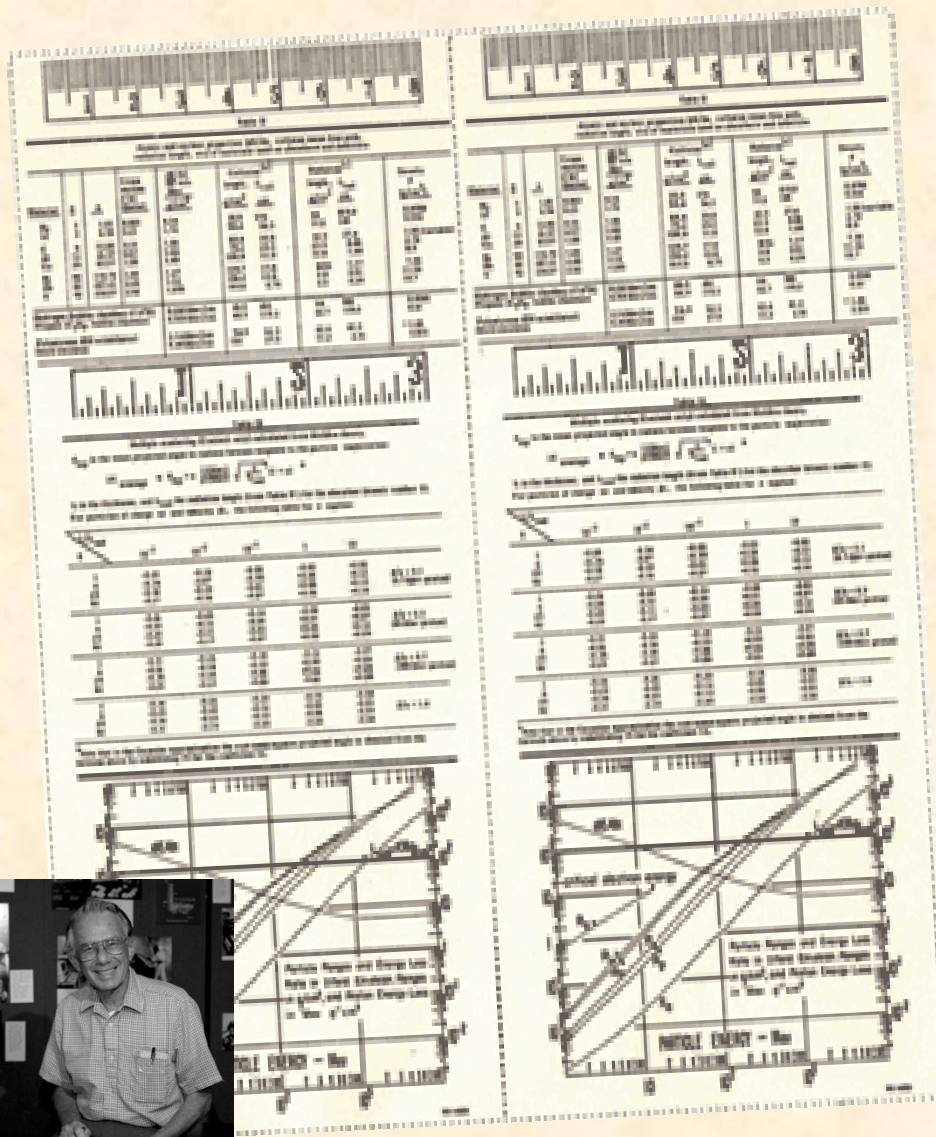


π

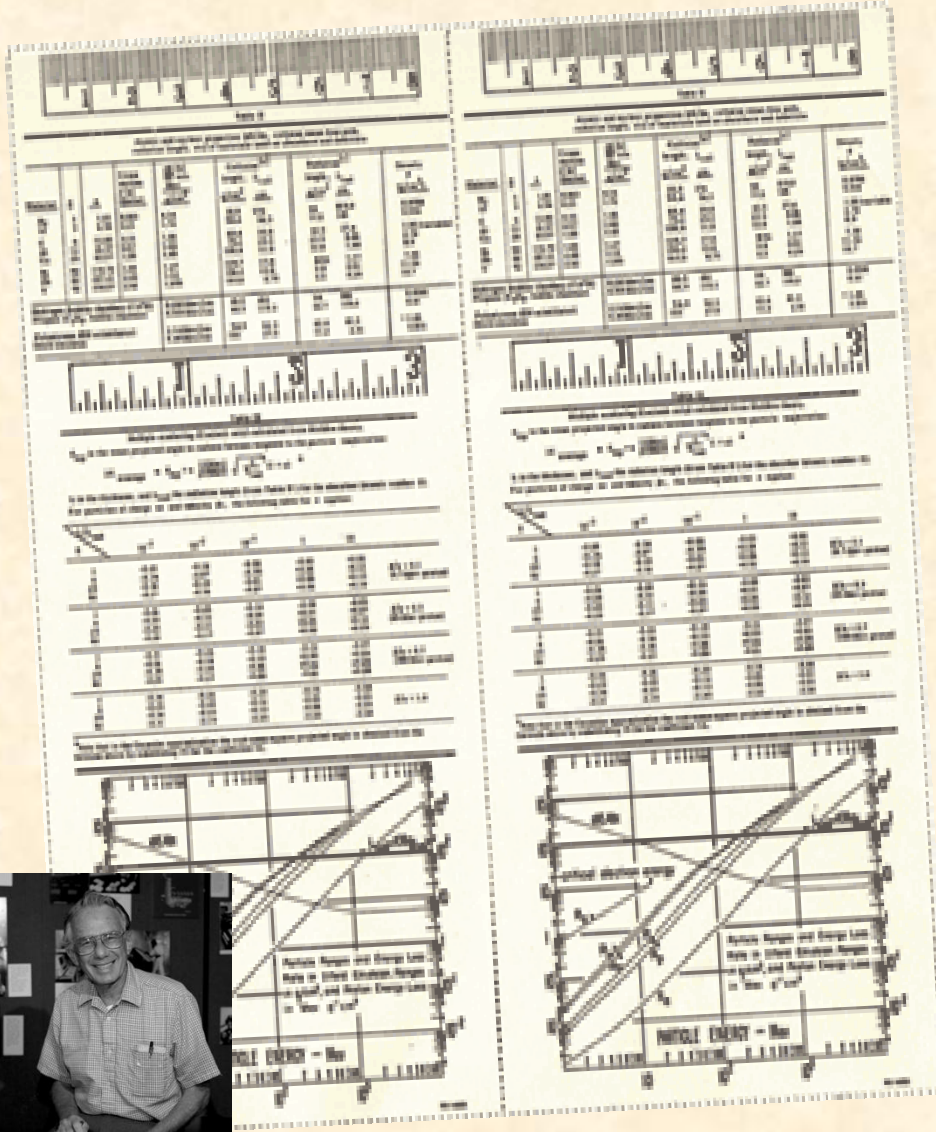


N

Particle Data Group



Particle Data Group



REVIEW OF PARTICLE PROPERTIES Particle Data Group

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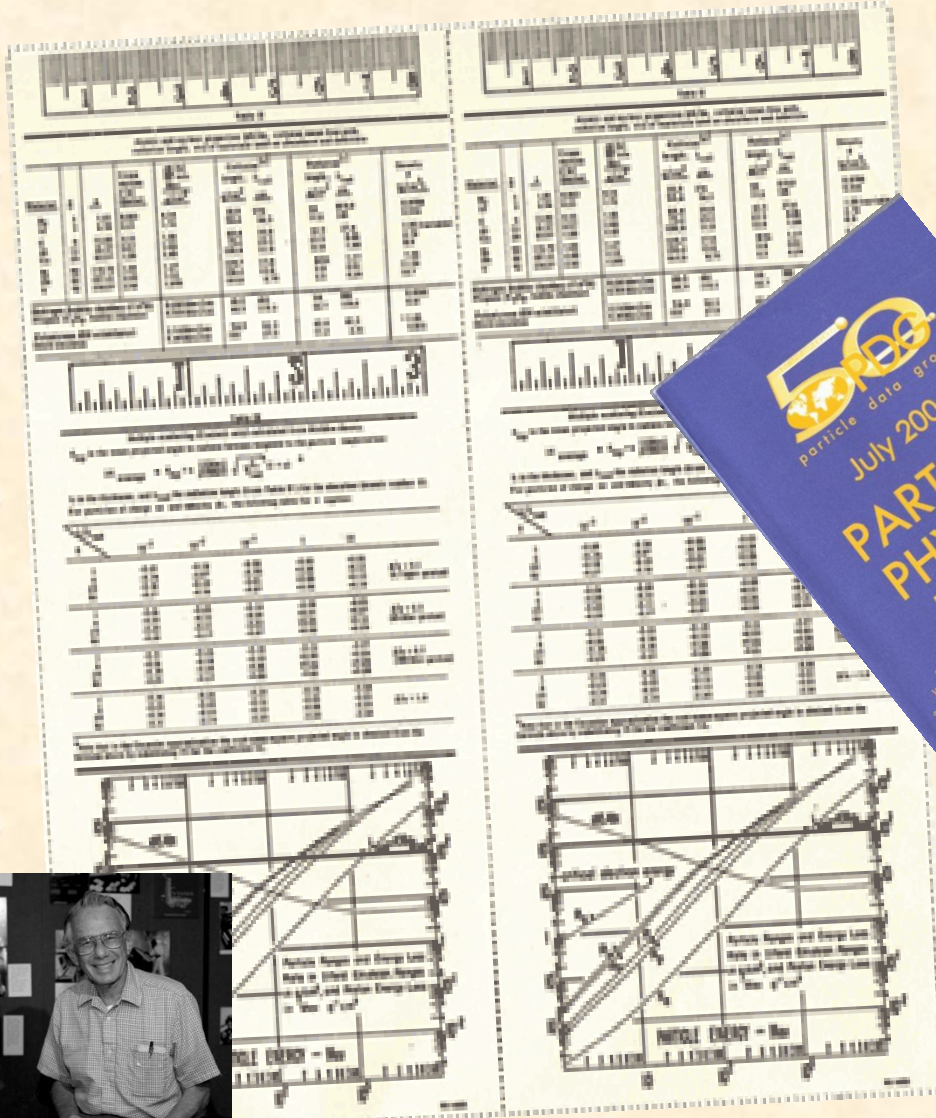
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April 1984 Edition

