HEPP-EPS 2005 Summary
Part II

Alberto Guffanti

DESY, Zeuthen

DESY, Zeuthen
September 7th, 2005

Outline

Detectors and Data Handling (GRID)

Tests of SM

Non-perturbative field theory

High Energy Nuclear Physics

Hard QCD

Astroparticle physics

Physics beyond the SM

String Theory and Extra Dimensions

Rare Decays

Dark Matter and Dark Energy

Plenary Sessions

CP Violation

Hadronic Physics

Neutrino Physics

Gravitational Waves

New Developments in Accelerator Physics and Technology

Quantum Groups and Non-Commutative Geometry

Heavy Flavours

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Physics beyond the SM

Disclaimer

This is a personal/biased/limited selection of the talks presented at the conference!!!
My apologies to all the speakers whose contributions I may have overlooked or not fully understood.

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CP Violation

Hadronic Physics

Neutrino Physics

Gravitational Waves

New Developments in Accelerator Physics and Technology

Quantum Groups and Non-Commutative Geometry

Heavy Flavours

(Lattice)

QCD

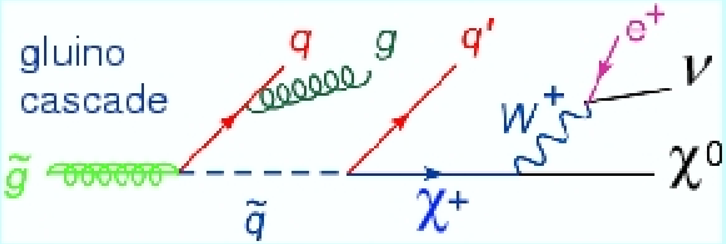
(and String Theory)

Twistors, MHV amplitudes etc.

L. Dixon

Signals and backgrounds

- New particles typically decay into old particles: quarks, gluons, charged leptons and neutrinos, photons, Ws & Zs (which in turn decay to leptons)



- Kinematic signatures are not always clean (*e.g.* mass bumps) if neutrinos, or other escaping particles (e.g. dark matter) are present

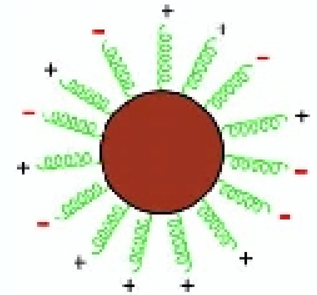
- Need to quantify the Standard Model backgrounds for a variety of multi-particle processes, to maximize potential for new physics discoveries

Twistors, MHV amplitudes etc.

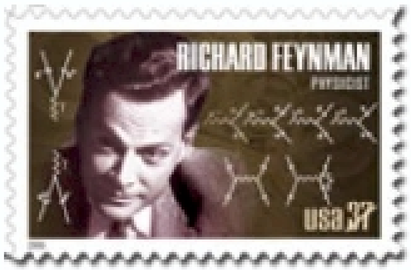
L. Dixon

A better way to compute?

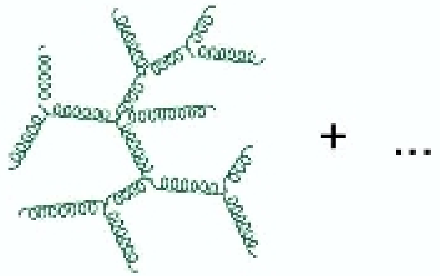
- Backgrounds (and many signals) require detailed understanding of scattering amplitudes for many ultra-relativistic ("massless") particles -- especially quarks and gluons of QCD



- Feynman told us how to do this – in principle



- Feynman rules, while very general, are not optimized for these processes
- Important to find more efficient methods, making use of hidden symmetries of QCD



Twistors, MHV amplitudes etc.

L. Dixon

MHV rules for trees

Rules quite efficient, extended to many collider applications

- massless quarks — Georgiou, Khoze, hep-th/0404072; Wu, Zhu, hep-th/0406146; Georgiou, Glover, Khoze, hep-th/0407027
- Higgs bosons (*Hgg* coupling) — LD, Glover, Khoze, hep-th/0411092; Badger, Glover, Khoze, hep-th/0412275
- vector bosons (W, Z, γ^*) — Bern, Forde, Kosower, Mastrolia, hep-th/0412167

- Related approach to QCD + massive quarks but more directly from field theory — Schwinn, Weinzierl, hep-th/0503015

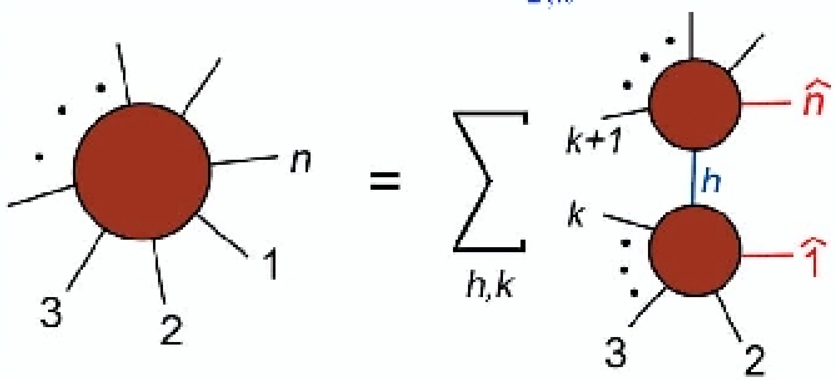
Twistors, MHV amplitudes etc.

L. Dixon

Even better than MHV rules

On-shell recursion relations Britto, Cachazo, Feng, hep-th/0412308

$$A_n(1,2,\ldots,n) = \sum_{h=\pm}\sum_{k=2}^{n-2} A_{k+1}(\hat{1},2,\ldots,k,-\hat{K}_{1,k}^{-h}) \times \frac{i}{K_{1,k}^2} A_{n-k+1}(\hat{K}_{1,k}^{h},k+1,\ldots,n-1,\hat{n})$$



A_{k+1} and A_{n-k+1} are on-shell tree amplitudes with fewer legs, evaluated with momenta shifted by a complex amount

Trees are recycled into trees!

Twistors, MHV amplitudes etc.

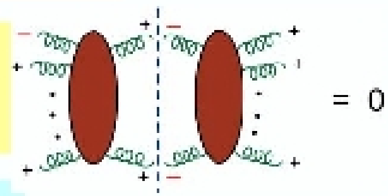
L. Dixon

On-shell recursion at one loop

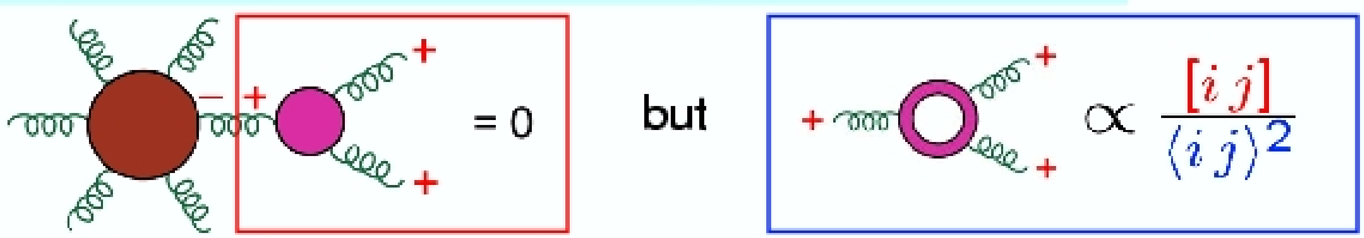
Bern, LD, Kosower, hep-th/0501240, hep-th/0505055, hep-ph/0507005

- Same techniques work for one-loop amplitudes
  -- much harder to obtain by other methods than are trees.

- Warm up with special tree-like one-loop amplitudes with no cuts, only poles: $A_n^{1-\text{loop}}(1^\pm, 2^+, 3^+, \ldots, n^+)$



- New features arise compared with tree case due to different collinear behavior of loop amplitudes:



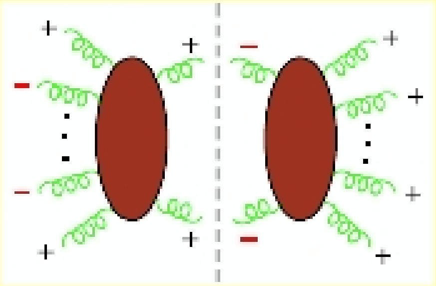
- With a little guesswork, can still find, and solve in closed form, recursion relations for these two infinite sequences of amplitudes

Twistors, MHV amplitudes etc.

