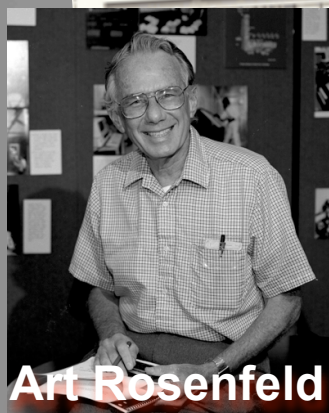


Particle Data Group



Art Rosenfeld

1956





Mesons

Baryons

**Gauge
Bosons
Higgs**

Neutrinos



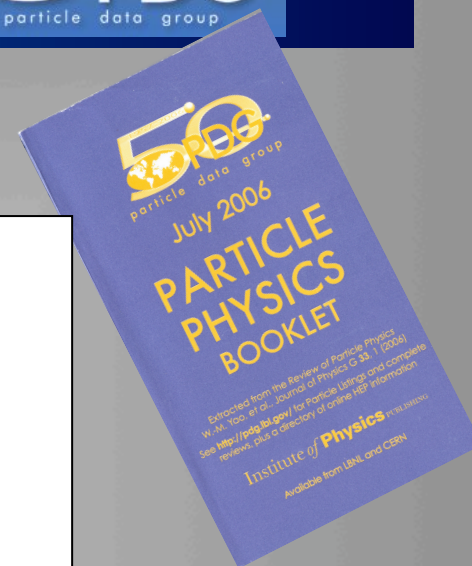


Charles WOHL



Ron WORKMAN

Baryons





Charles WOHL

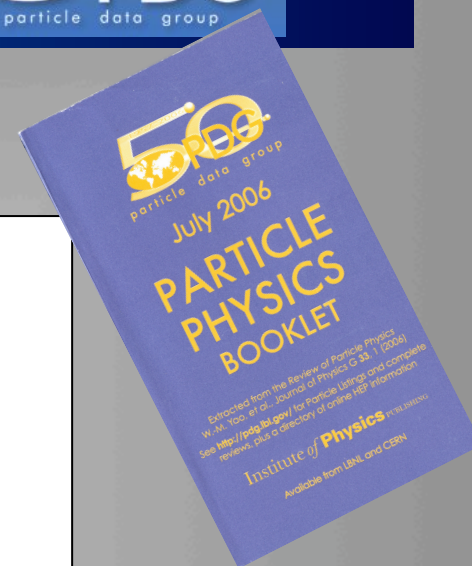


Ron WORKMAN



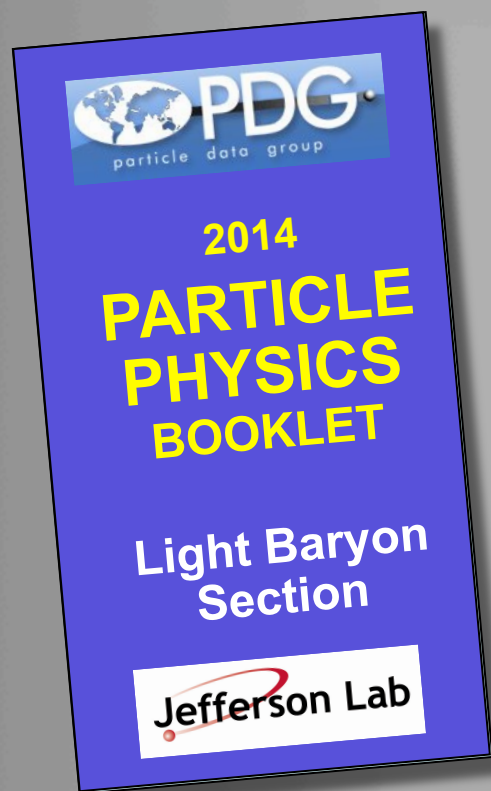
Eberhard KLEMP

Baryons



Baryons@PDG

Jefferson Lab



The Team



Baryons



Global working

Political Map of the World, April 2006

AUSTRALIA
Bosnia and Herzegovina
Slovenia / AZORES
★
Scale 1:100,000,000
Reference Projections
Standard parallels 30°N and 30°S

Independent state
Dependency or area of special sovereignty
Island / Island group
Capital

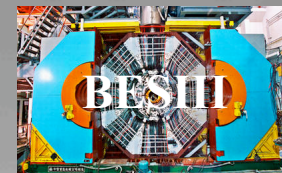
ANL-
Osaka

SAID

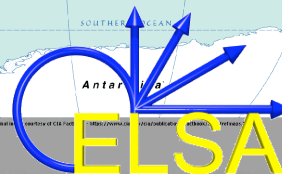
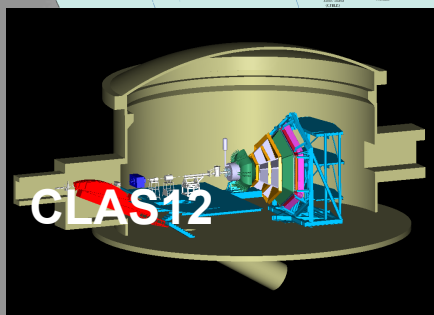
MAID

Bonn-
Gatchina

Baryons into the future



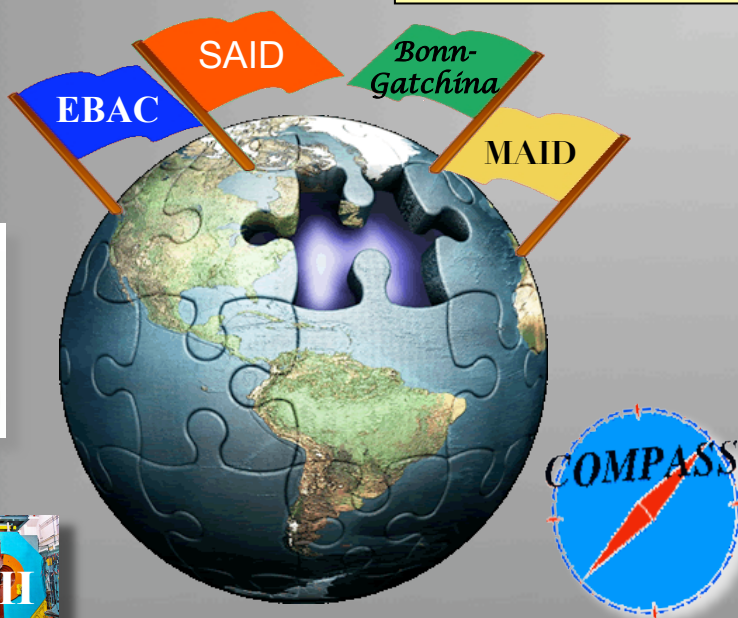
PANDA





Opportunity for synergy

JLab Physics Analysis Center (JPAC)
umbrella for coordinating
and networking amplitude analyses



Link to global baryon community
through N^* , pwa conferences
& workshops

The Team



Started February 1st, 2013

Baryons



N*(1440)

N(1440) $1/2^+$

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

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

N(1440) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1420 to 1470 (≈ 1440) OUR ESTIMATE			
1430 ± 8	ANISOVICH	12A	DPWA Multichannel
1485.0 ± 1.2	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1462 ± 10	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
1440 ± 30	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1410 ± 12	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1440 ± 12	ANISOVICH	10	DPWA Multichannel
1439 ± 19	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
1436 ± 15	SARANTSEV	08	DPWA Multichannel
1468.0 ± 4.5	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1518 ± 5	PENNER	02C	DPWA Multichannel
1479 ± 80	VRANA	00	DPWA Multichannel
1463 ± 7	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
1467	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
1465	LI	93	IPWA $\gamma N \rightarrow \pi N$
1471	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
1380	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$
1390	² LONGACRE	75	IPWA $\pi N \rightarrow N\pi\pi$