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July 1984

Particle Data Group



The image shows the cover of the 'July 2006 Particle Data Group Particle Physics Booklet'. The cover is blue with a yellow and white logo at the top that says '50th Particle Data Group'. Below the logo, it reads 'July 2006 PARTICLE PHYSICS BOOKLET'. At the bottom, it states 'Extracted from the Review of Particle Physics, W. Am. Phys. Soc., Journal of Physics G 34, 1 (2008). See <http://pdg.lbl.gov/> for particle listings and complete reviews, plus a directory of crime 'R' information. Institute of Physics INSTITUTE OF PHYSICS Available from ILM and CERN'.

The image shows the title page of the 'April 1984 Edition' of the 'REVIEW OF PARTICLE PROPERTIES' by the 'Particle Data Group'. The page lists the names and affiliations of the group members from various international institutions, including Lawrence Berkeley Laboratory, University of California, Berkeley; California Institute of Technology, Pasadena; University of Colorado Medical Center, Denver; University of Glasgow; University of Helsinki; University of Illinois; University of Karlsruhe; University of Kyoto; University of Madrid; University of Michigan; University of Minnesota; University of Oxford; University of Pennsylvania; University of Rochester; University of Toronto; University of Wisconsin; and many others. At the bottom, it states 'Reprinted from Reviews of Modern Physics, Vol. 56, No. 2, Part 2, April 1984. Printed at CERN, Geneva July 1984'.





Mesons

Baryons

**Gauge
bosons**

Neutrinos



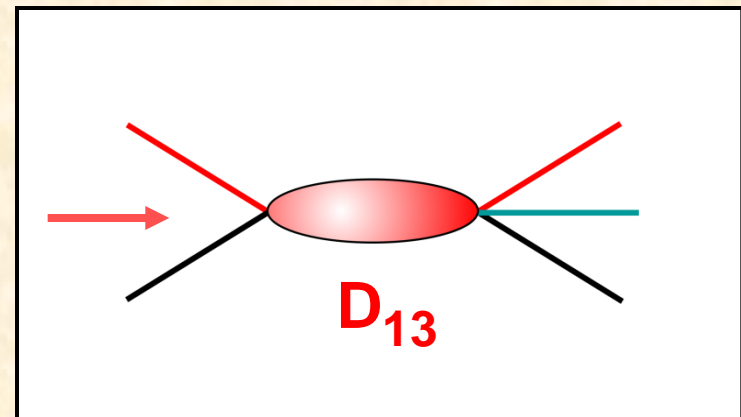
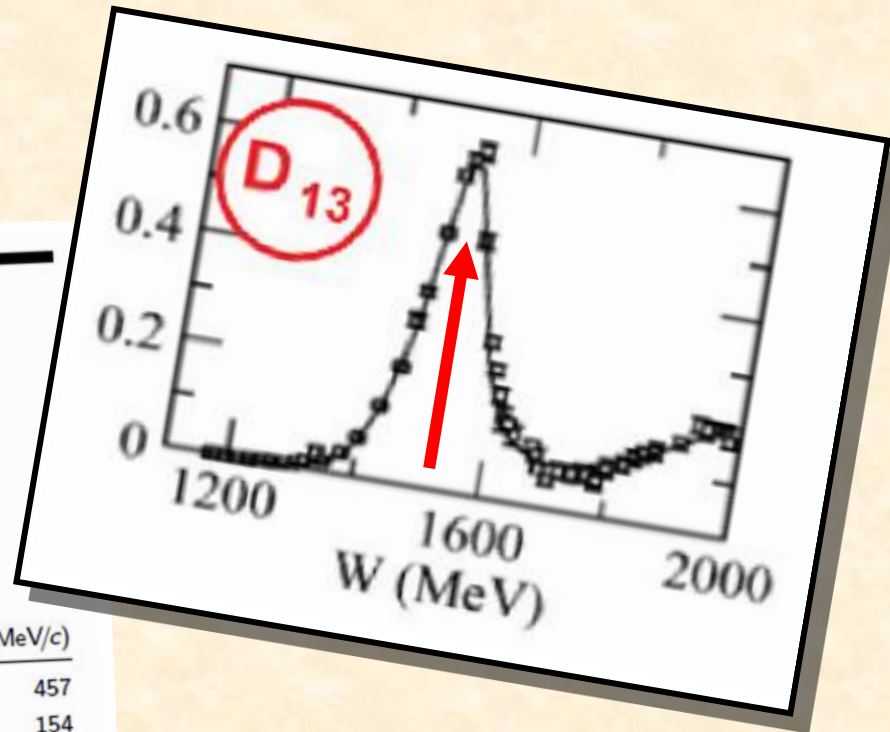
$N^*(1520) D_{13}$

$N(1520) D_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1515 to 1525 (≈ 1520) MeV
 Breit-Wigner full width = 100 to 125 (≈ 115) MeV
 $p_{\text{beam}} = 0.74 \text{ GeV}/c$ $4\pi\chi^2 = 23.5 \text{ mb}$
 Re(pole position) = 1505 to 1515 (≈ 1510) MeV
 $-2\text{Im}(\text{pole position}) = 105 \text{ to } 120$ (≈ 110) MeV

$N(1520)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	0.55 to 0.65	457
$N\eta$	$(2.3 \pm 0.4) \times 10^{-3}$	154
$N\pi\pi$	40-50 %	414
$\Delta\pi$	15-25 %	230
$N\rho$	15-25 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<8 %	-
$p\gamma$	0.46-0.56 %	470
$p\gamma$, helicity=1/2	0.001-0.034 %	470
$p\gamma$, helicity=3/2	0.44-0.53 %	470
$n\gamma$	0.30-0.53 %	470
$n\gamma$, helicity=1/2	0.04-0.10 %	470
$n\gamma$, helicity=3/2	0.25-0.45 %	470



$N^*(1710) P_{11}$

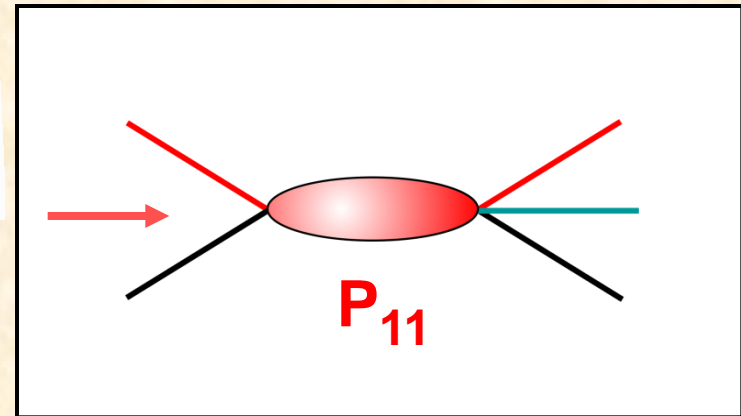
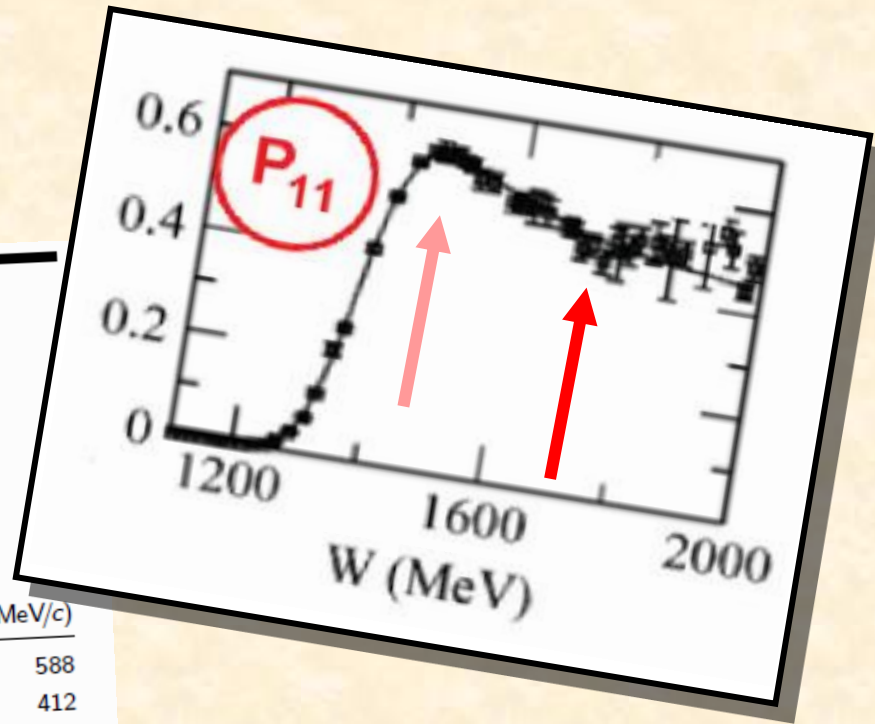
$N(1710) P_{11}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Breit-Wigner mass = 1680 to 1740 (≈ 1710) MeV
 Breit-Wigner full width = 50 to 250 (≈ 100) MeV
 $p_{\text{beam}} = 1.07 \text{ GeV}/c$ $4\pi\chi^2 = 14.2 \text{ mb}$
 Re(pole position) = 1670 to 1770 (≈ 1720) MeV
 $-2\text{Im}(\text{pole position}) = 80 \text{ to } 380$ (≈ 230) MeV