L. Dixon

Loop amplitudes with cuts

- Also can do loop amplitudes with cuts (hep-ph/0507005)
- First compute cuts using unitarity.
- Remaining rational-function terms contain "spurious singularities", e.g.



$$\sim \frac{\ln(r) + 1 - r}{(1-r)^2}, \qquad r = s_2/s_1$$

- Accounting for them properly yields simple "overlap diagrams" in addition to recursive diagrams
- No loop integrals required to bootstrap rational functions from cuts and lower-point amplitudes
- Method tested on 5-point amplitudes, used to compute new QCD results:

$$A_6^{1\ \mathrm{loop}}(1^-,2^-,3^+,4^+,5^+,6^+),\ A_7^{1\ \mathrm{loop}}(1^-,2^-,3^+,4^+,5^+,6^+,7^+)$$

Lattice QCD

C. Davies

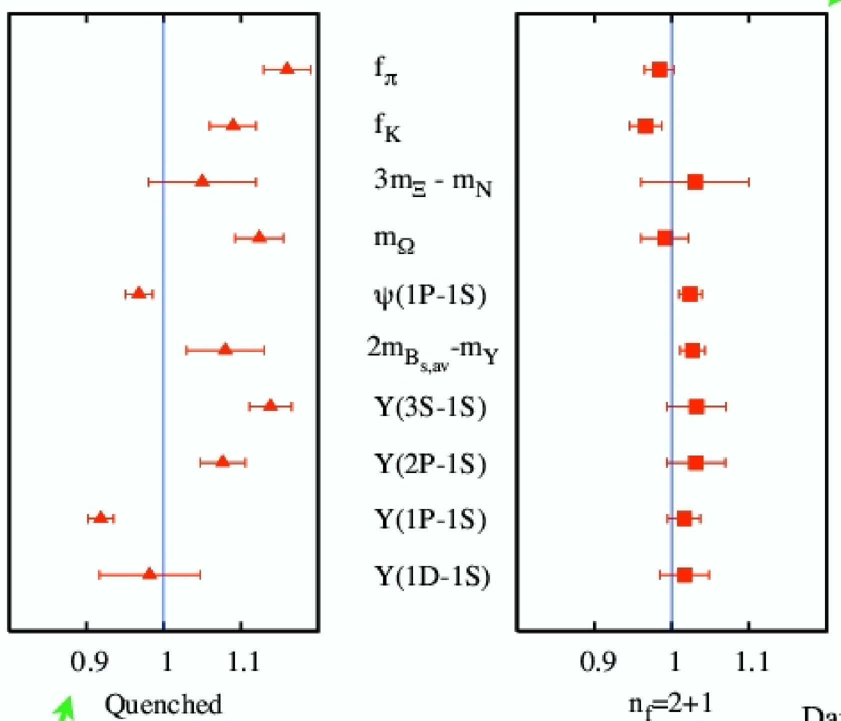
Take-home message

- There has been a revolution in lattice QCD since 2003
- Quenched approximation (ignores sea quarks) is dead - stop quoting results from it
- Lattice QCD now delivering fully unquenched results: hadron masses that agree with expt; precise parameters of QCD; matrix elements relevant to CKM physics.

Lattice QCD

C. Davies

2005 Updated summary of results



Results including u,d and s sea quarks agree with experiment *across the board* -from light to heavy hadrons. Parameters of QCD are *unambiguous*

Quenched results are both *wrong* and *ambiguous*

Davies et al, hep-lat/0304004, Aubin et al, hep-lat/0407028, Toussaint+Davies, hep-lat/0409129, Gray et al, hep-lat/0507013, Heller, this meeting, Bernard et al, LAT05

Lattice QCD

C. Davies

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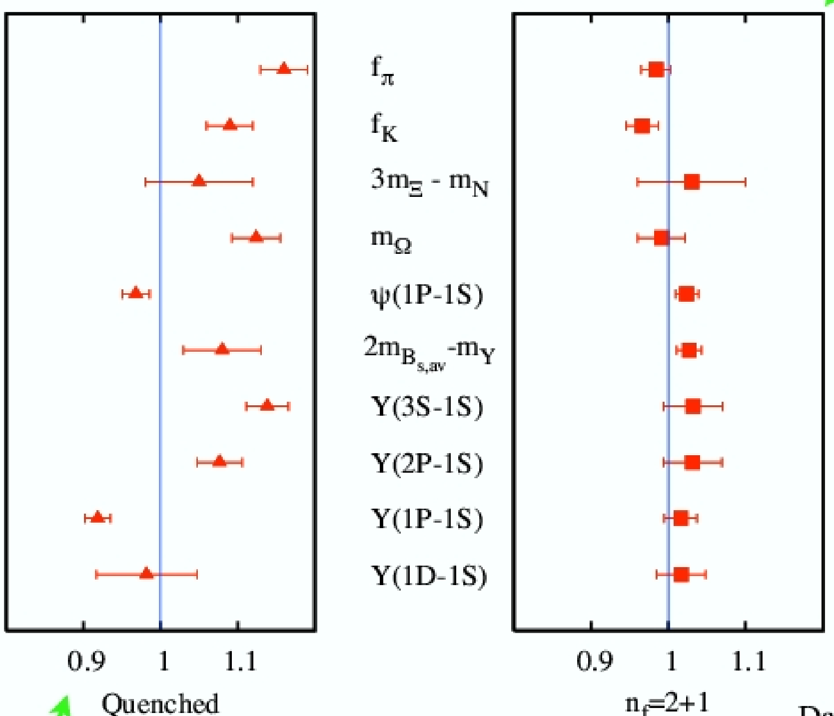

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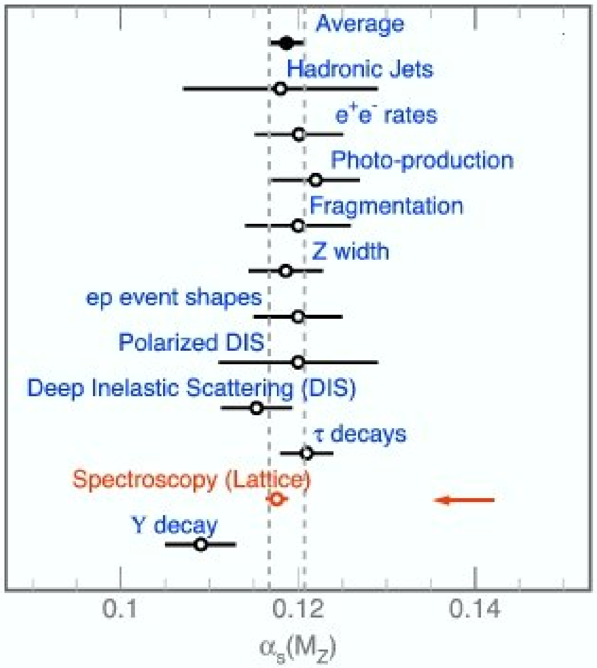
Quenched results are both *wrong* and *ambiguous*

Davies et al,
Aubin et al,
Toussaint+D
Gray et al, h
Heller, this r
LAT05

$$\alpha_{\overline{MS}}^{(5)}(M_Z) = 0.1170(12)$$

Mainly c_5 (8) and *a* (7)