N(1440) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
200 to 450 (≈ 300) OUR ESTIMATE			
365 ± 35	ANISOVICH	12A	DPWA Multichannel
284 ± 18	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
391 ± 34	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
340 ± 70	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
135 ± 10	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
335 ± 50	ANISOVICH	10	DPWA Multichannel
437 ± 141	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
335 ± 40	SARANTSEV	08	DPWA Multichannel
360 ± 26	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
668 ± 41	PENNER	02C	DPWA Multichannel
490 ± 120	VRANA	00	DPWA Multichannel

N*(1440)

Citation: J. Beringer *et al.* (Particle Data Group), PR D86, 010001 (2012) (URL: <http://pdg.lbl.gov>)

360 ± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
440	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
315	LI	93	IPWA	$\gamma N \rightarrow \pi N$
545 ± 170	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
200	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
200	² LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

N(1440) POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1350 to 1380 (≈ 1365) OUR ESTIMATE			
1370 ± 4	ANISOVICH	12A	DPWA Multichannel
1359	³ ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1385	⁴ HOEHLER	93	SPED $\pi N \rightarrow \pi N$
1375 ± 30	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1370 ± 4	ANISOVICH	10	DPWA Multichannel
1363 ± 11	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
1371 ± 7	SARANTSEV	08	DPWA Multichannel
1357	⁵ ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1383	VRANA	00	DPWA Multichannel
1346	⁶ ARNDT	95	DPWA $\pi N \rightarrow N\pi$
1360	⁷ ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
1370	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
1381 or 1379	⁸ LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
1360 or 1333	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
160 to 220 (≈ 190) OUR ESTIMATE			
190 ± 7	ANISOVICH	12A	DPWA Multichannel
162	³ ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
164	⁴ HOEHLER	93	SPED $\pi N \rightarrow \pi N$
180 ± 40	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
193 ± 7	ANISOVICH	10	DPWA Multichannel
151 ± 13	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
192 ± 20	SARANTSEV	08	DPWA Multichannel
160	⁵ ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
316	VRANA	00	DPWA Multichannel
176	⁶ ARNDT	95	DPWA $\pi N \rightarrow N\pi$
252	⁷ ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
228	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
209 or 210	⁸ LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
167 or 234	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

N*(1440)

promoting poles & residues

Citation: J. Beringer et al. (Particle Data Group), PR **D86**, 010001 (2012) (URL: <http://pdg.lbl.gov>)

N(1440) 1/2⁺

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

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

N(1440) POLE POSITION

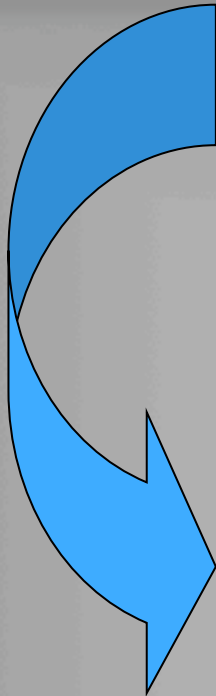
REAL PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1350 to 1380 (≈ 1365) OUR ESTIMATE			
1370 ± 4	ANISOVICH	12A	DPWA Multichannel
1359	³ ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
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1370 ± 4	ANISOVICH	10	DPWA Multichannel
1363 ± 11	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
1371 ± 7	SARANTSEV	08	DPWA Multichannel
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1383	VRANA	00	DPWA Multichannel
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1360	⁷ ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
1370	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
1381 or 1379	⁸ LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
1360 or 1333	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
160 to 220 (≈ 190) OUR ESTIMATE			
190 ± 7	ANISOVICH	12A	DPWA Multichannel
162	³ ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
164	⁴ HOEHLER	93	SPED $\pi N \rightarrow \pi N$
180 ± 40	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
193 ± 7	ANISOVICH	10	DPWA Multichannel
151 ± 13	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
192 ± 20	SARANTSEV	08	DPWA Multichannel
160	⁵ ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
316	VRANA	00	DPWA Multichannel
176	⁶ ARNDT	95	DPWA $\pi N \rightarrow N\pi$
252	⁷ ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
228	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
209 or 210	⁸ LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
167 or 234	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

N*(1440)



N(1440) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1420 to 1470 (≈ 1440) OUR ESTIMATE			
1430 \pm 8	ANISOVICH	12A	DPWA Multichannel
1485.0 \pm 1.2	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1462 \pm 10	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
1440 \pm 30	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1410 \pm 12	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1440 \pm 12	ANISOVICH	10	DPWA Multichannel
1439 \pm 19	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
1436 \pm 15	SARANTSEV	08	DPWA Multichannel
1468.0 \pm 4.5	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1518 \pm 5	PENNER	02C	DPWA Multichannel
1479 \pm 80	VRANA	00	DPWA Multichannel
1463 \pm 7	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
1467	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
1465	LI	93	IPWA $\gamma N \rightarrow \pi N$
1471	CUTKOSKY	90	IPWA $\pi N \rightarrow \pi N$
1380	¹ LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$
1390	² LONGACRE	75	IPWA $\pi N \rightarrow N\pi\pi$

N(1440) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
200 to 450 (≈ 300) OUR ESTIMATE			
365 \pm 35	ANISOVICH	12A	DPWA Multichannel
284 \pm 18	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
391 \pm 34	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
340 \pm 70	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
135 \pm 10	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
335 \pm 50	ANISOVICH	10	DPWA Multichannel
437 \pm 141	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$
335 \pm 40	SARANTSEV	08	DPWA Multichannel
360 \pm 26	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
668 \pm 41	PENNER	02C	DPWA Multichannel
490 \pm 120	VRANA	00	DPWA Multichannel

N*(1440)

N(1440) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	55–75 %
Γ_2	$N\eta$	(0.0±1.0) %
Γ_3	$N\pi\pi$	30–40 %
Γ_4	$\Delta\pi$	20–30 %
Γ_5	$\Delta(1232)\pi$, P -wave	15–30 %
Γ_6	$N\rho$	<8 %
Γ_7	$N\rho$, $S=1/2$, P -wave	(0.0±1.0) %
Γ_8	$N\rho$, $S=3/2$, P -wave	
Γ_9	$N(\pi\pi)_{S=0}^{I=0}$	10–20 %
Γ_{10}	$p\gamma$	0.035–0.048 %
Γ_{11}	$p\gamma$, helicity=1/2	0.035–0.048 %
Γ_{12}	$n\gamma$	0.02–0.04 %
Γ_{13}	$n\gamma$, helicity=1/2	0.02–0.04 %

N(1440) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE (%)	DOCUMENT ID	TECN	COMMENT		
55 to 75 OUR ESTIMATE					
62 ±3	ANISOVICH	12A	DPWA Multichannel		
78.7±1.6	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$		
69 ±3	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$		
68 ±4	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$		
51 ±5	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$		
• • • We do not use the following data for averages, fits, limits, etc. • • •					
60 ±6	ANISOVICH	10	DPWA Multichannel		
62 ±4	BATINIC	10	DPWA $\pi N \rightarrow N\pi, N\eta$		
75.0±2.4	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$		
57 ±1	PENNER	02C	DPWA Multichannel		
72 ±5	VRANA	00	DPWA Multichannel		
68	ARNDT	95	DPWA $\pi N \rightarrow N\pi$		
$\Gamma(N\eta)/\Gamma_{\text{total}}$					Γ_2/Γ
VALUE (%)	DOCUMENT ID	TECN	COMMENT		
0±1	VRANA	00	DPWA Multichannel		