$N(1710)$ DECAY MODES

	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	588
$N\eta$	(6.2 ± 1.0) %	412
$N\omega$	(13.0 ± 2.0) %	†
ΛK	5–25 %	269
$N\pi\pi$	40–90 %	557
$\Delta\pi$	15–40 %	394
$N\rho$	5–25 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	10–40 %	–
$p\gamma$	0.002–0.05%	598
$p\gamma$, helicity=1/2	0.002–0.05%	598
$n\gamma$	0.0–0.02%	597
$n\gamma$, helicity=1/2	0.0–0.02%	597



N*(1710) P₁₁

Citation: K. Nakamura et al. (Particle Data Group), JP G 37, 075021 (2010) and 2011 partial update for the 2012 edition (URL: http://pdg.lbl.gov)

••• We do not use the
20
-167
149

The following

Mode	Gamma
Nπ	Γ ₁
Nη	Γ ₂
Nω	Γ ₃
AK	Γ ₄
ΣK	Γ ₅
Nππ	Γ ₆
Δπ	Γ ₇
Δ(123)	Γ ₈
Nρ	Γ ₉
Nρ, S	Γ ₁₀
Nρ, S	Γ ₁₁
N(ππ) ₁	Γ ₁₂
pγ	Γ ₁₃
pγ, hel	Γ ₁₄
nγ	Γ ₁₅
nγ, hel	Γ ₁₆

Γ(Nπ)/Γ_{total}
VALUE
0.10 to 0.20 OUR

MODUL
VALUE (MeV)
15
9
8±2
••• W
24
37
149
••• We do not use

Γ(Nη)/Γ_{total}
VALUE
0.062±0.010
0.36±0.11
0.06±0.01
••• We do
0.06±0.08

Γ(Nω)/Γ_{total}
VALUE
0.13±0.02

(Γ_iΓ_f)^{1/2}/Γ_{total} in N
VALUE
+0.12 to +0.18 OUR
+0.16
+0.14

Γ(AK)/Γ_{total}
VALUE
0.05±0.03
0.05±0.02
0.1±0.1

Γ(ΣK)/Γ_{total}
VALUE
••• We do not use
0.07±0.07

(Γ_iΓ_f)^{1/2}/Γ_{total}
VALUE
••• We do not use
-0.034

(Γ_iΓ_f)^{1/2}/Γ_{total}
VALUE
±0.16
-0.21±0.04
-0.17
+0.20

Γ(Δ(1232))
VALUE
0.39±0.08

(Γ_iΓ_f)^{1/2}
VALUE
±0.6
+0.05±0.1
+0.19
-0.20

HTTP

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Page 2

Page 1

Created: 6/10/2011 12:00

Citation: K. Nakamura et al. (Particle Data Group), JP G 37, 075021 (2010) and 2011 partial update for the 2012 edition (URL: http://pdg.lbl.gov)

Γ₃/Γ

Γ(Nρ, S=1/2, P-wave)/Γ_{total}
VALUE
0.17±0.01

(Γ_iΓ_f)^{1/2}/Γ_{total} in Nπ → N(1710) → Nρ, S=3/2, P-wave
VALUE
+0.31

(Γ_iΓ_f)^{1/2}/Γ_{total} in Nπ → N(1710) → N(ππ)_{S-wave}
VALUE
±0.14 to ±0.22 OUR ESTIMATE
+0.04±0.05
-0.26
-0.28

Γ(N(ππ)_{S-wave})/Γ_{total}
VALUE
0.01±0.01

DOCUMENT ID	TECN	COMMENT	Γ ₁₀ /Γ
VRANA	00	DPWA Multichannel	

DOCUMENT ID	TECN	COMMENT	(Γ ₁ Γ ₁₁) ^{1/2} /Γ
2 LONGACRE	77	IPWA πN → πNπ	

DOCUMENT ID	TECN	COMMENT	(Γ ₁ Γ ₁₂) ^{1/2} /Γ
MANLEY	92	IPWA πN → πN & Nππ	
2 LONGACRE	77	IPWA πN → Nππ	
3 LONGACRE	75	IPWA πN → Nππ	

DOCUMENT ID	TECN	COMMENT	Γ ₁₂ /Γ
VRANA	00	DPWA Multichannel	

N(1710) PHOTON DECAY AMPLITUDES

Papers on γN amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G 33 1 (2006).

N(1710) → pγ, helicity-1/2 amplitude A_{1/2}
VALUE (GeV^{-1/2})
+0.009±0.022 OUR ESTIMATE

0.025±0.010
0.007±0.015
0.006±0.018
0.028±0.009
••• We do not use the following data for averages, fits, limits, etc. •••

DOCUMENT ID	TECN	COMMENT
ANISOVICH	10	DPWA Multichannel
ARNDT	96	IPWA γN → πN
CRAWFORD	83	IPWA γN → πN
AWAJI	81	DPWA γN → πN
PENNER		fits, limits, etc. •••
LI	02D	DPWA Multichannel
	93	IPWA γN → πN

N(1710) → nγ, helicity-1/2 amplitude A_{1/2}
VALUE (GeV^{-1/2})
-0.002±0.015
-0.002±0.018
-0.001±0.003
••• We do not use the following data for averages, fits, limits, etc. •••

-0.024
0.052±0.003

DOCUMENT ID	TECN	COMMENT
ARNDT	96	IPWA γN → πN
AWAJI	81	DPWA γN → πN
FUJII	81	DPWA γN → πN
PENNER		fits, limits, etc. •••
LI	02D	DPWA Multichannel
	93	IPWA γN → πN

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Page 5

Created: 6/16/2011 12:05

Citation: K. Nakamura et al. (Particle Data Group), JP G 37, 075021 (2010) and 2011 partial update for the 2012 edition (URL: http://pdg.lbl.gov)

N(1710) P₁₁

Most of the results published in 1982 edition, Phys. Rev. D 25, 1171 (1982) and Journal of Physics G 13, 1699 (1987)

The latest GWL resonance.

REAL PART
VALUE (MeV)
1670 to 1770 (≈)

1708±18
1690
1698
1690±20
••• We do not use
1711±15
1679
1770
1636
1708 or 1712
1720 or 1711

MODUL
VALUE (MeV)
50 to 250 (≈ 100) (

200±35
480±230
93±30
90±30
120±15
••• We do not use
180±17
386±59
143±100
105±10
540
550
120
75

IMAGI
VALUE (MeV)
80 to 380 (

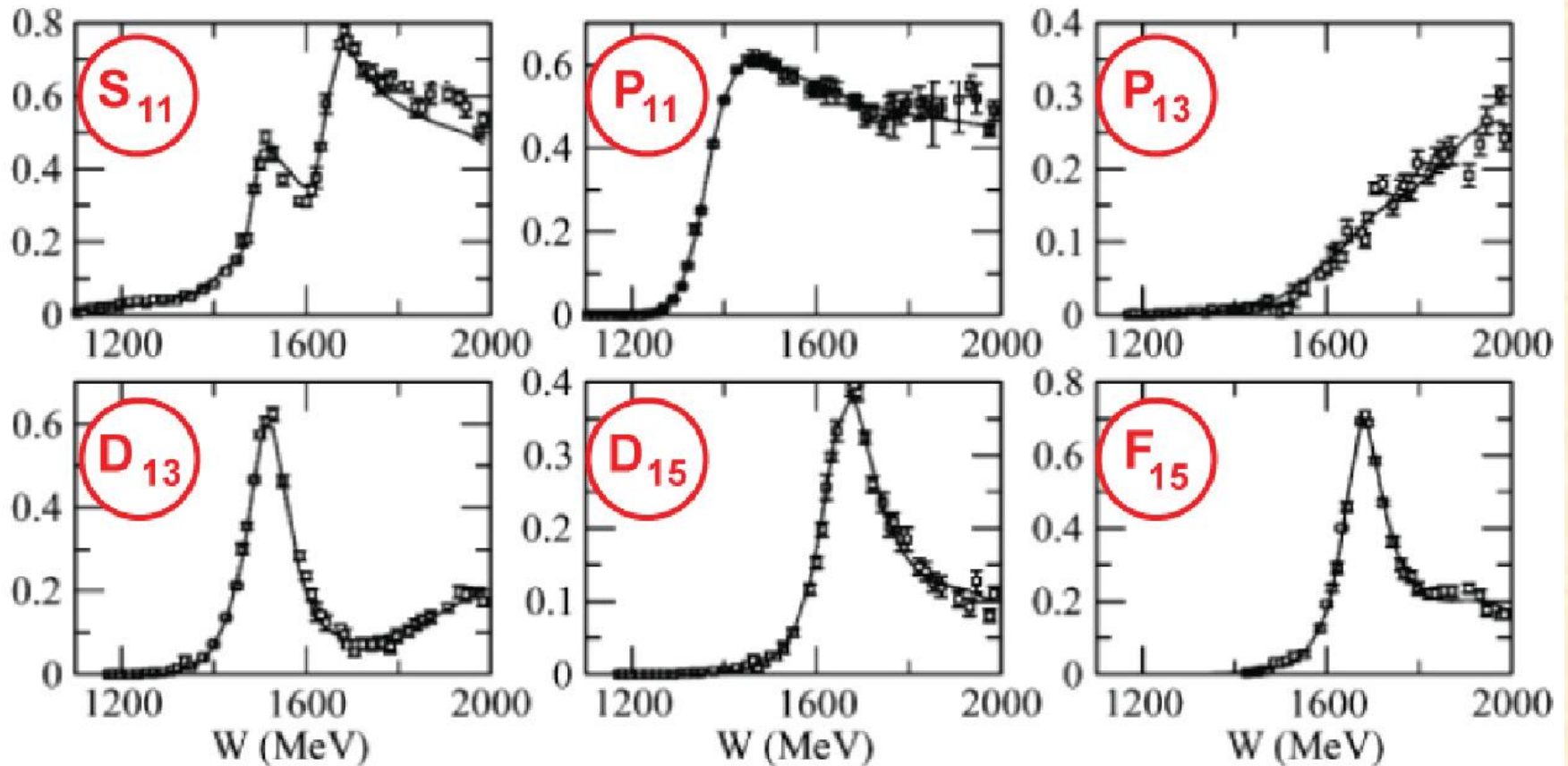
200±20
200
88
80±20
••• We do not use
174±16
132
378
544
17 or 22
123 or 115