2004 PDG = 0.1187(20)

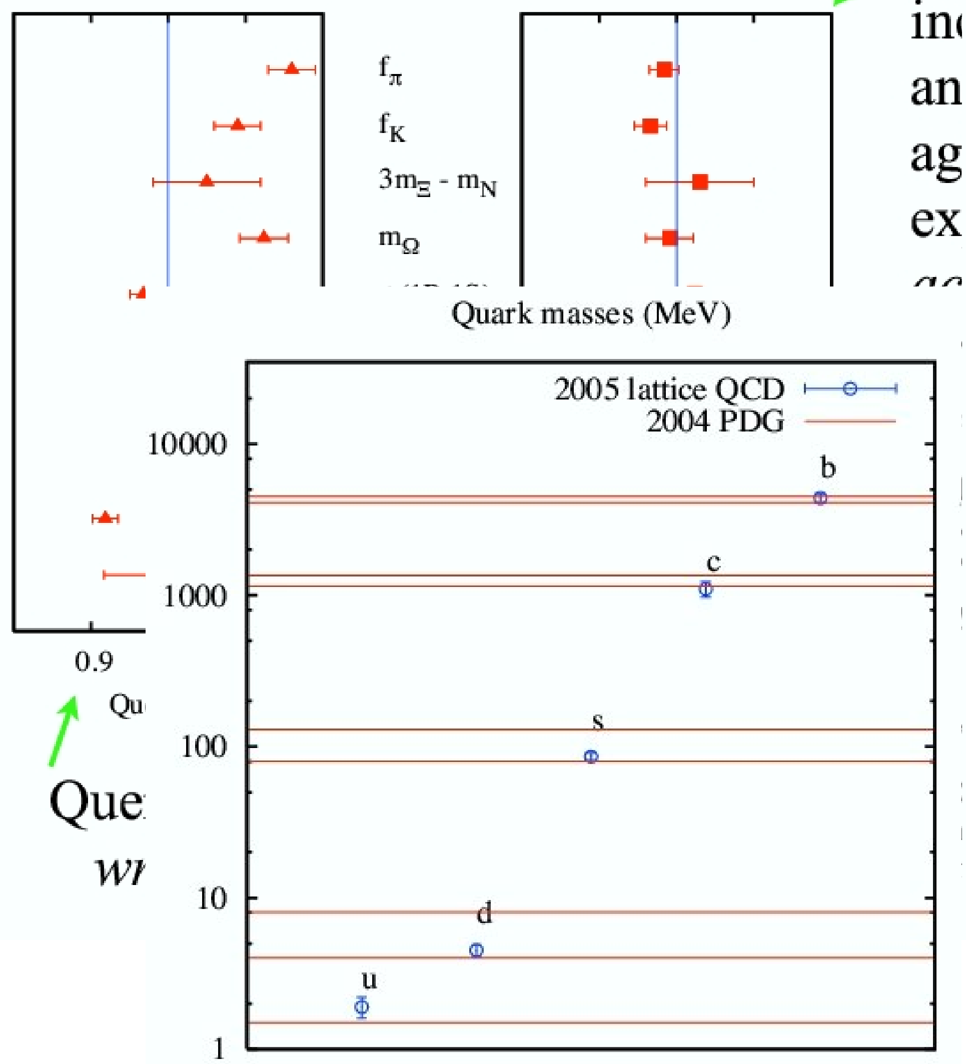


NEW

Lattice QCD

C. Davies

2005 Updated summary of results



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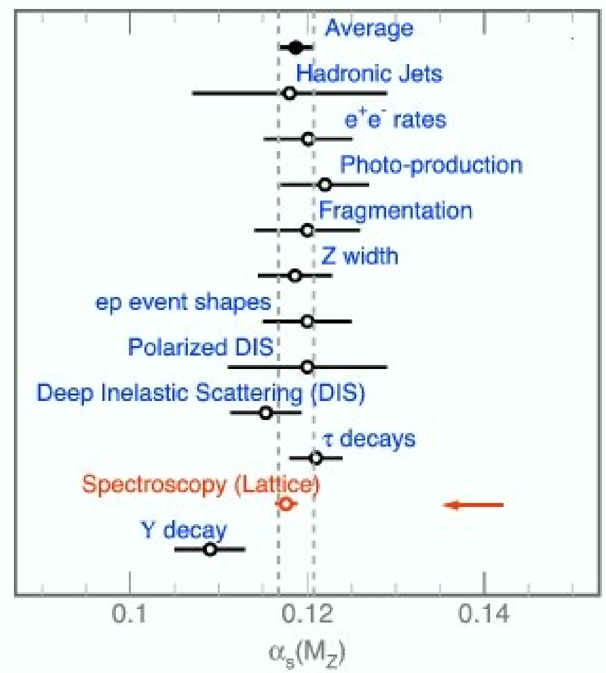
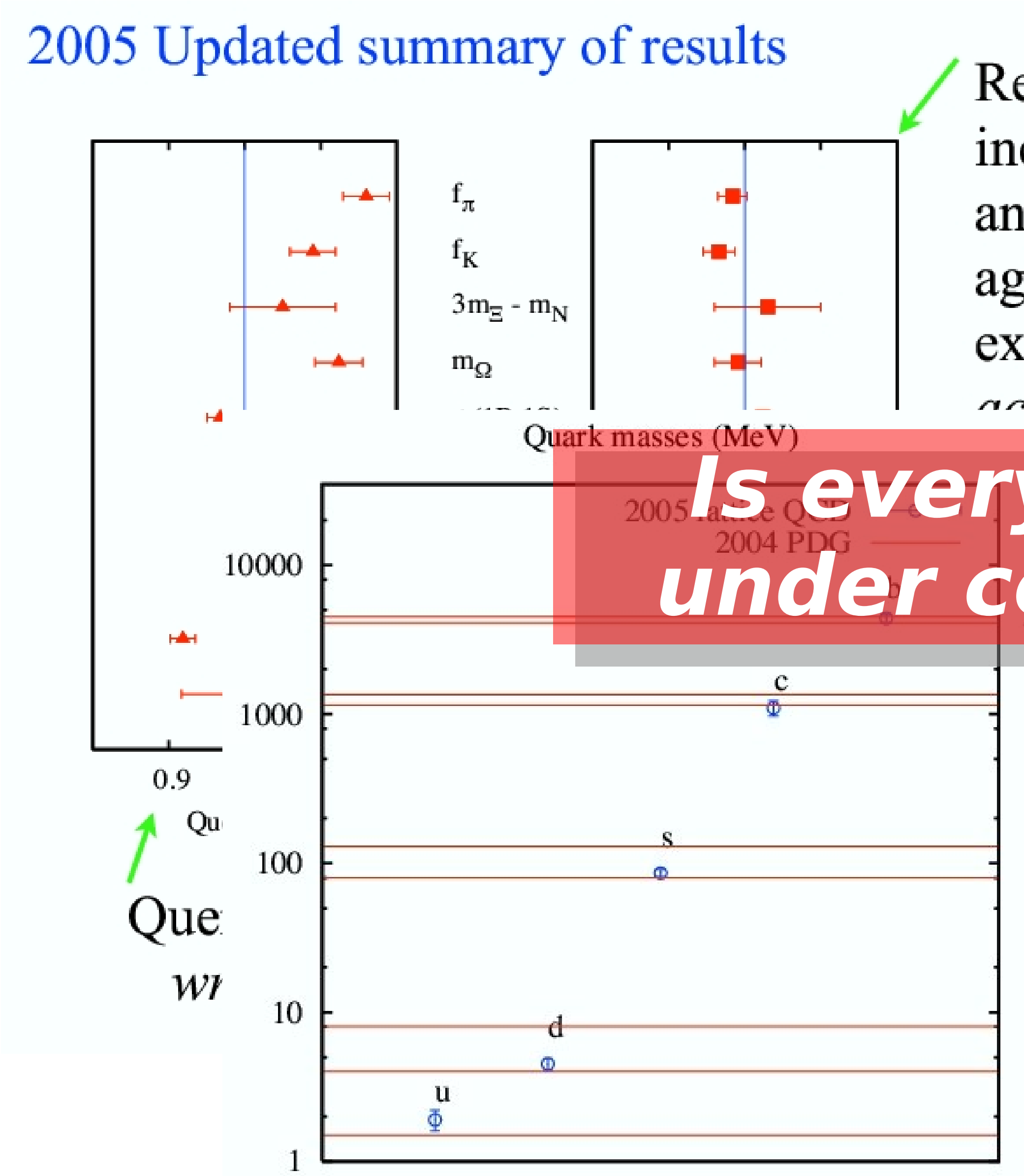


NEW

Lattice QCD

C. Davies

2005 Updated summary of results



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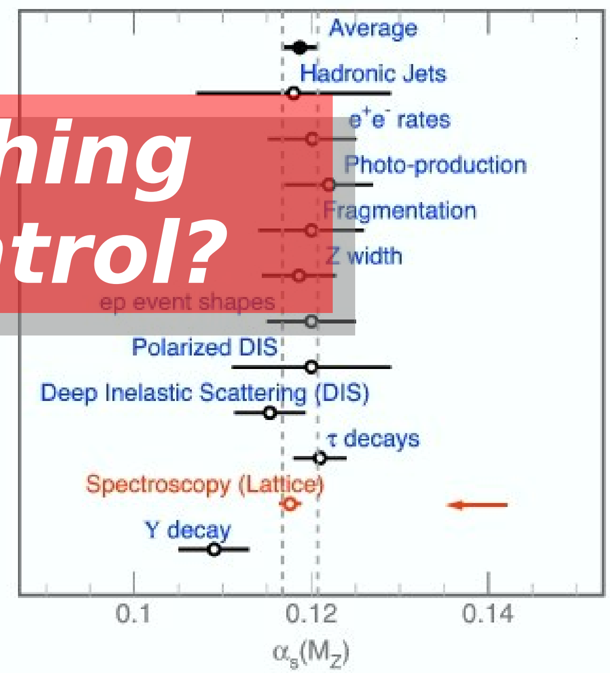


NEW

Is everything under control?

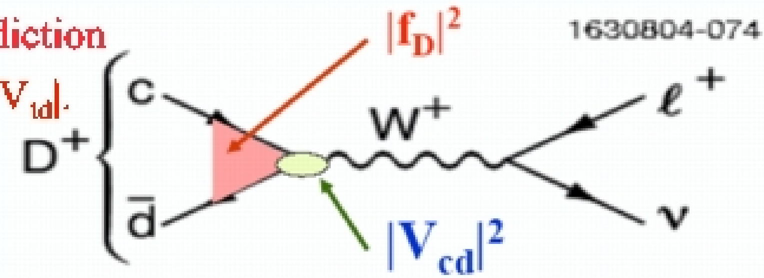
Lattice QCD

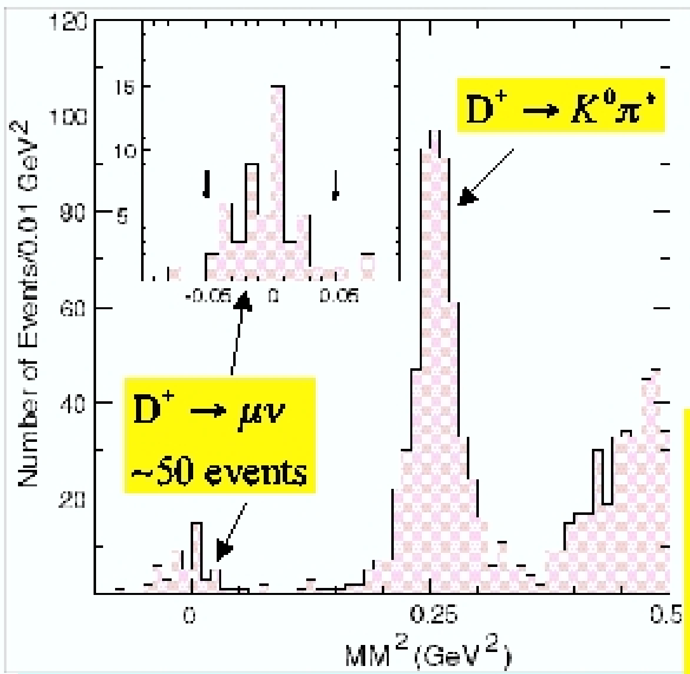
Charming News:
Testing the Lattice with CLEO-c

(Shipsey)

Test lattice f_D @ CLEO-c ➔ confidence in f_B prediction

➔ turn measurement of B^o-$\overline{B^o}$ mixing into precise $|V_{td}|$.