Note: Signs of couplings from $\pi N \rightarrow N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase

N*(1440)

N(1440) PHOTON DECAY AMPLITUDES

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

N(1440) $\rightarrow p\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
-0.060\pm0.004 OUR ESTIMATE			
-0.061 \pm 0.008	ANISOVICH	12A	DPWA Multichannel
-0.051 \pm 0.002	DUGGER	07	DPWA $\gamma N \rightarrow \pi N$
-0.063 \pm 0.005	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
-0.069 \pm 0.018	CRAWFORD	83	IPWA $\gamma N \rightarrow \pi N$
-0.063 \pm 0.008	AWAJI	81	DPWA $\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
-0.052 \pm 0.010	ANISOVICH	10	DPWA Multichannel
-0.061	DRECHSEL	07	DPWA $\gamma N \rightarrow \pi N$
-0.087	PENNER	02D	DPWA Multichannel
-0.085 \pm 0.003	LI	93	IPWA $\gamma N \rightarrow \pi N$
-0.129	10 WADA	84	DPWA Compton scattering

N(1440) $\rightarrow n\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
+0.040\pm0.010 OUR ESTIMATE			
0.045 \pm 0.015	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
0.037 \pm 0.010	AWAJI	81	DPWA $\gamma N \rightarrow \pi N$
0.030 \pm 0.003	FUJII	81	DPWA $\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.054	DRECHSEL	07	DPWA $\gamma N \rightarrow \pi N$
0.121	PENNER	02D	DPWA Multichannel
0.085 \pm 0.006	LI	93	IPWA $\gamma N \rightarrow \pi N$

Criteria for “above the line” contributions

$N(1680) \rightarrow p\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($\text{GeV}^{-1/2}$)

DOCUMENT ID

TECN

COMMENT

$+0.133 \pm 0.012$ OUR ESTIMATE

0.135 ± 0.006

ANISOVICH

12A

DPWA Multichannel

0.134 ± 0.002

DUGGER

07

DPWA $\gamma N \rightarrow \pi N$

0.145 ± 0.005

ARNDT

96

IPWA $\gamma N \rightarrow \pi N$

0.132 ± 0.010

CRAWFORD

83

IPWA $\gamma N \rightarrow \pi N$

0.115 ± 0.008

AWAJI

81

DPWA $\gamma N \rightarrow \pi N$

~~We do not use the following data for averages, fits, limits, etc.~~

0.136 ± 0.012

ANISOVICH

10

DPWA Multichannel

0.134

DRECHSEL

07

DPWA $\gamma N \rightarrow \pi N$

0.154 ± 0.002

LI

93

IPWA $\gamma N \rightarrow \pi N$

Criteria for “above the line” contributions

A) Uncertainties in resonance parameters.

The publication must have a detailed discussion on how the uncertainties of parameters were estimated and why the author(s) believe that they approximately represent real uncertainties. This requires that the error estimates go beyond the simple fit error as e.g. given by Minuit, and the robustness of the results must be demonstrated.

Criteria for “above the line” contributions

B) Fit quality.

Concrete measures for the fit quality must be provided. The reduced global χ^2 value of the fit, while useful, is insufficient. Other possibilities include quoting variations of local χ^2 value in kinematic regions where evidence for new states or significantly improved information on resonance parameters is claimed.

Criteria for “above the line” contributions



C) Weight factors in observables.

Analyses often use weight factors for certain data sets to either increase or reduce their impact on the results. This has been particularly important when polarization observables are involved, which usually are very sensitive to amplitude interferences but often have much poorer statistics than differential cross section data. To evaluate sensitivities, the resulting resonance parameters should be checked against variations of the specific weight factors.

Extending the PDG database

longer term

Aim to form a 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^* 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**