PHAS
VALUE (°)

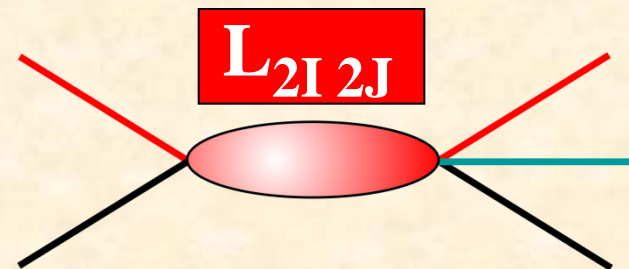
-167
175

Citation: K. Nakamura et al. (Particle Data Group), JP G 37, 075021 (2010) and 2011 partial update for the 2012 edition (URL: http://pdg.lbl.gov)

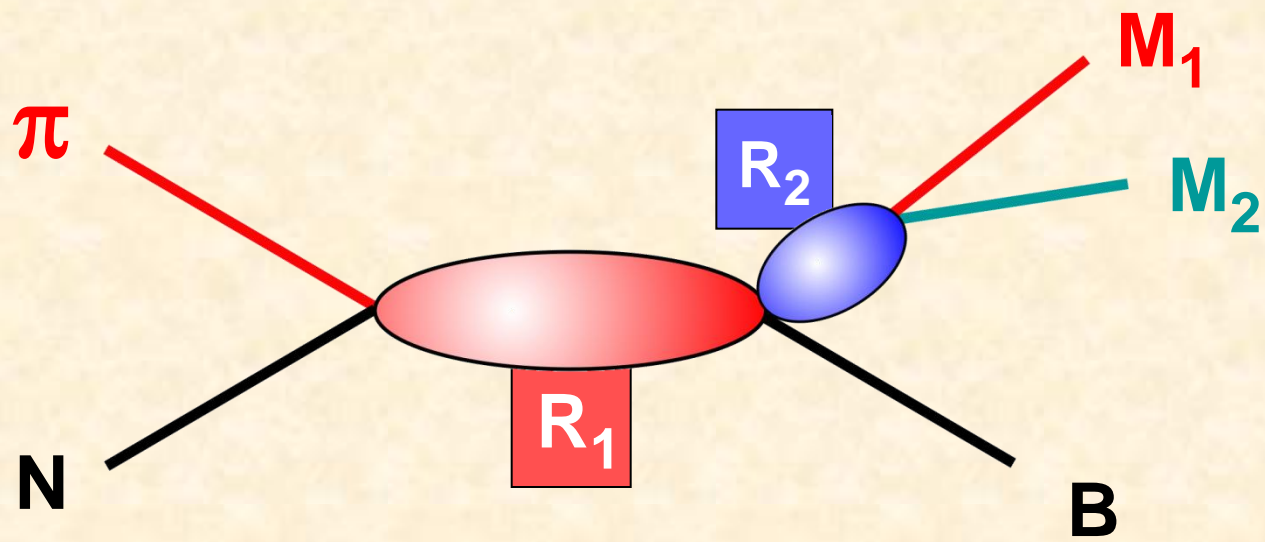
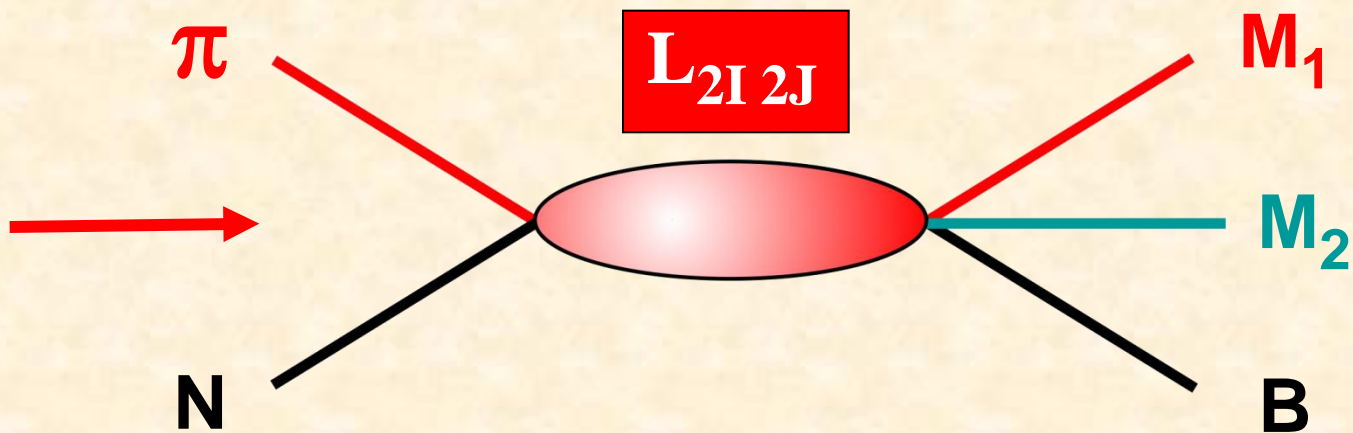
πN amplitudes



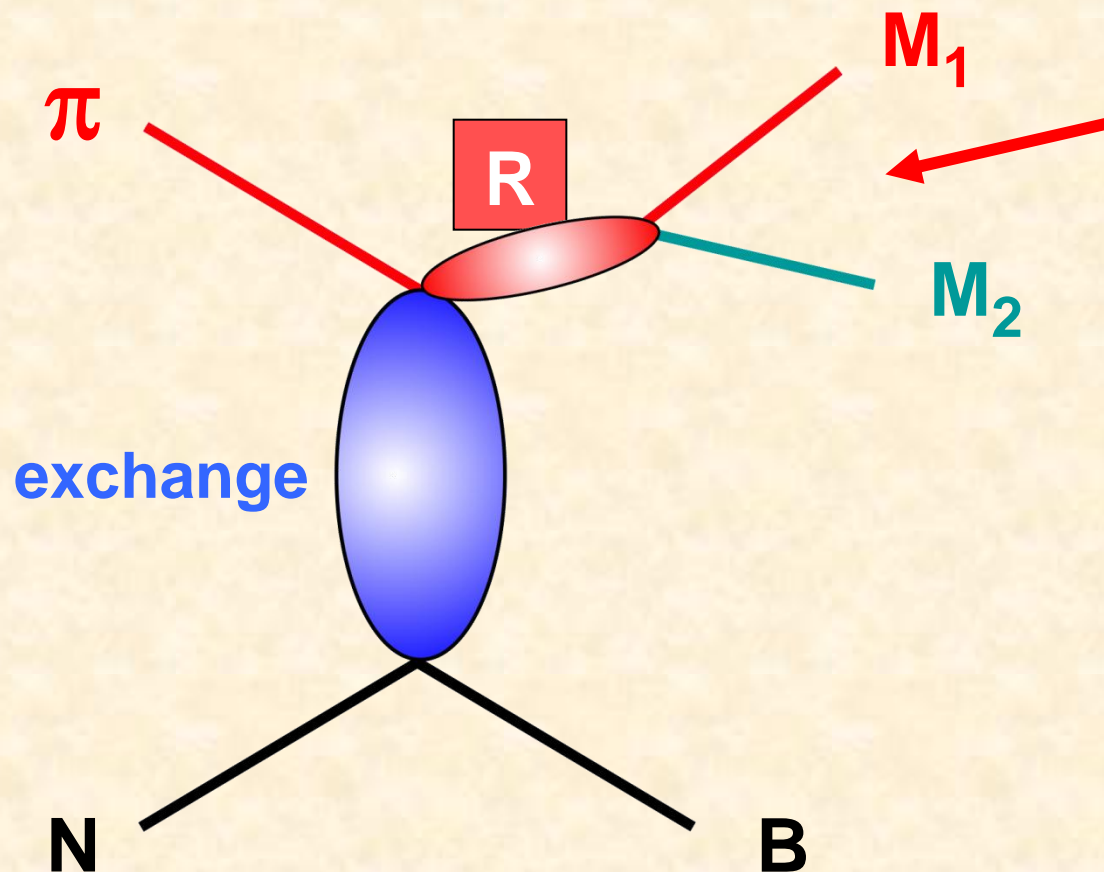
Isospin 1/2
Imaginary T



Reaction Mechanisms



Reaction Mechanisms



Hadron Archive Data Repository ONLINE

Publicly accessible web-base archiving/updating

- The full range of data on cross-sections and polarization asymmetries measured in hadro and photo-production of hadron resonances
- For each N^* and meson its mass, width, and all decay couplings
- Transition form-factors for excited N^* 's
- For each analysis, the partial wave amplitudes in which these excited hadrons occur
 - a graphical representation of the data
 - a graphical comparison of the partial waves in each analysis
 - a detailed exposition of the methods used in each analysis