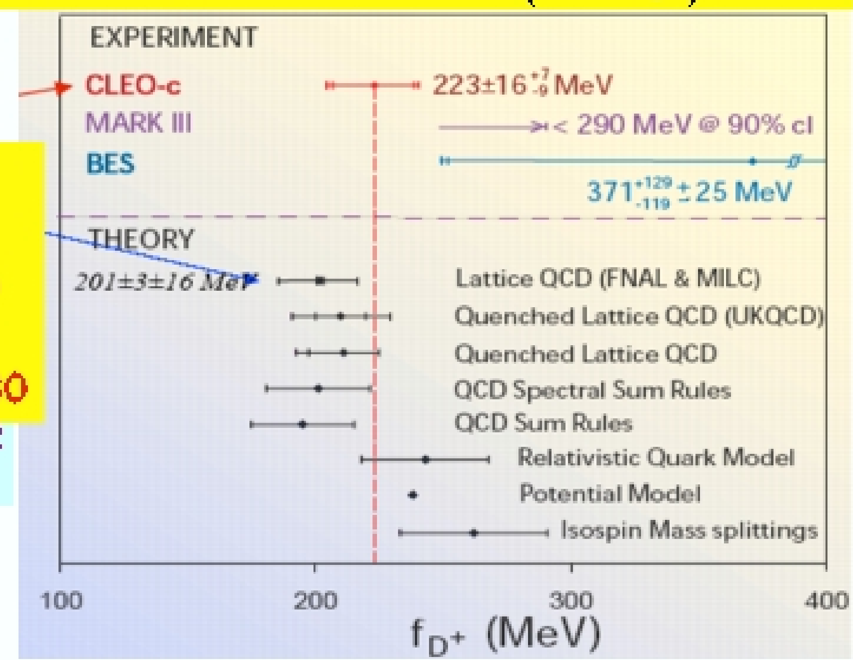




$$\Gamma(D^+ \to \ell^+\nu) = \frac{1}{8\pi} G_F^2 f_{D+}^2 m_\ell^2 M_P \left(1 - \frac{m_\ell^2}{M_P^2}\right)^2 |V_{cd}|^2$$

This work

FNAL
MILC
HPQCD
hep-lat
0506030



$$MM^2 = (E_D - E_\ell)^2 - (\vec{p}_D - \vec{p}_\ell)^2$$

1.8 million DD decays at ψ(3770)

X30 Mark III X10 BES II

Hadronic Physics
&
Exotics

Hadronic Physics

C. Quigg

Quarkonium Spectroscopy

A flood of beautiful new results

- CLEO discovery of $h_c(1^1P_1)$ in $\psi' \to \pi^0 h_c$ — Miller
  $M(h_c) = 3524.4 \pm 0.6 \pm 0.4$ MeV $\approx \langle M(1^3P_J)\rangle - 1$ MeV
- Belle $\gamma\gamma \to \eta_c, \chi_{c0}, \chi_{c2} \to h^+h^-, h^+h^-h^+h^-$ — Sokolov
  rates $\Gamma(\eta_c \to \gamma\gamma)\mathcal{B}(\eta_c \to f)$ about $1/3\times$ PDG rates
- CLEO observation of $\psi(3770) \to \pi\pi J/\psi$ — Miller
  $\mathcal{B}(\psi(3770) \to \pi^+\pi^- J/\psi) = (189 \pm 22^{+7}_{-4}) \times 10^{-5}$
  and $\Gamma(\psi(3770) \to \gamma\chi_{c1}) = 78 \pm 19$ keV
- KEDR $M(\psi') = 3686.117 \pm 0.012 \pm 0.015$ MeV — Todyshev
  $M(\psi(3770)) = 3773.5 \pm 0.9 \pm 0.6$ MeV
- Belle Observe $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S)$ — Sokolov
  38 ± 6.9 events, $\mathcal{B} = (1.1 \pm 0.2 \pm 0.4) \times 10^{-4}$
- CLEO Observe $\chi'_b(2^3P_{2,1}) \to \pi^+\pi^-\chi_b(1^3P_{2,1})$ — Duboscq
  $\Gamma \approx 0.9$ keV (first non-$^3S_1$ transition seen)

Hadronic Physics

C. Quigg

Exotic Baryons (Pentaquarks)

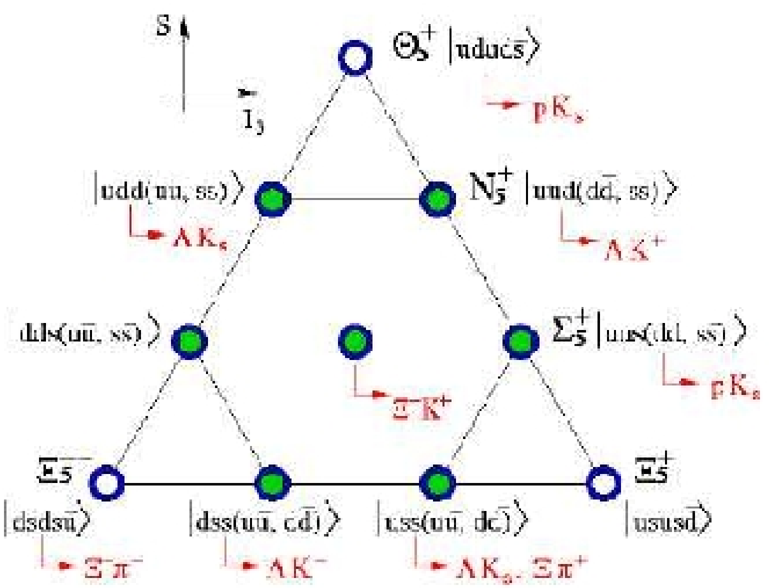
Claims for narrow exotic baryons:

$\Theta^+(\approx 1540)$: many sightings . . .

$\Theta^{++}(1530)$: STAR

$\Xi^{--,0}(1862)$: NA49

$\Theta_c^0(3099)$: H1



No claim is unchallenged!

Hard to argue that every experiment is significant, correctly interpreted.

Hadronic Physics

C. Quigg

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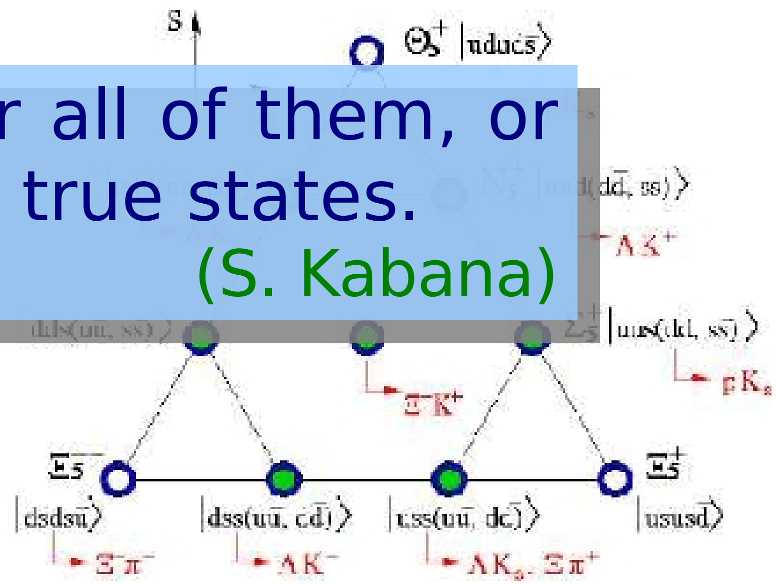


Some of them, or all of them, or none of them are true states.
(S. Kabana)

No claim is unchallenged!

Hard to argue that every experiment is significant, correctly interpreted.