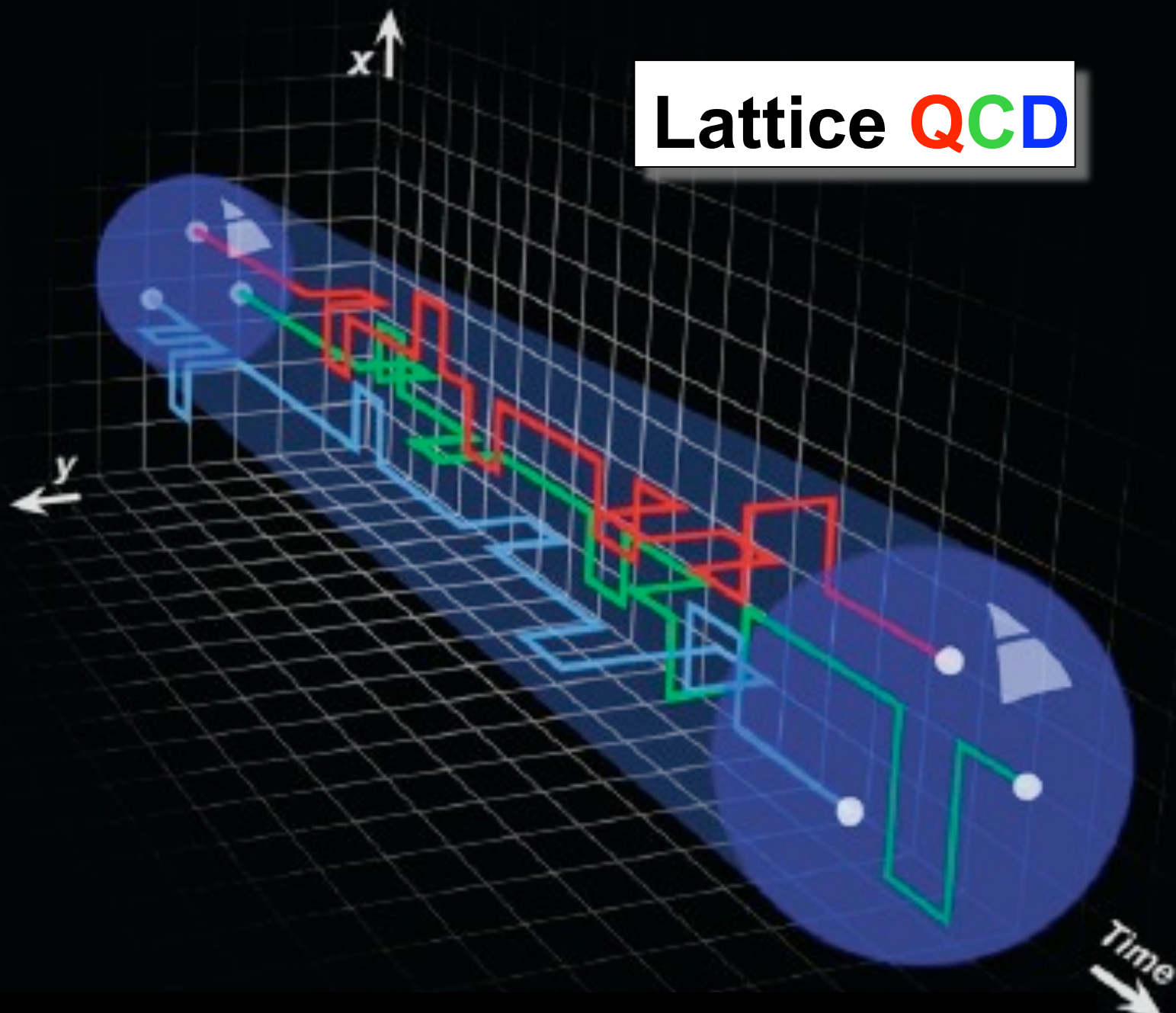
a graphical representation of the data

a graphical comparison of the partial waves in each analysis

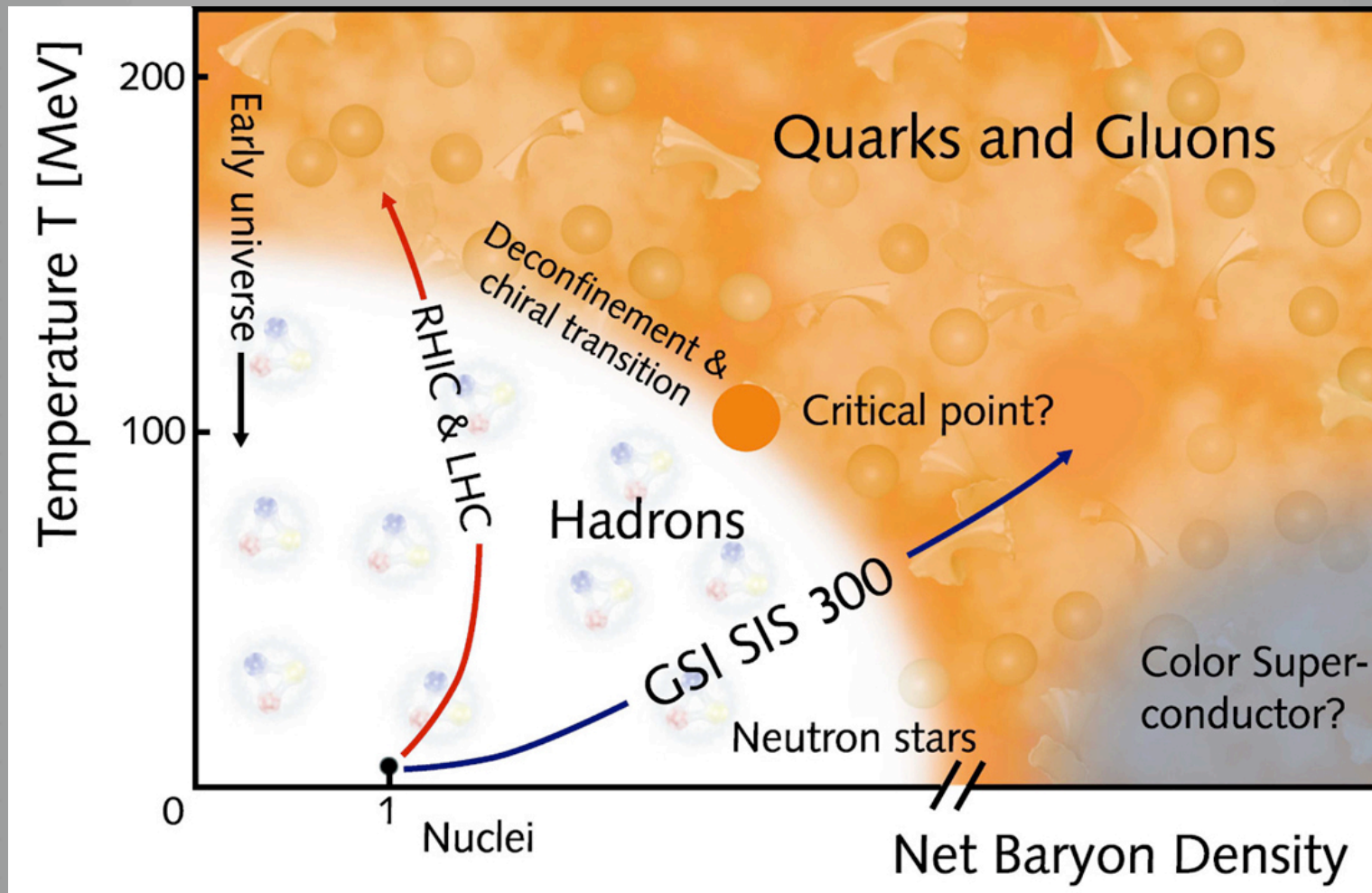
a detailed exposition of the methods used in each analysis

Where appropriate to be compared with the detailed predictions of QCD

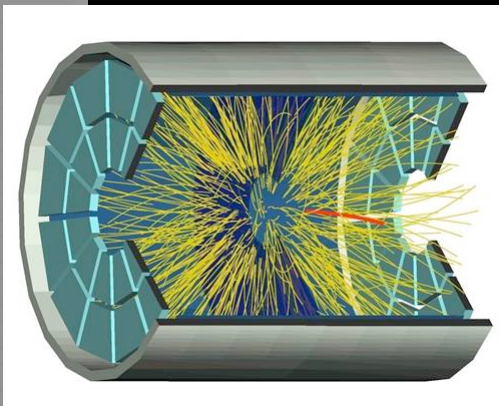
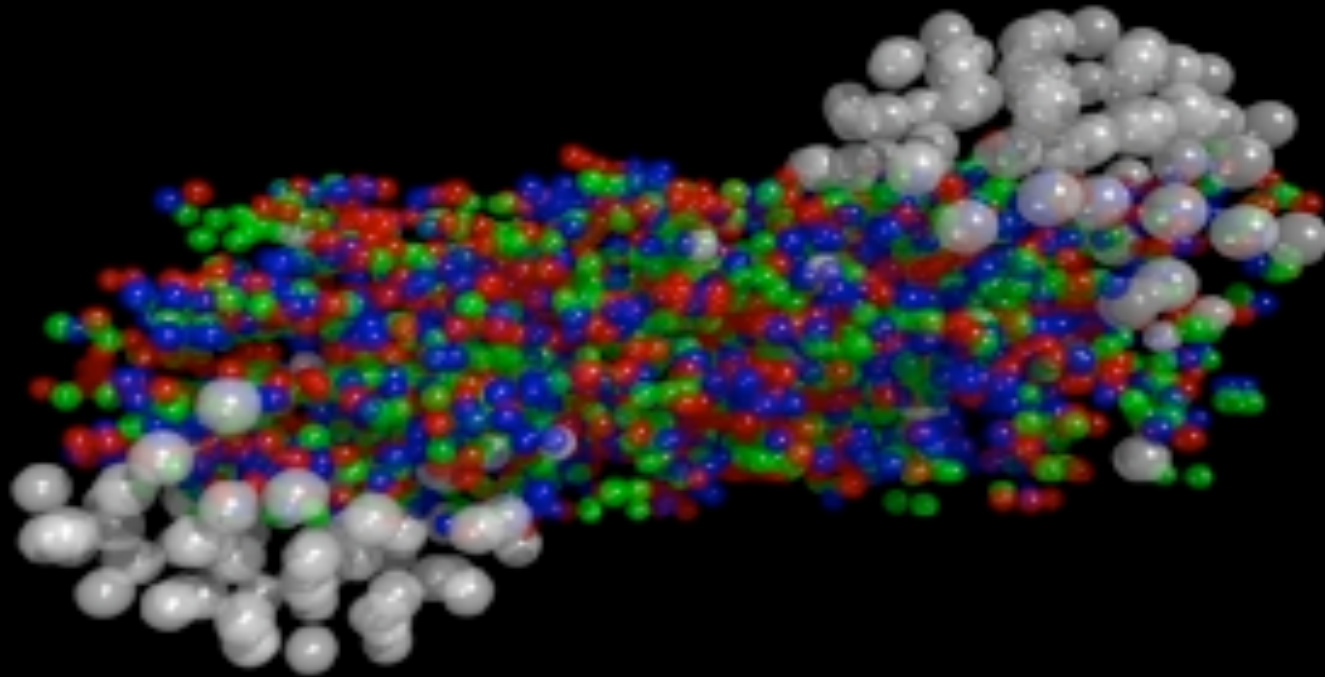
Lattice QCD