Where appropriate to be compared with the detailed predictions of **QCD**

Existing HE/ME Databases

The Durham HepData Project

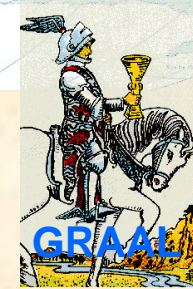
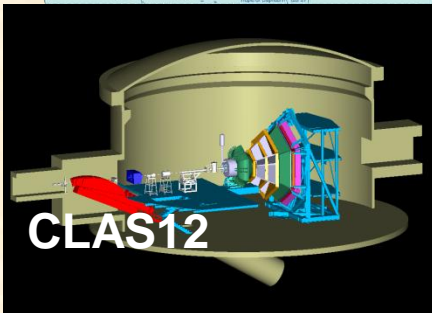
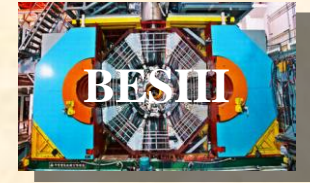
Reaction Database



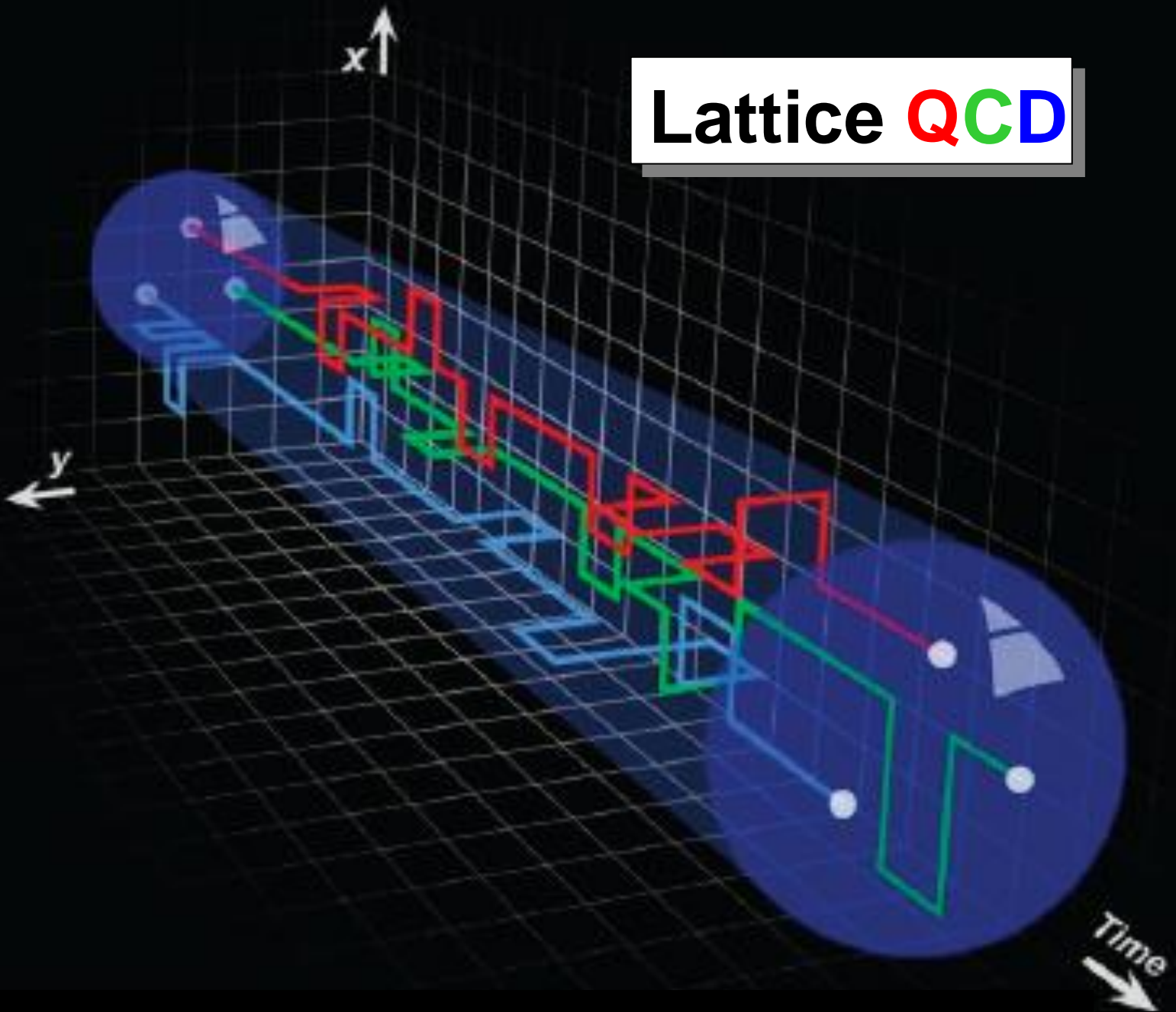
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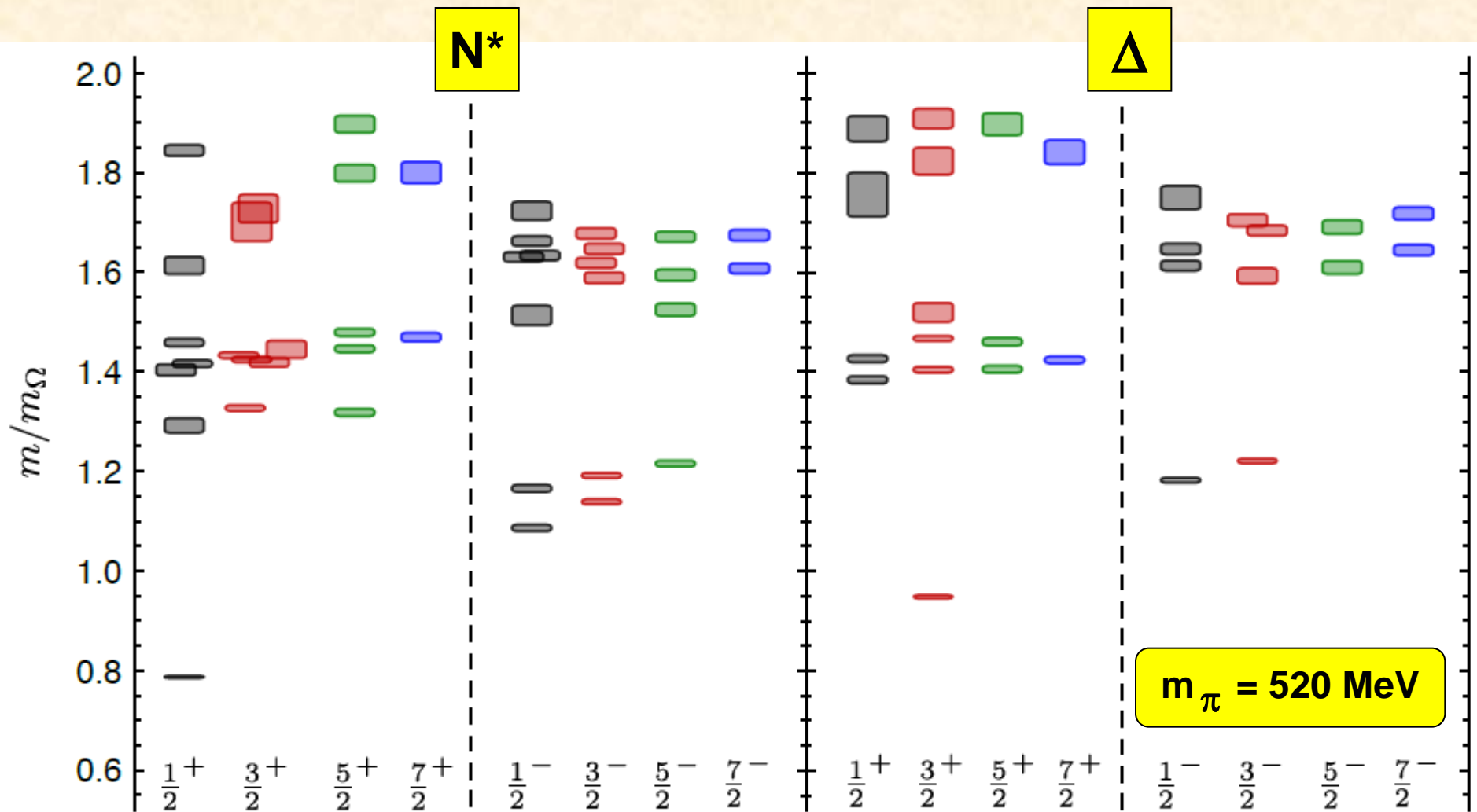
Global working