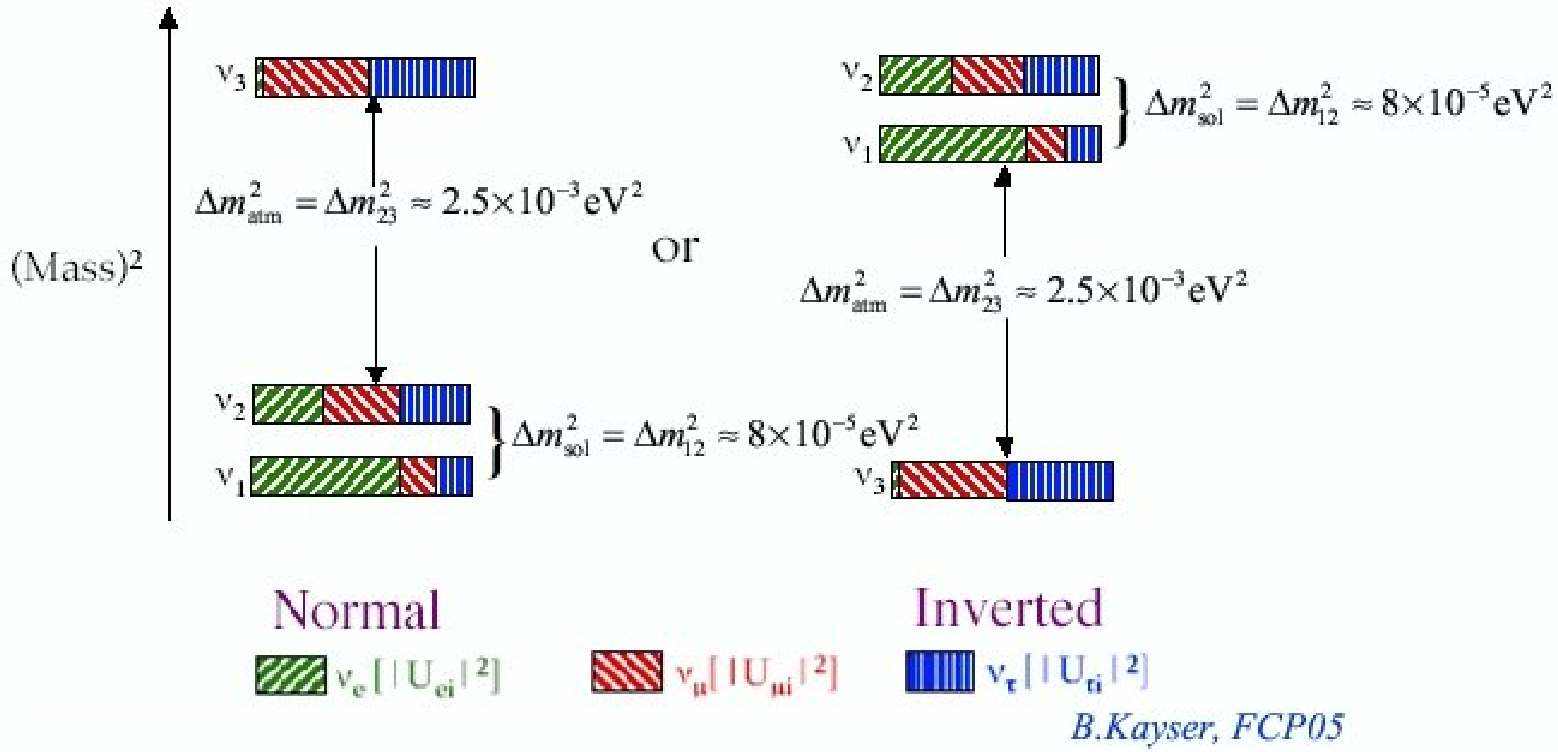
Neutrinos

Neutrinos

J. Klein

What We've Learned in Past ~ 10 years

➢ Mixing Summary



Don't know yet absolute offset for m:

$$\langle m_\beta \rangle = \sqrt{\left|\sum_{i=1}^{3} U_{ei}{}^2\, m_i\right|^2} < 2.2\,\text{eV}$$ (direct searches from tritium β-decay)

$$\sum m_i < (0.4-1.0)\,\text{eV}$$ (cosmological data+model)

Neutrinos

J. Klein

Recent Solar Sector Measurements

- SNO Phase I+II Results

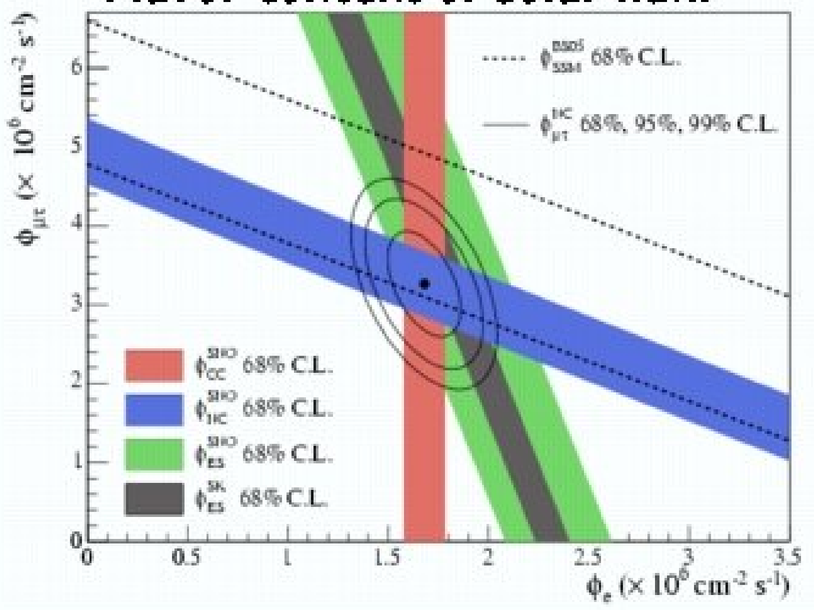
$$\Phi_{CC} = 1.68^{+0.06}_{-0.06}(stat.)^{+0.08}_{-0.09}(sys.)\times 10^6 cm^{-2}s^{-1}$$

$$\Phi_{ES} = 2.35^{+0.22}_{-0.22}(stat.)^{+0.15}_{-0.15}(sys.)\times 10^6 cm^{-2}s^{-1}$$

$$\Phi_{NC} = 4.94^{+0.21}_{-0.21}(stat.)^{+0.38}_{-0.34}(sys.)\times 10^6 cm^{-2}s^{-1}$$

$$\Phi_{BP04} = 5.82 \pm 1.34\times 10^6 cm^{-2}s^{-1}$$

Flavor content of solar flux.