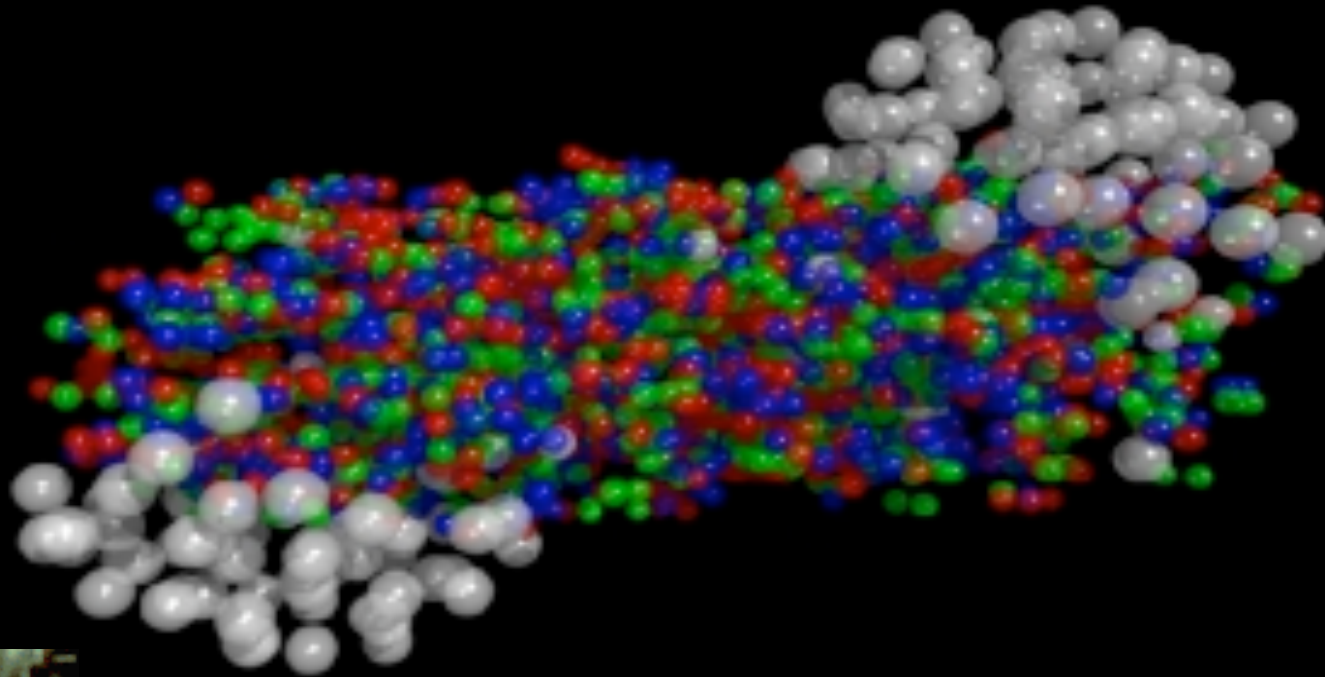
Phase Diagram of Strongly Interacting Matter