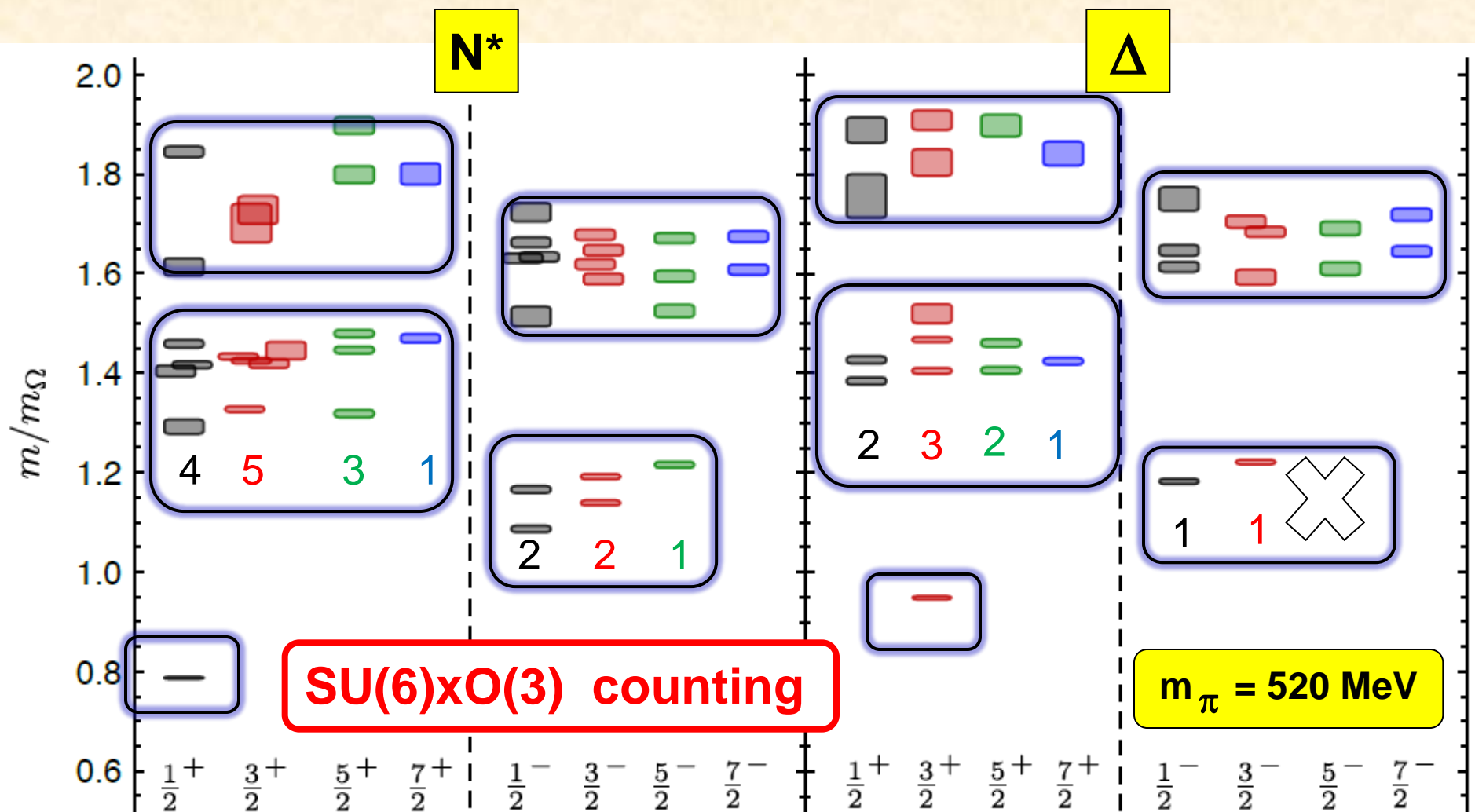
Lattice QCD



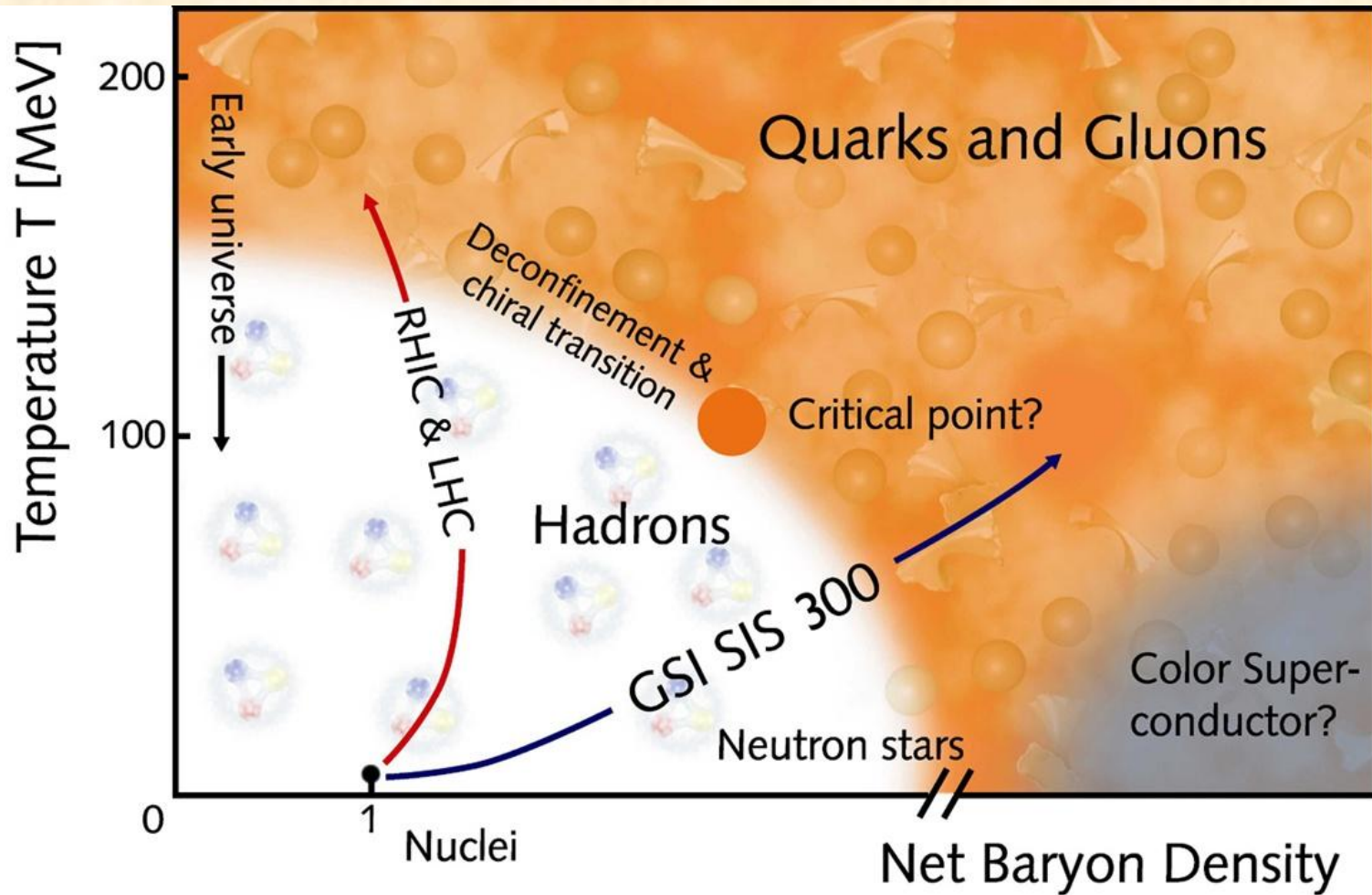
Spin identified N^* and Δ states



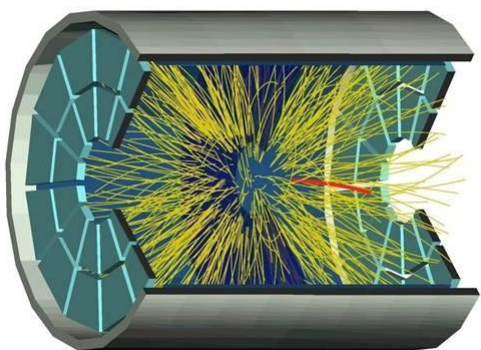
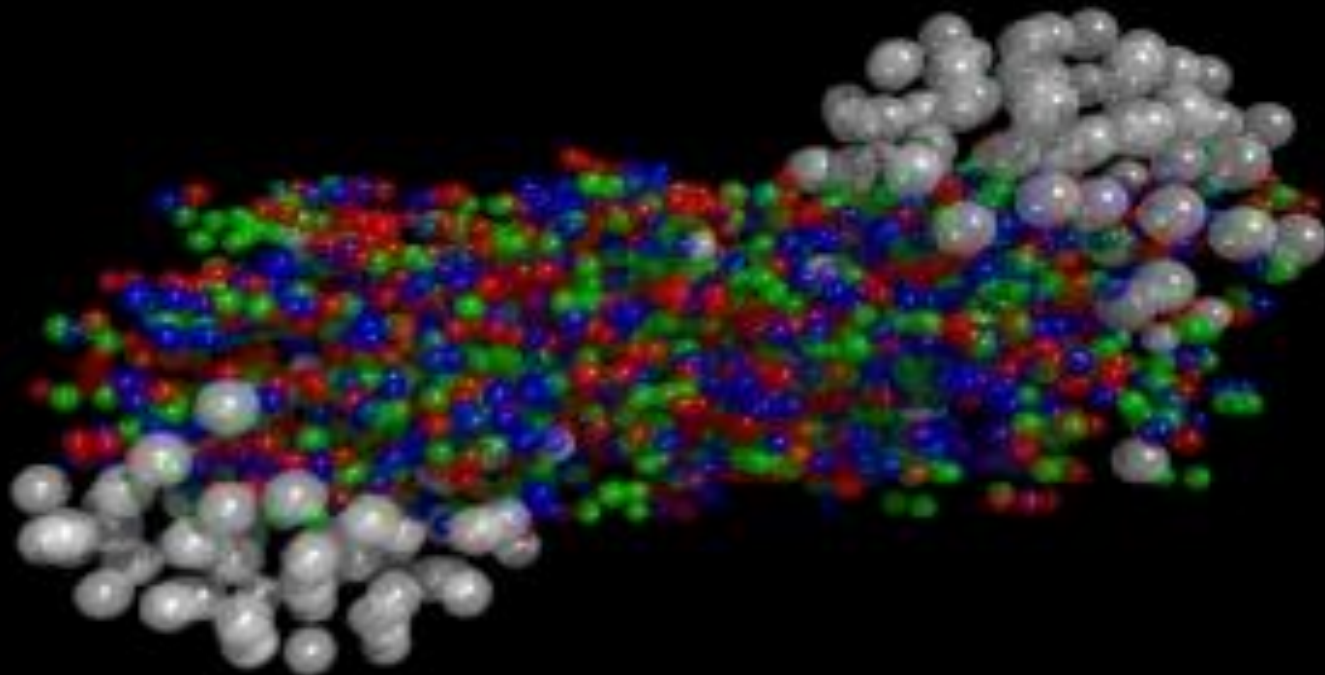
Spin identified N^* and Δ states