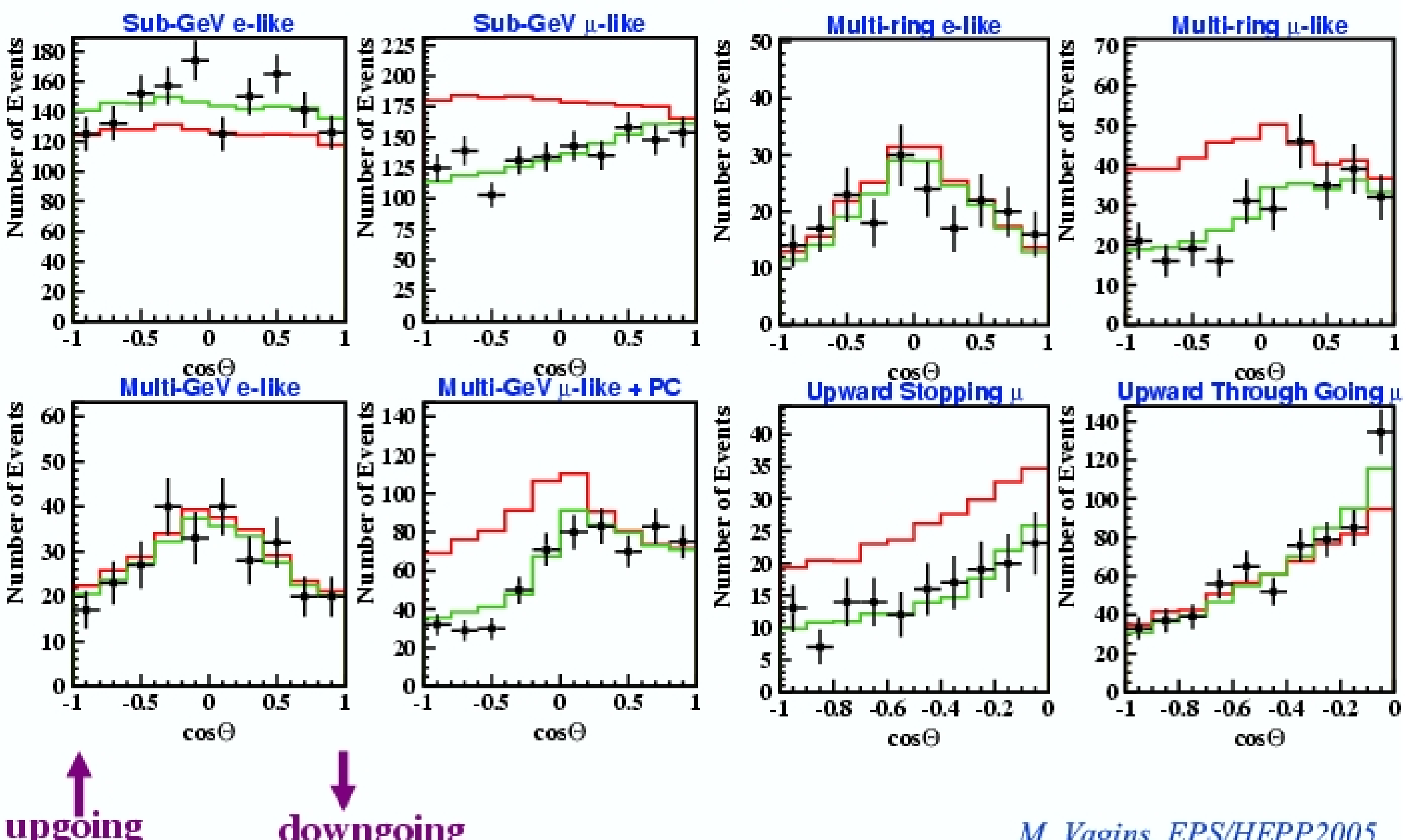
Neutrinos

J. Klein

Recent Atmospheric Sector Measurements

➢Zenith angle distributions showing ν_μ disappearance

SK-II   S-K II: 627 live-days   SK-II



M. Vagins, EPS/HEPP2005

Neutrinos

F. Sánchez

$0\nu\ 2\beta$ decay

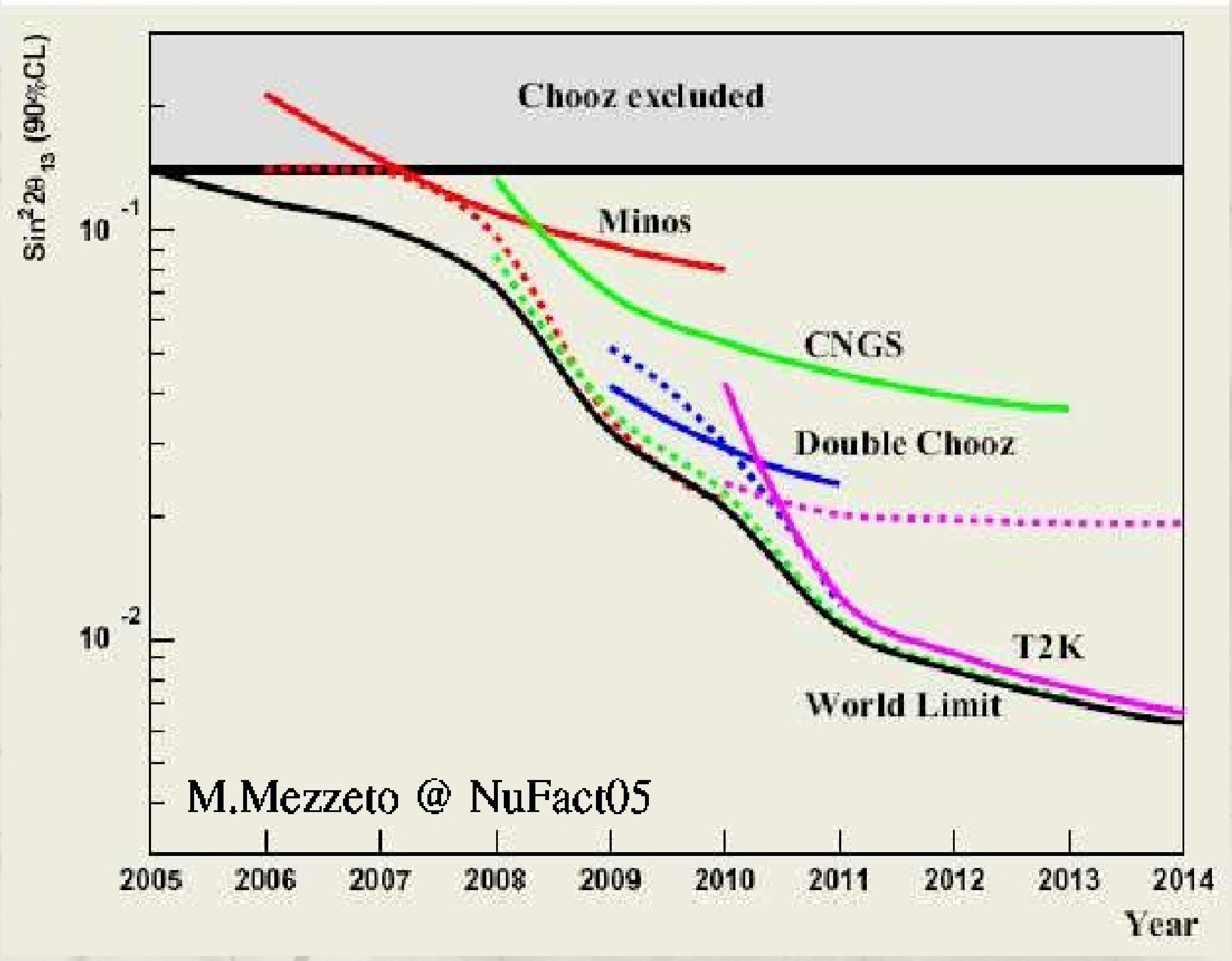
Experiment	Mass(Kg y)	Isotopes	Sensitivity (eV)	Technique
NEMO3	(6,9) (0,9) (0,04)	^{100}Mo, ^{82}Se, ^{150}Nd,...	0,7-1,2	Tracking
Cuoricino	40	^{130}Te	0,3-1,6	Bolometers
Gerda	100	^{76}Ge	0,09-0,29	Calorimeters
Cuore	740	^{130}Te	0,02-0,09	Bolometers
MOON	5000	^{100}Mo	0,02	Scint Tracking
Majorana	5000	^{76}Ge	0,04	Calorimeters
EXO	5000	^{136}Xe	0,05-0,07	Tag final $^{136}Ba^{+}$

and many others: CARVEL(^{48}Ca), CAMEO(^{116}Cd), CANDLES(^{48}Ca), COBRA(^{116}Cd&^{130}Te), DCBA(^{150}Nd),...

Neutrinos

F. Sánchez

Prospects: θ_{13} sensitivity



Approved experiments

F.Sánchez (UAB/IFAE), EPS Conference, Lisboa July 2005.

Astroparticles, Cosmology & Dark Matter

Cosmology

Can we talk about a Cosmological SM?

G. Veneziano

Too many questions are still left unanswered:

- What makes that dark 95% of the Universe?
- What is the source of inflation ?
- What fixes the initial conditions that force the Universe to inflate?
- How do we put together cosmology and particle physics, gauge and gravitational interactions?
- Etc. etc.

If we did have a CSM the field would be as theory driven as HEP, see LHC program...

Cosmology

G. Veneziano

A long (& incomplete) theorist's shopping list

- Cosmological singularity & time arrow
- Primordial perturbations & transplanckian problem
- Initial conditions
- Unconventional cosmologies & perturbations
- Fundamental strings as cosmic strings?
- Reheating
- Baryogenesis
- Dark matter
- Dark energy

Cosmology

G. Veneziano

Will more data pin down a CSM?

1. Dark matter searches (UKDMC, HDMS, ...)
2. Acceleration from Supernovae (SNAP) and CMB
3. UHECR (AUGER, ..)
4. Non-gaussianity, isocurvature in CMB (WMAP, PLANCK)
5. CMB polarization (B-mode at PLANCK?)
6. 2D and 3D Galaxy surveys and LSS (SDSS, ...)
7. Sunyaev-Zel'dovich effect
8. GW bkgnd (Pulsar timing, LIGO, VIRGO, LISA,..)

……

They will certainly help!

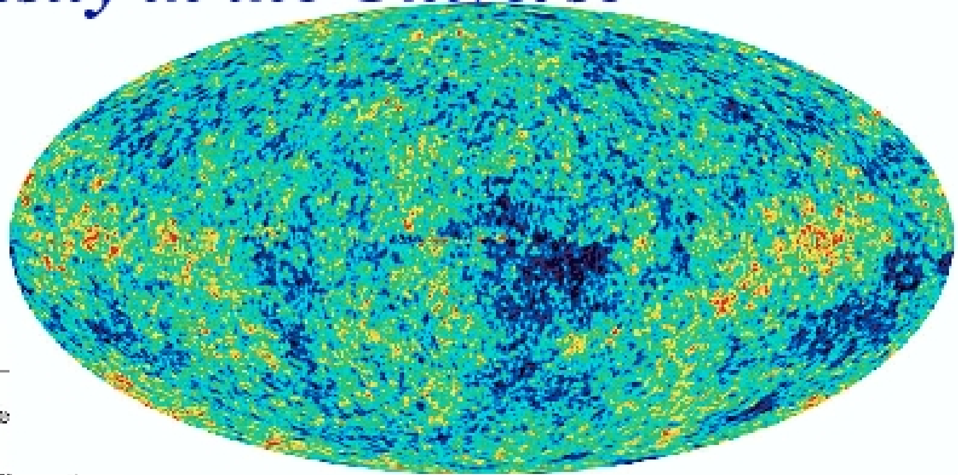
Cosmology

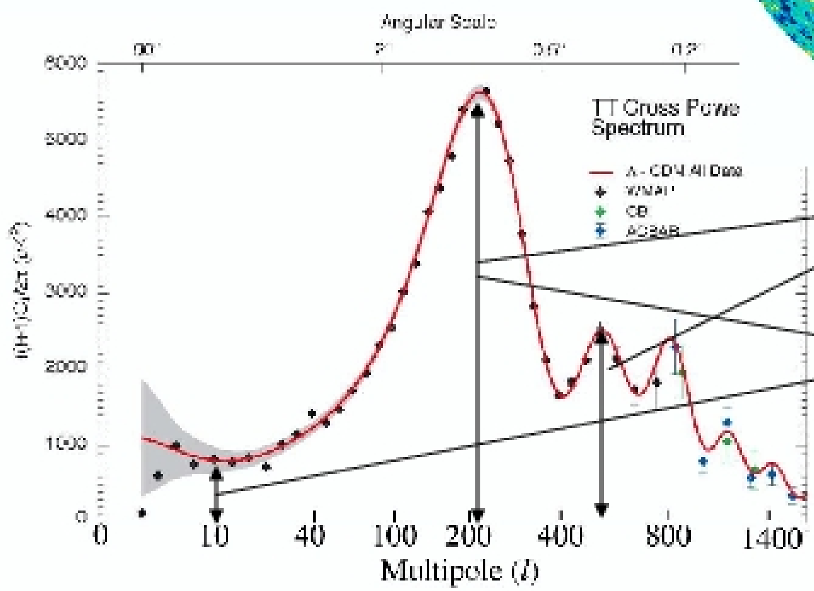
A. Bettini

The matter density in the Universe

WMAP (and others) data on CMB

At t=372 000 y cold dark matter shaped the primordial density fluctuations through gravitational potential