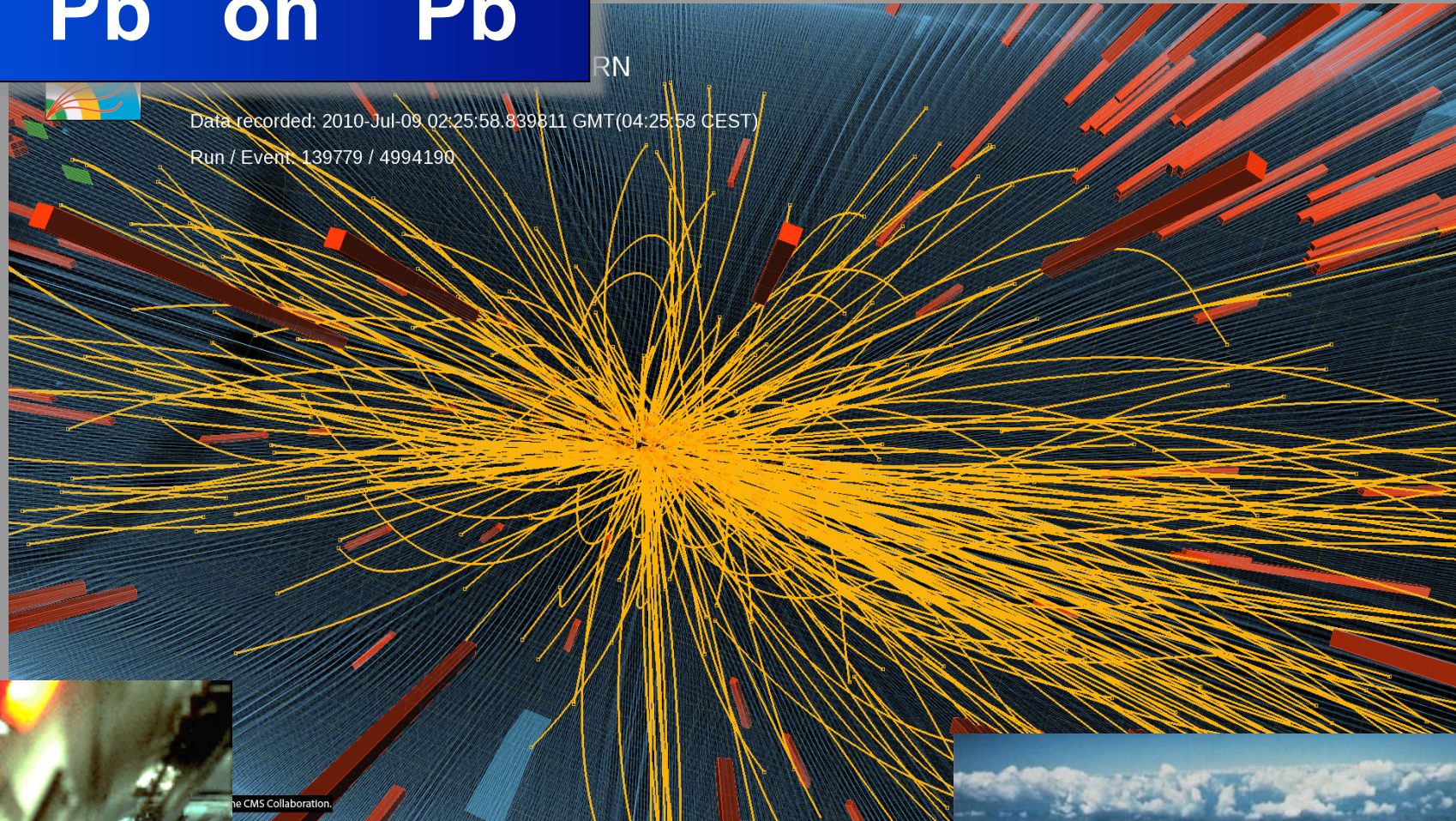
Au on Au



Pb on Pb



Pb on Pb



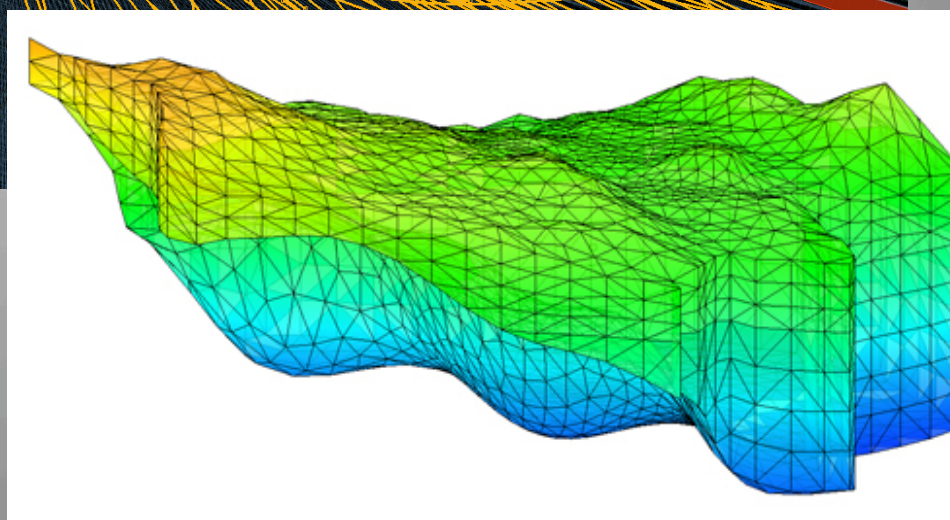
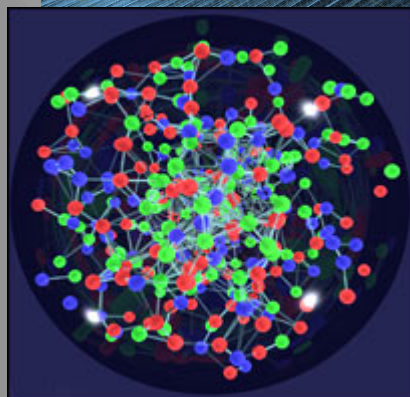
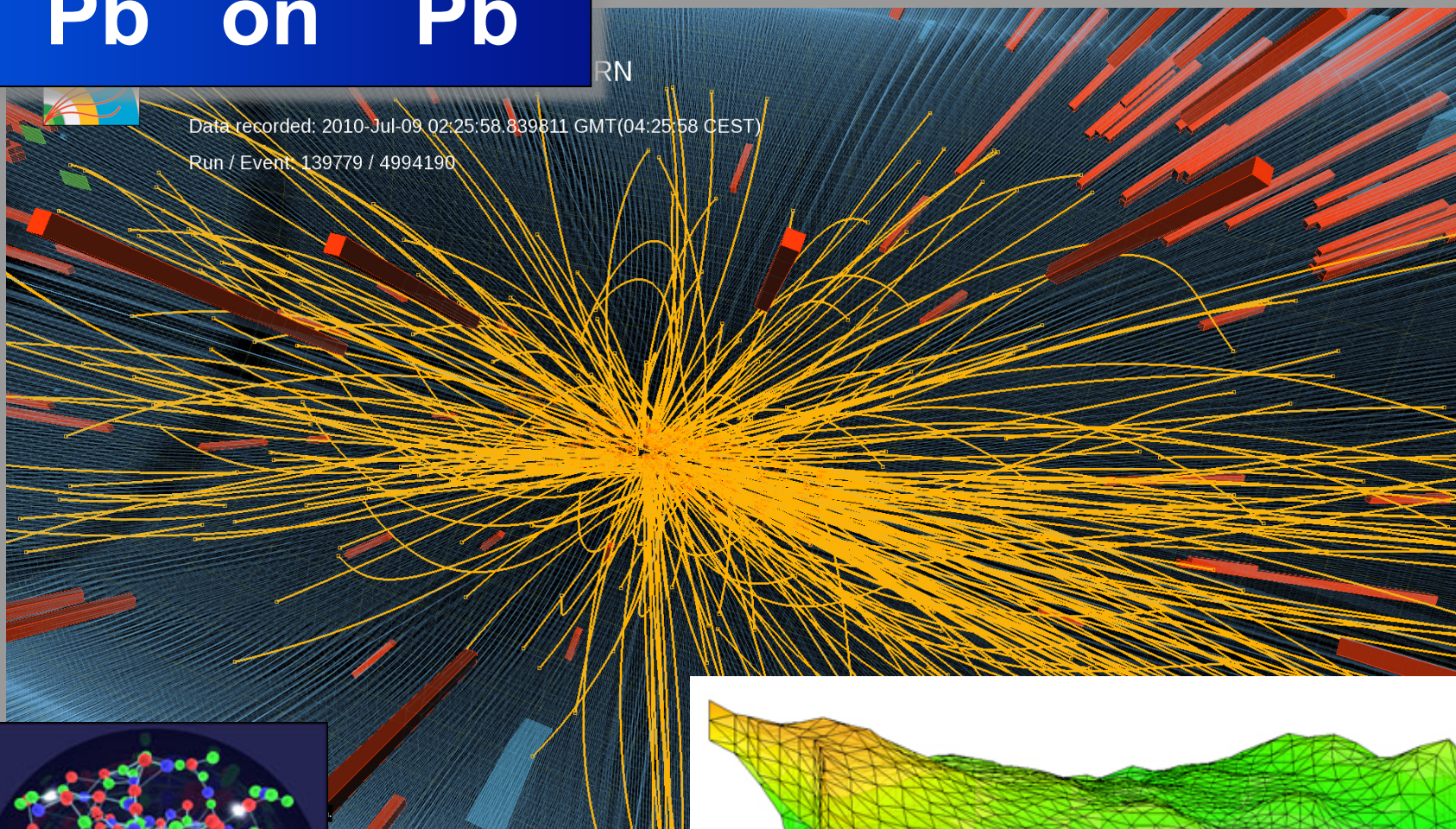
Pb on Pb



Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)