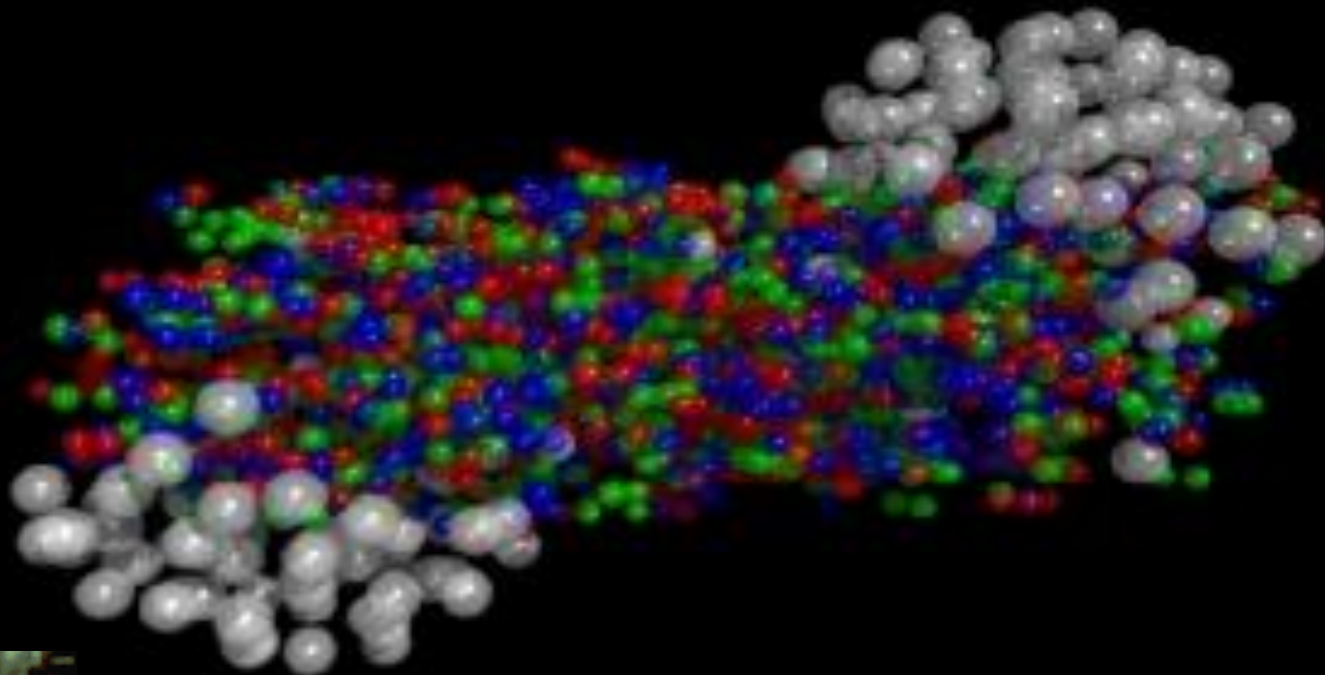
Phase Diagram of Strongly Interacting Matter



Au on Au



Pb on Pb

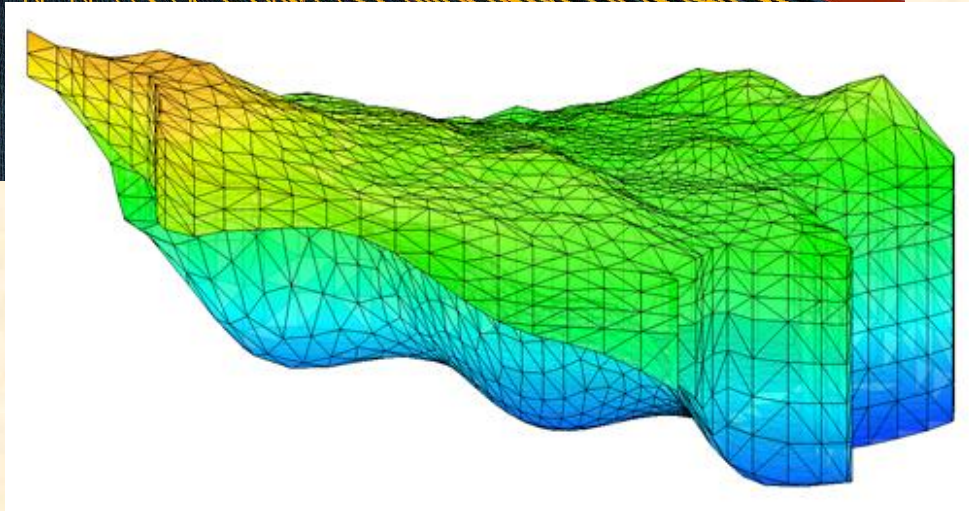
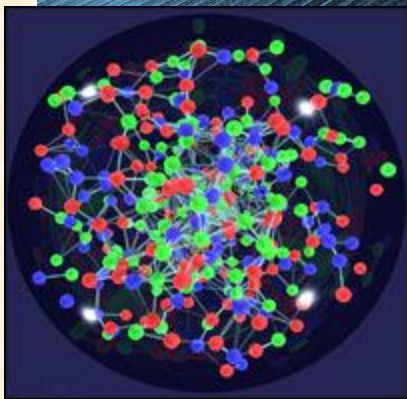
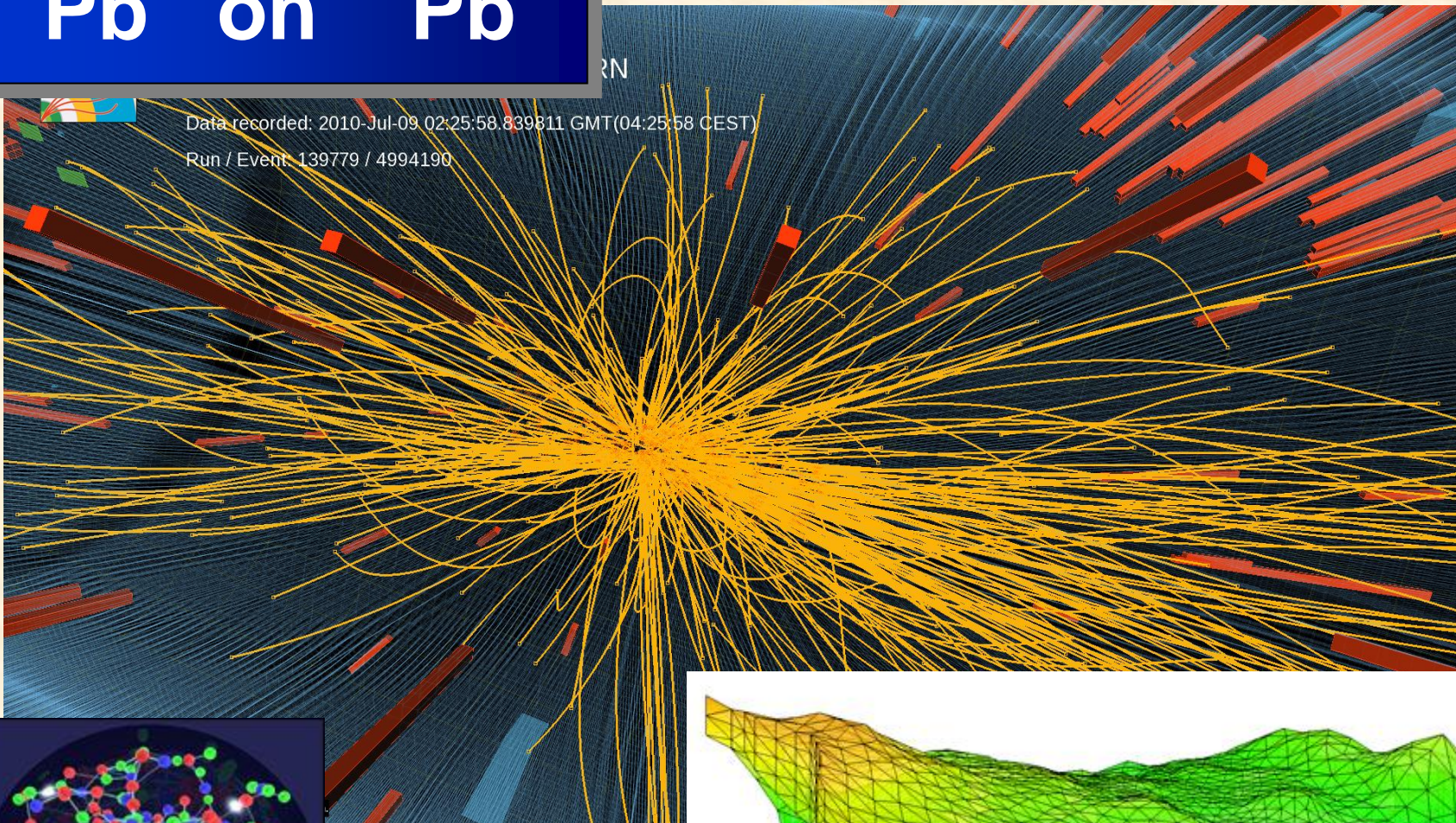