$\Omega_b h^2$ mainly from 2nd/1st peaks heights

$\Omega_m h^2$ from 1st peak height + other peaks positions + LSS + other data = 0.0224±0.0009

$\mathbf{\Omega_m=0.27\pm0.04}$
$\mathbf{\Omega_b=0.044\pm0.004}$

At t = **few seconds.** D$_2$ **nucleosynthesis** $\Rightarrow h^2\Omega_b$**=0.020±0.002**

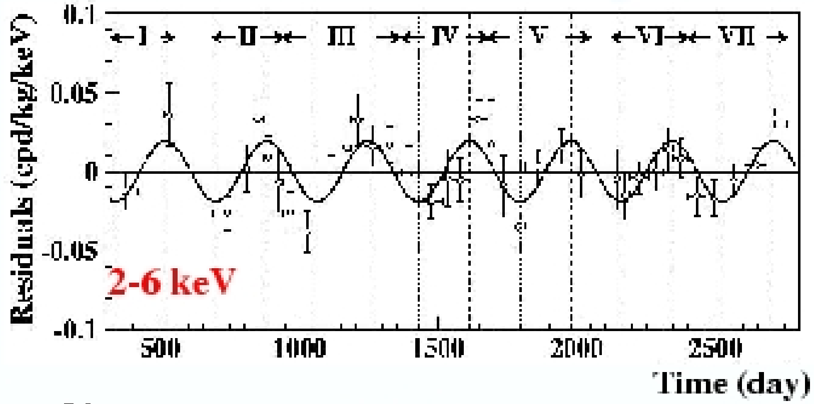
At later epochs from galaxy cluster kinematics, X-ray gases, lensing$\Rightarrow$ $\mathbf{\Omega_m \approx 0.30}$

Largest fraction of the mass is non baryonic and dark

Dark Matter

A. Bettini

DAMA. A first WIMP candidate



Fitting three parameters:

A = (0.0200 ± 0.0032) dru

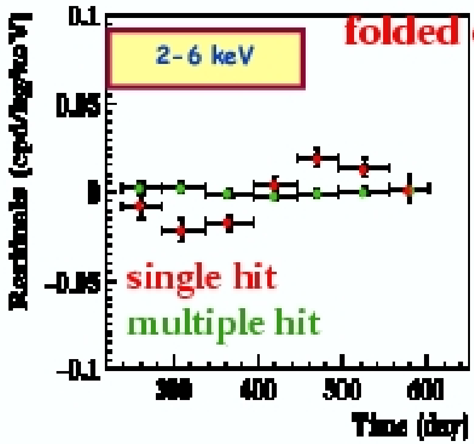
t_0 = (140 ± 22) d

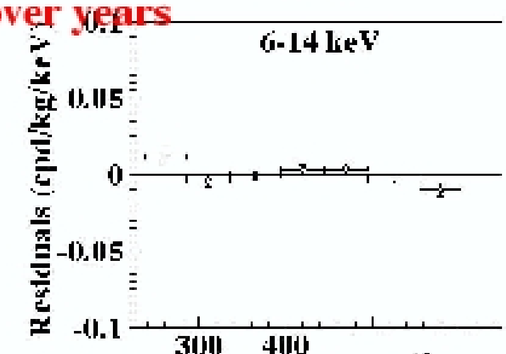
T = (1.00 ± 0.01) y

Statistical significance 6.3 σ

6 signal characteristics satisfied

Model independent evidence





Control of possible modulation fakes from *T*, Rn, noise, energy scale, efficiency, backgrounds, μ flux modulation

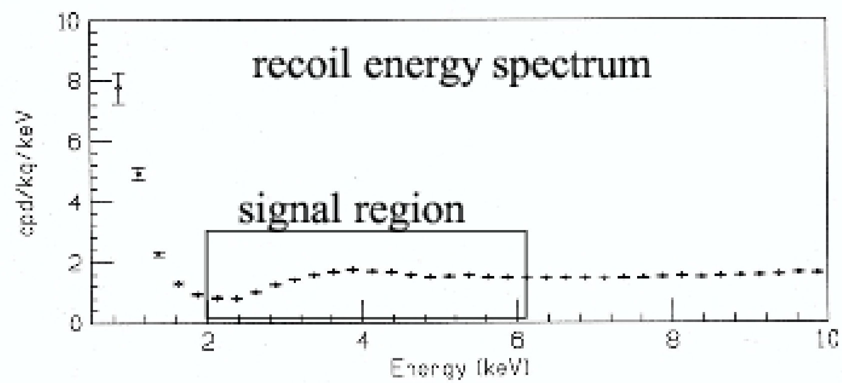
⇒ all shown to be <1%

Rate in the signal region 1-1.5 dru = time averag

signal (S_0) + background (b)

$A/S_0 = 0.02 \approx 5\% \Rightarrow S_0 \approx 0.4$ dru

$\Rightarrow b \approx 0.6$ **dru**

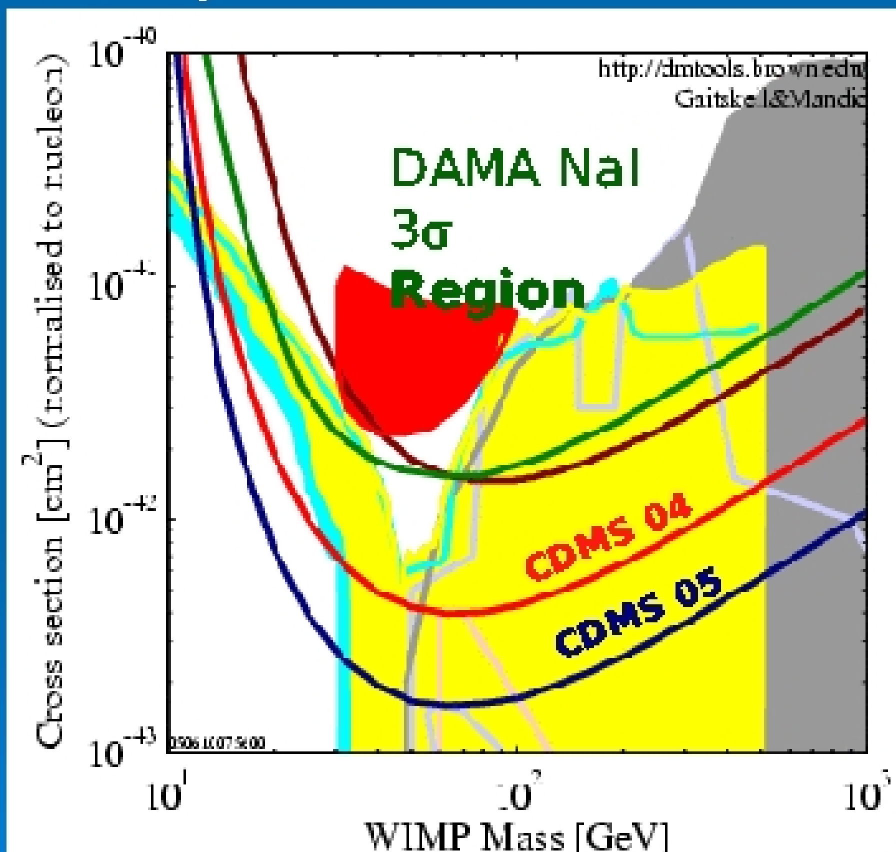


Dark Matter

L. Baudis

Resulting Experimental Upper Limits

90% CL upper limits assuming standard halo
A^2 scaling



Upper limits on the WIMP-nucleon cross sections:

4×10^{-43} cm^2 for 60 GeV/c^2 WIMPs
Phys. Rev. Lett. 93, 211301, (2004)