Run / Event: 139779 / 4994190

RN

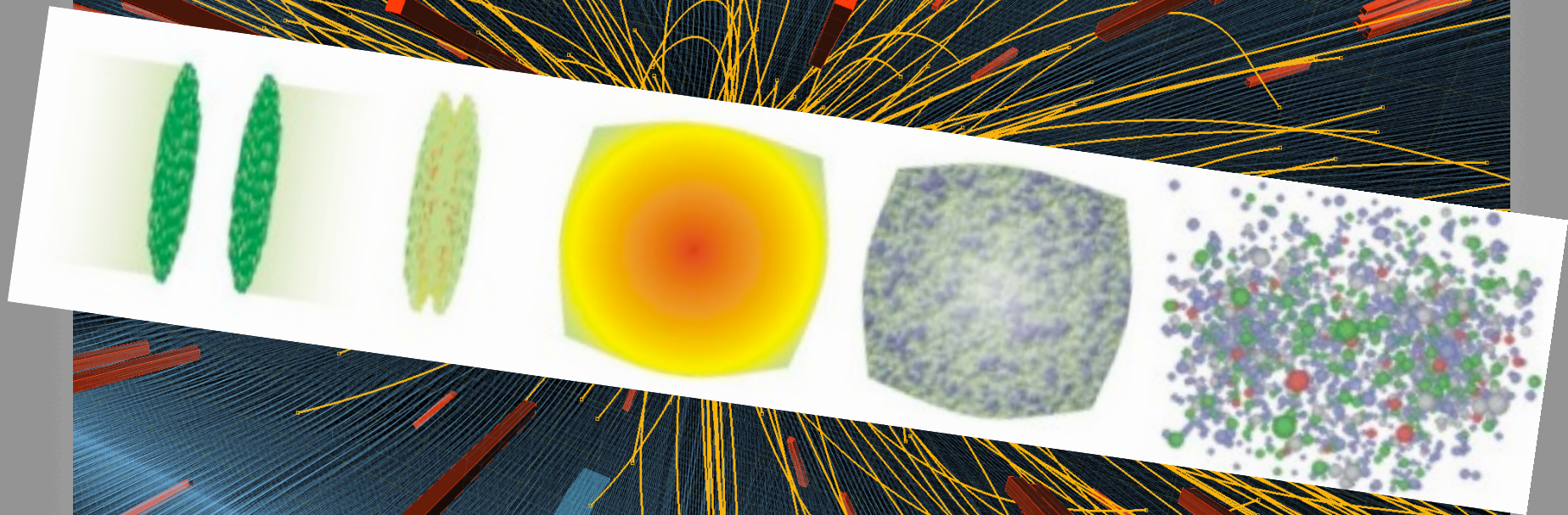


Pb on Pb

RN

Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)

Run / Event: 139779 / 4994190

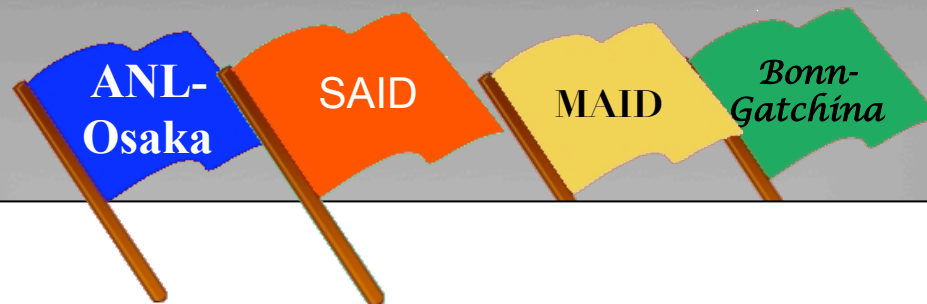


(c) Copyright CERN, 2010. For the benefit of the CMS Collaboration.

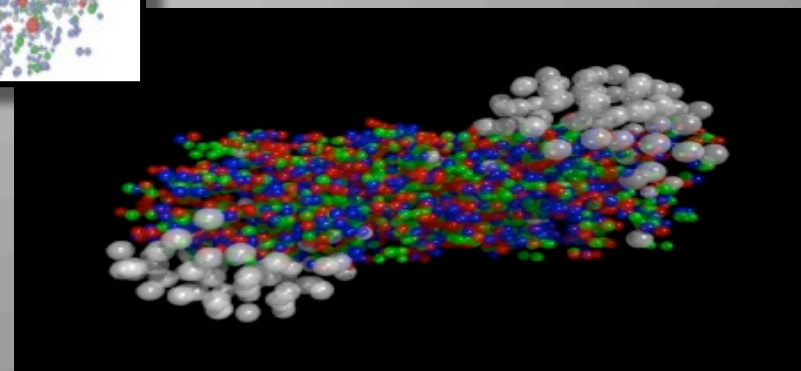
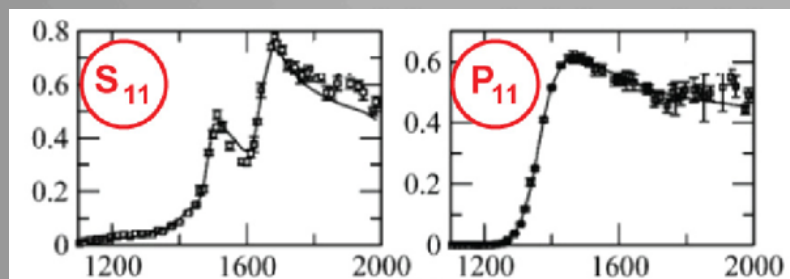
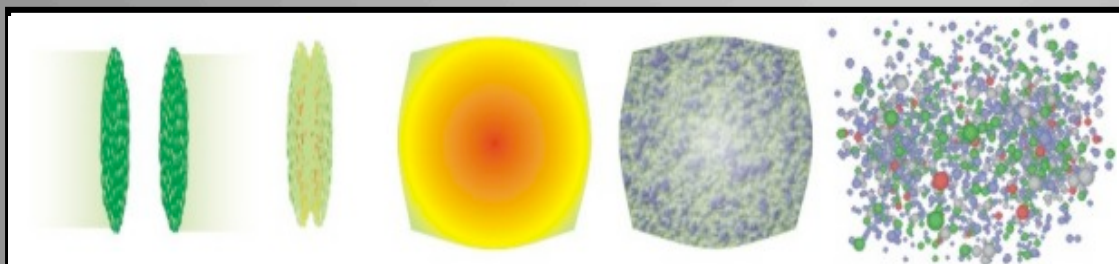
<http://quench.cern.ch/>