Pb on Pb

RN

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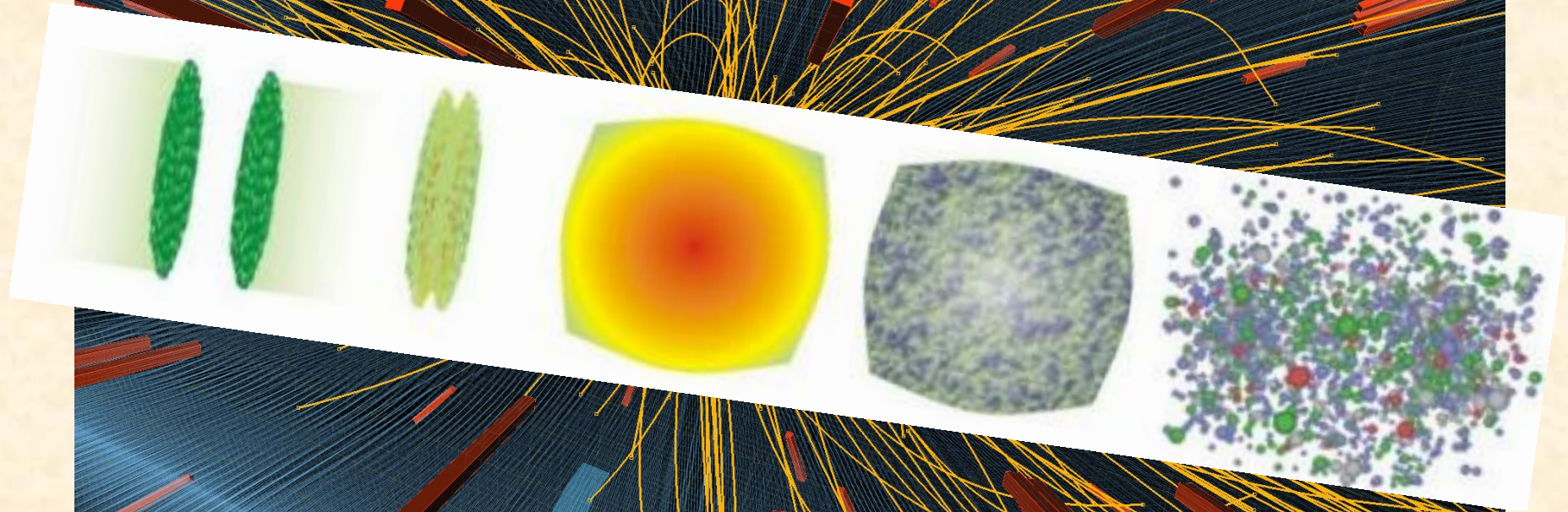
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Pb on Pb

RN

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Run / Event: 139779 / 4994190



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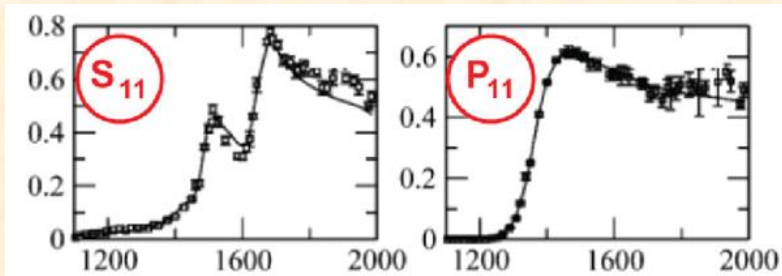
<http://figuena.cern.ch/2010/>

Ultrarelativistic Quantum Molecular Dynamics

Emerging needs for Excited Hadron Data



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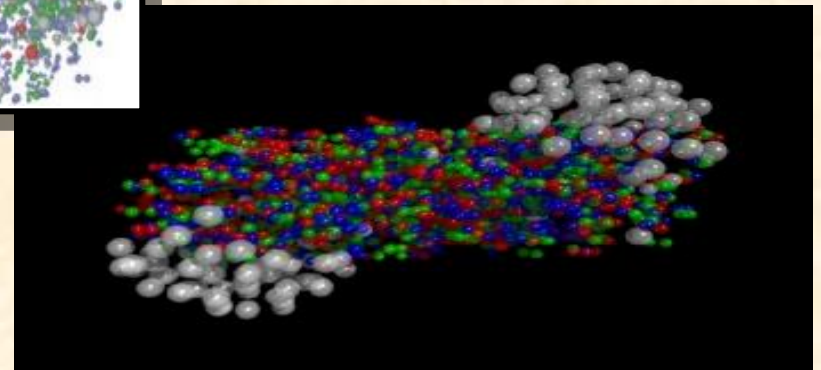
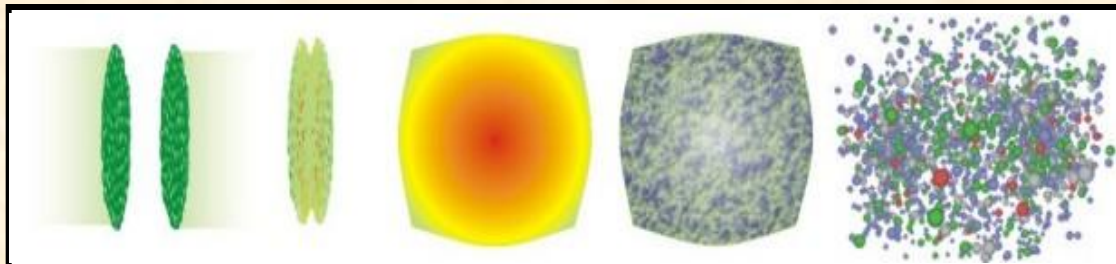


Hadron Archive Data Repository ONLINE

Emerging needs for Excited Hadron Data



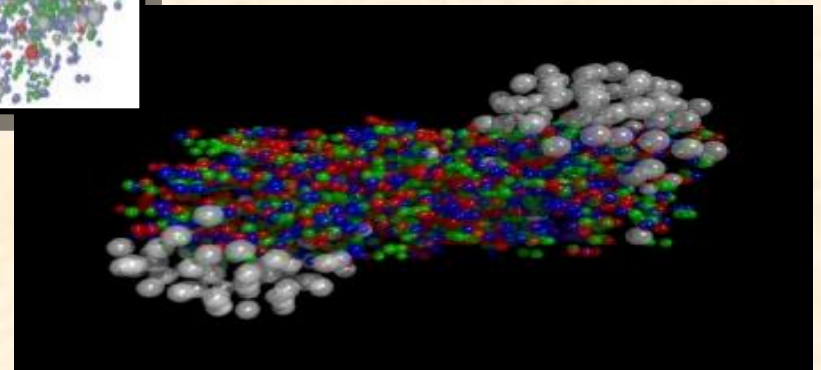
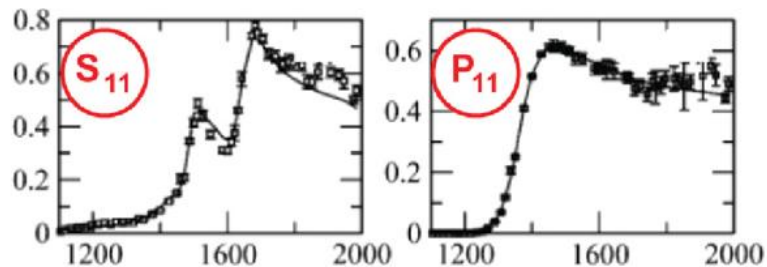
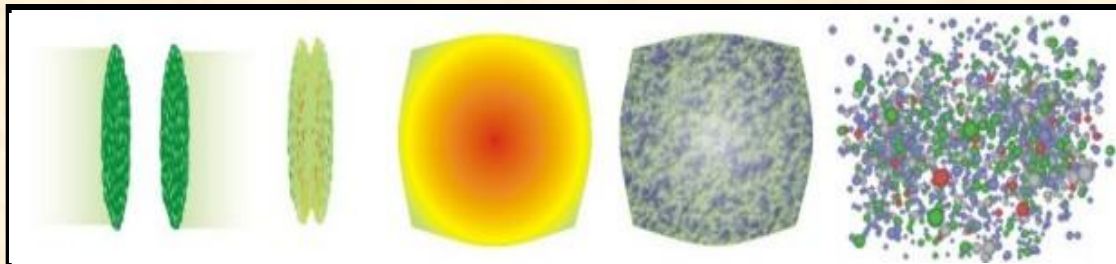
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