1.7×10^{-43} cm^2 for 60 GeV/c^2 WIMPs
Combined limit from 2 runs

Excludes large regions of SUSY parameter space under some frameworks

Predictions: Ellis & Olive, Baltz & Gondolo, Mandic & all

Cosmic Rays

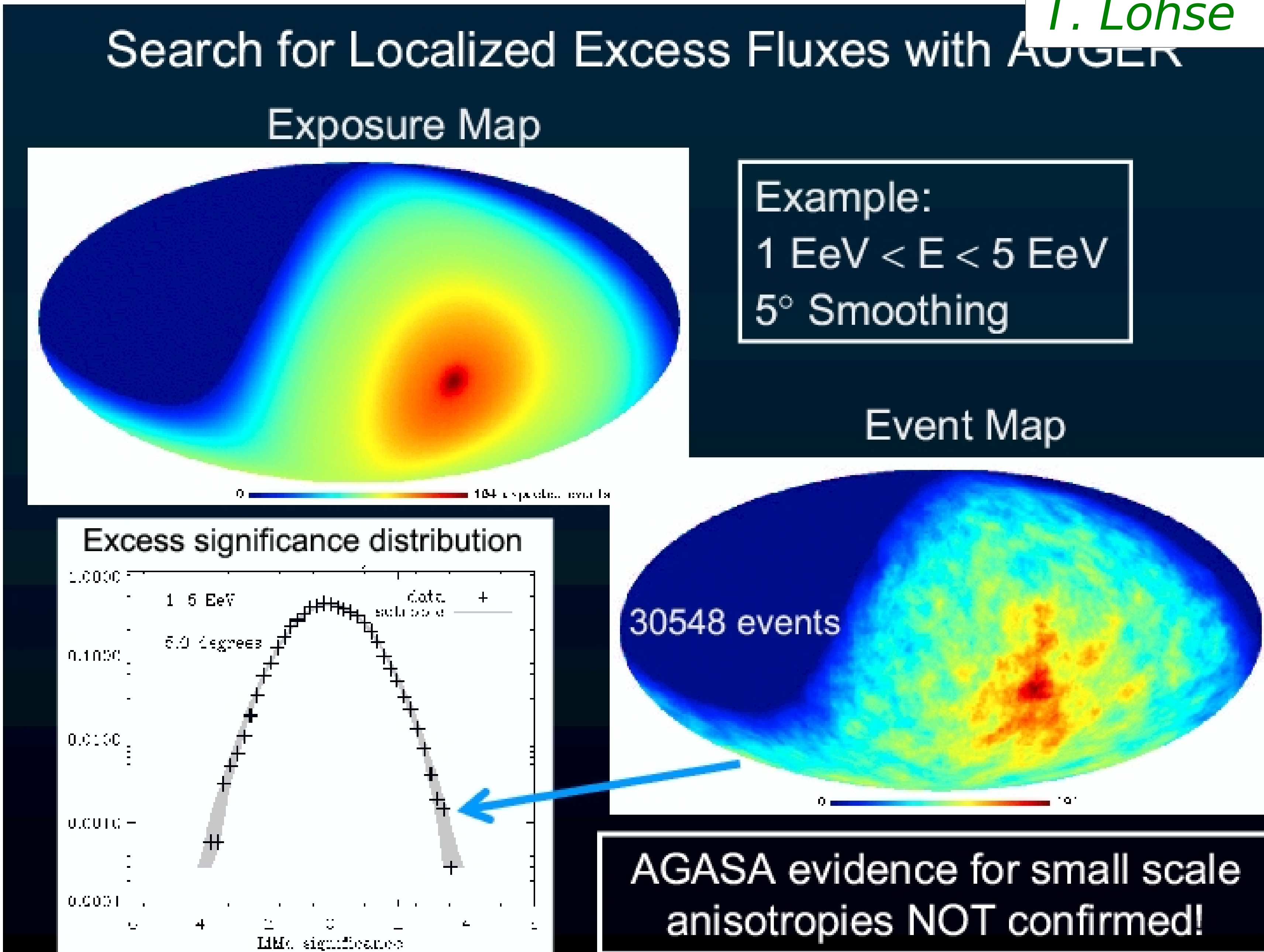
T. Lohse

Summary

- Cosmic ray puzzle persists…but is under pressure by massive attack from EAS-arrays, ν- and γ-telescopes
- Progress in understanding knee, ankle and GZK-region AUGER data disfavour small scale anisotropies
- Cosmic ν-detection in multi-messenger campaigns? Neutrino astronomy might start sooner than expected!
- Major break-through in TeV-γ-astronomy
  - supernova shells are $\geq$ 100 TeV accelerators
  - large population of extended galactic TeV sources discovered
  - first microquasar-candidate established as $\geq$TeV accelerator
  - diffuse galactic TeV emission (Milagro water Č-telescope)
  - TeV-γ from Active Galactic Nuclei at large red-shifts, …

Cosmic Rays

T. Lohse



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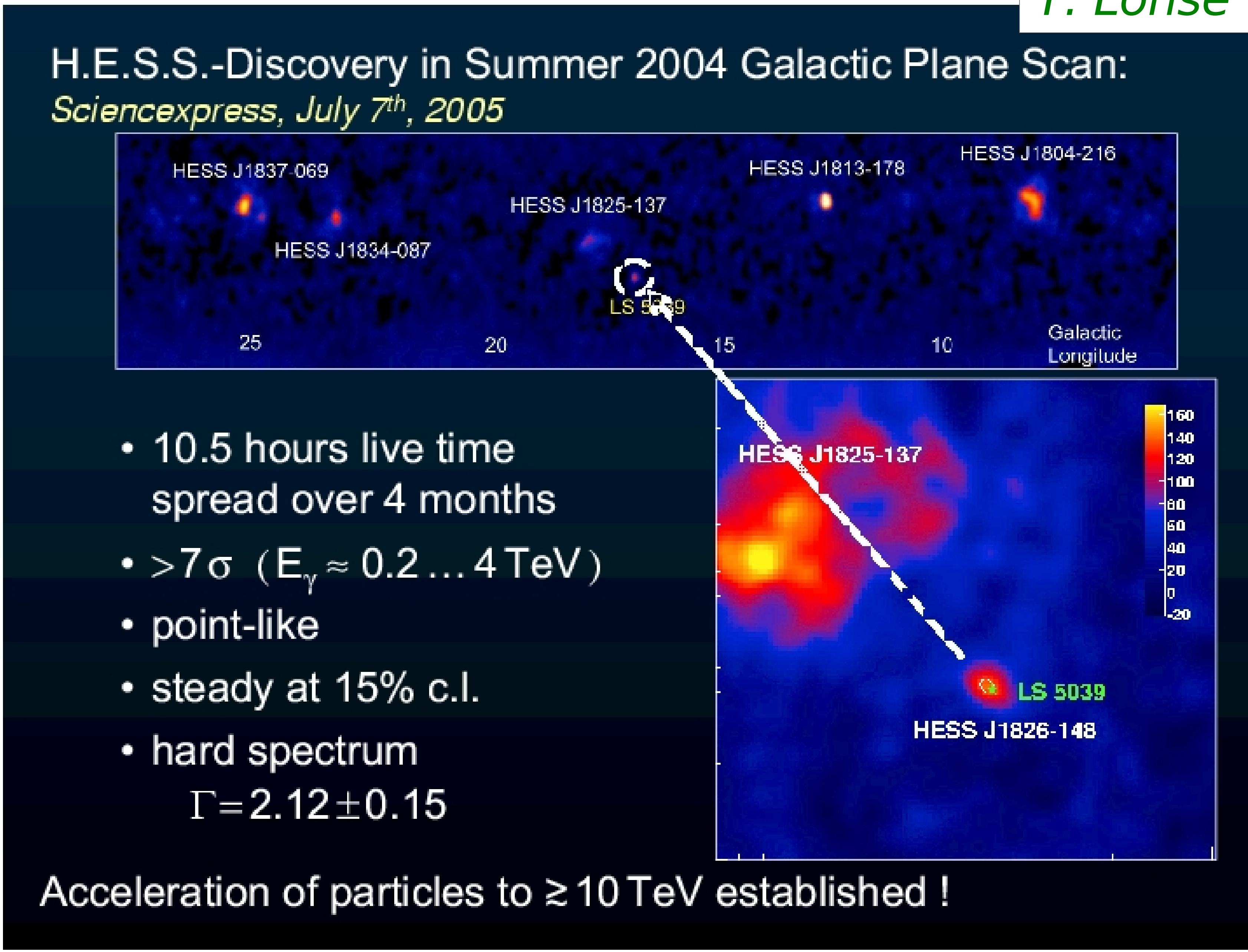

String Theory
&
Extra Dimensions

String Theory

Y. Oz

Candidate: String (M) Theory

String Theory

Y. Oz

Strings: Status Report

- String theory is a consistent theory of quantum gravity.
- String theory incorporates the standard model.
- String theory has not explained yet neither the big-bang singularity, nor the particular structure of the standard model.

String Theory

Y. Oz

Experimental Signatures

- Supersymmetry and the mechanism of supersymmetry breaking
- Detection of string scalar fields
- Magnetic monopoles
- Strings in the sky
- Extra dimensions
- Low scale quantum gravity

BSM Physics

R. Rattazzi

- Recent advances is string theory indicate that the many vacua hypothesis (The Landscape) may indeed be realized in Nature

Bousso,Polchinski '00
Giddings,Kachru,Polchinski '01
Kachru,Kallosh,Linde,Trivedi '03
Susskind '03
Douglas '03

- The anthropic viewpoint has also been applied to the electroweak hierarchy problem

Split SUSY ← { Agrawal,Barr,Donoghue,Seckel '97; Arkani-Hamed,Dimopoulos '04; Giudice,Romanino '04 }

↓

squarks and sleptons = superheavy

gauginos and higgsinos ~ weak scale (to provide DM and unification)

distinctive gluino phenomenology

Extra Dimensions

Ch. Grojean

Standard Scenari of EWSB

- Weakly Coupled Theories
  - (MS)SM
  - Little Higgs, i.e. Higgs as a Pseudo-Goldstone boson
- Strongly Coupled Theories
  - (extended, walking, top-color assisted) Technicolor

Since the blooming of extra-dimensions: two new approaches

- Higgs = component of gauge field in extra-dimensions
- Symmetry breaking by boundary conditions, a.k.a. Higgsless

$$m^2 = E^2 - \vec{p}_3^{\,2} - \vec{p}_\perp^{\,2}$$

a momentum along the extra dimension is equivalent to a 4D mass

Where do we go next?

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