Ultrarelativistic Quantum Molecular Dynamics

Emerging needs for Excited Hadron Data

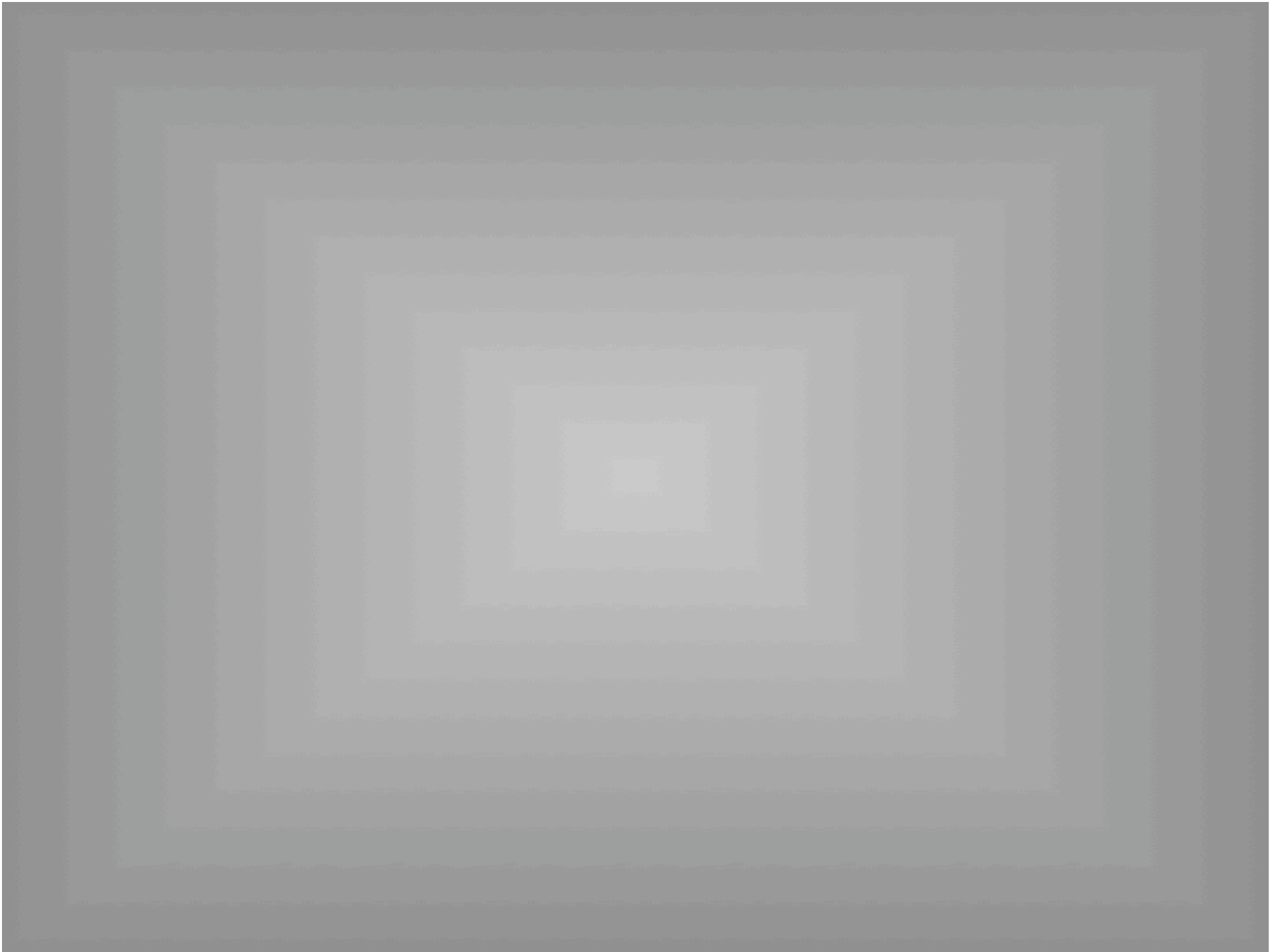


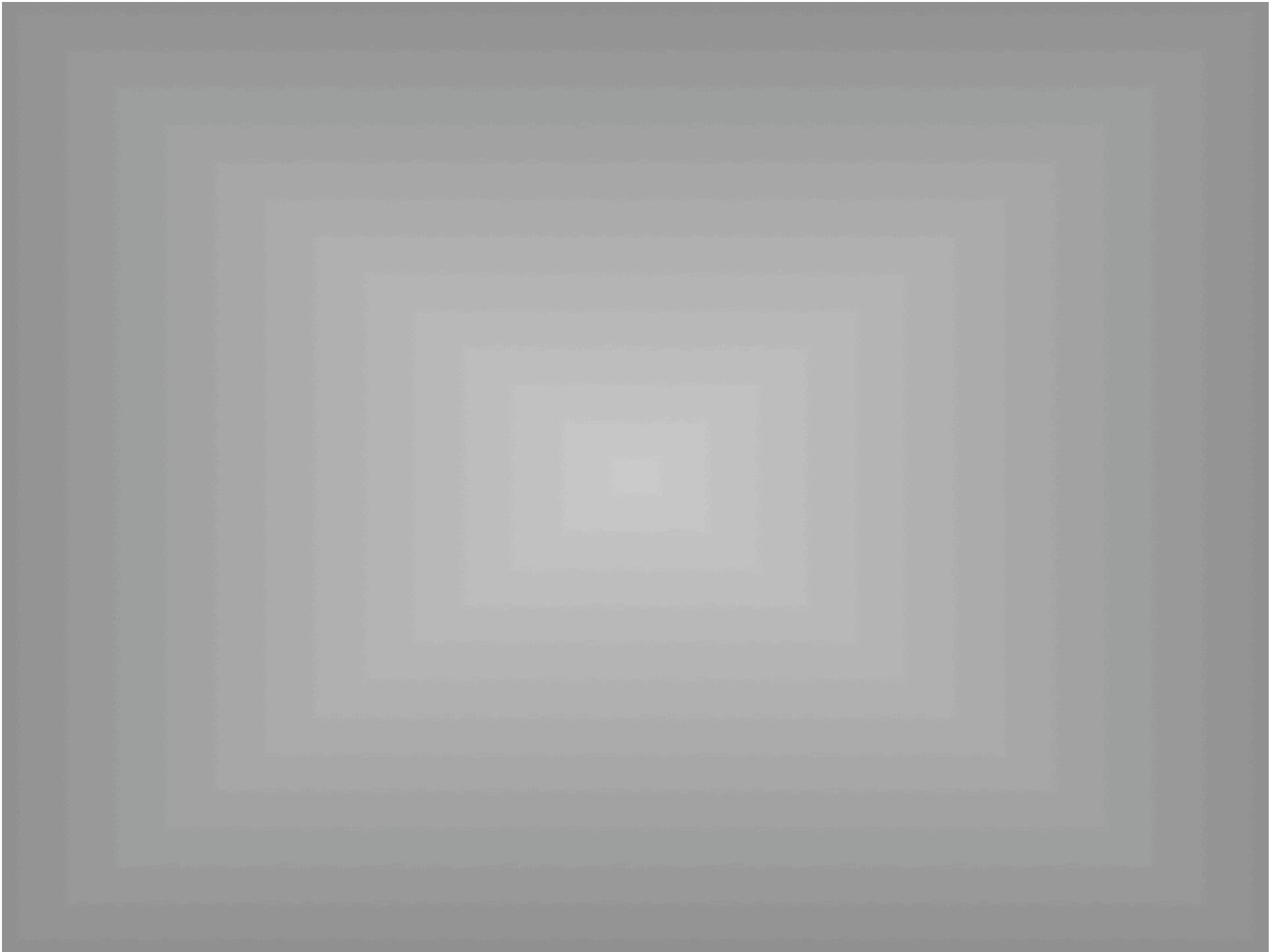
The George Washington University
Data Analysis Center





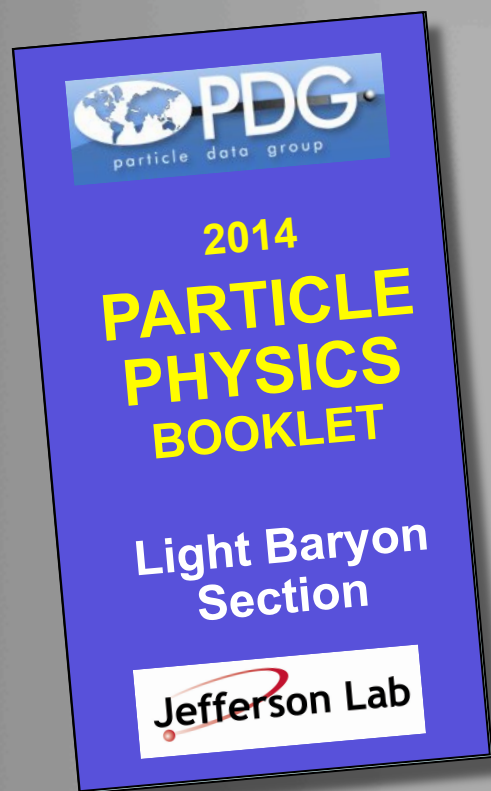
What would you like to see?





Baryons@PDG

Jefferson Lab



The Team



Baryons

