Theoretical Physics
at the
University of Liverpool




10 Permanent Staff
1 Retired Staff
1 Research Associate
14 PhD Students



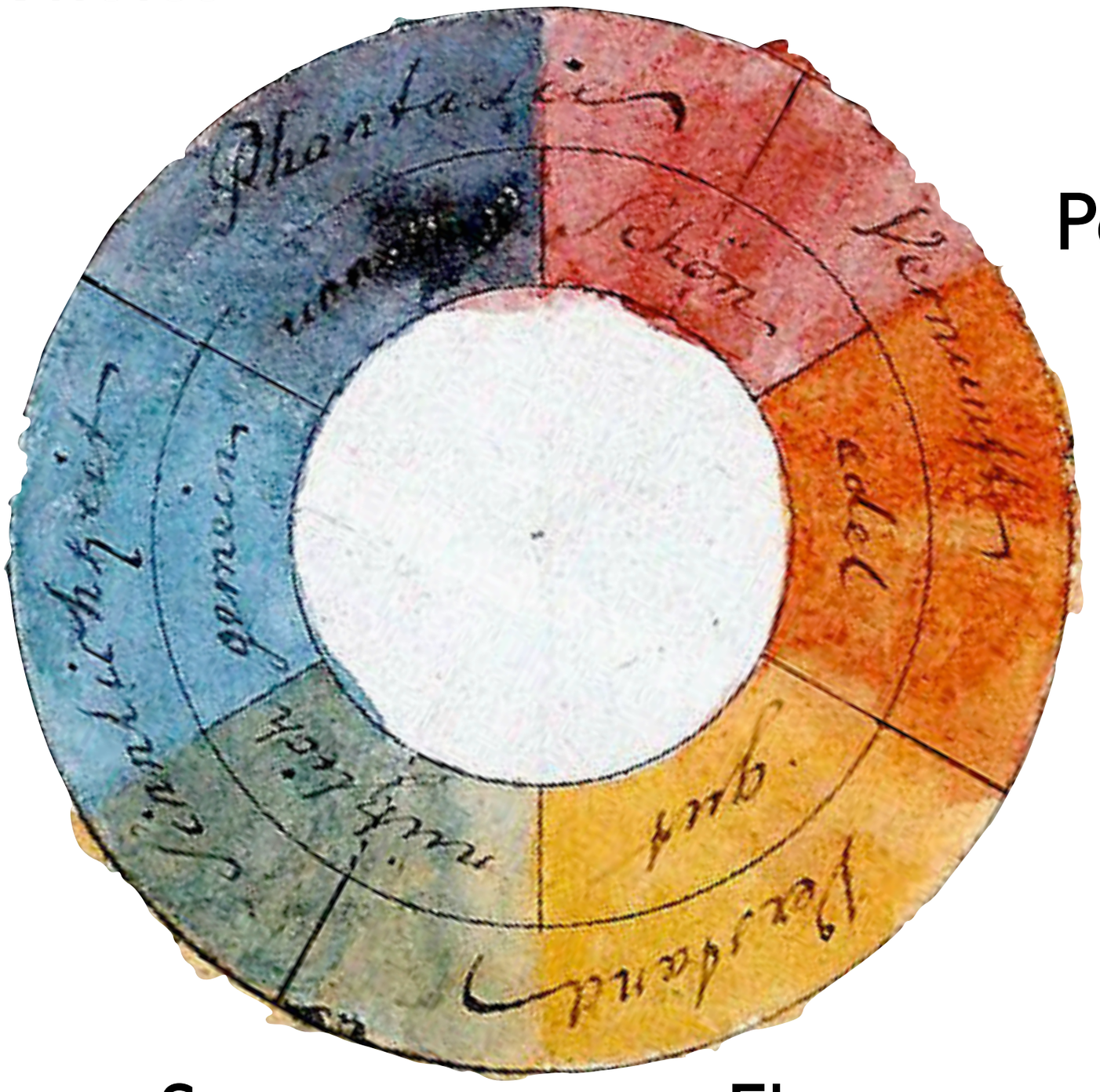


Lattice QCD

Black holes

Perturbative QCD

Unification



Dualities & F-Theory

Flavour physics

Super-symmetry

Electroweak interactions

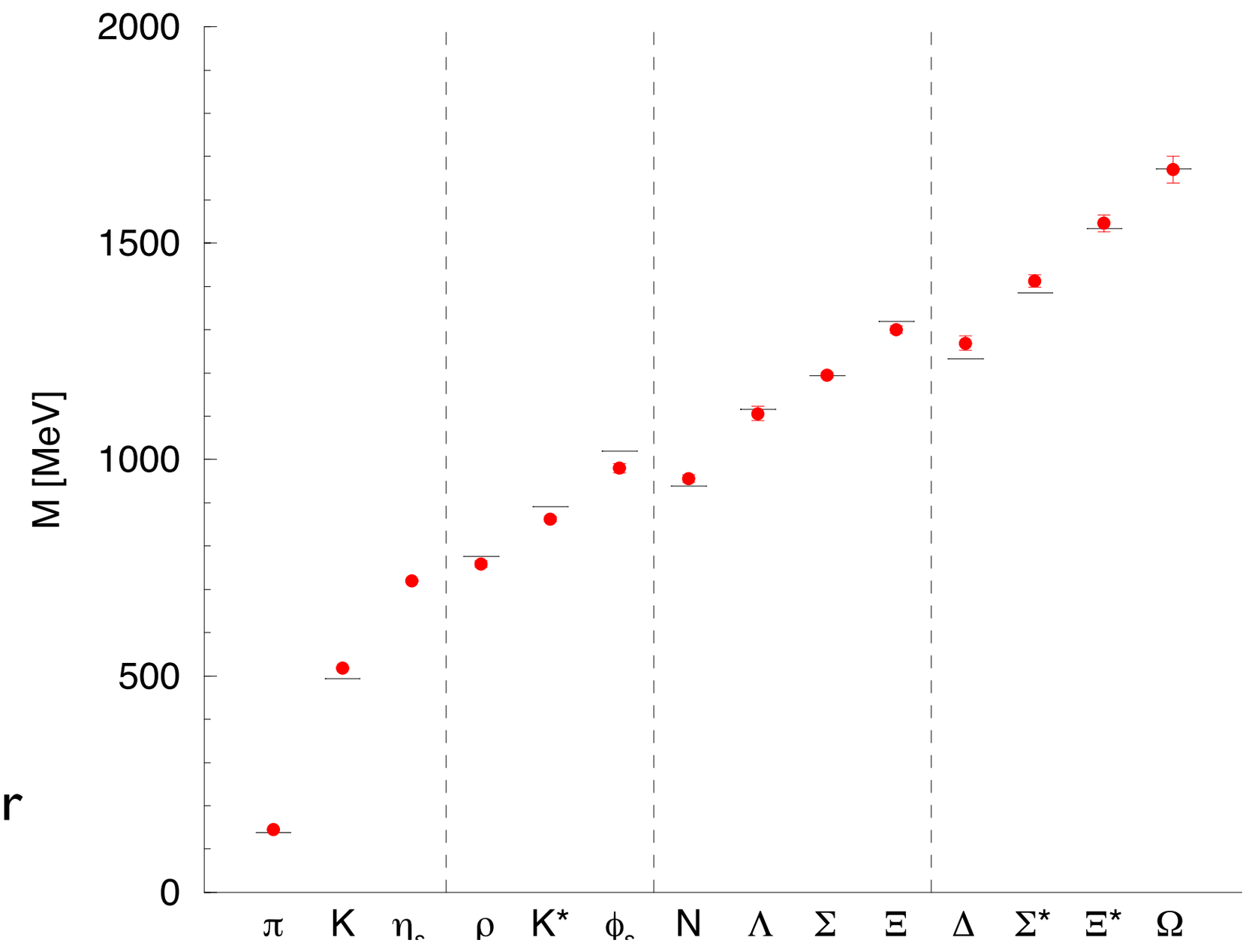
Lattice QCD – Paul Rakow

Solve Quantum Chromodynamics (QCD) on the lattice

QCD with up, down and strange quarks. Strange quark mass breaks $SU_F(3)$ symmetry.

Calculated masses depend on the $SU_F(3)$ breaking and agree with experimental data

Other sources of $SU_F(3)$ breaking, e.g. QED corrections are under investigation



Chris Michael


Chris Michael

Paul, hi

If you are writing a 1 page summary for Martin to use on Wed:
feel free to add a line mentioning:

Chris Michael is retired but still working with a European Lattice Collaboration

Recent activity (to appear in PRL):

\eta and \eta {\prime} mixing from lattice QCD
C. Michael, K. Ottnad, and C. Urbach
Accepted Thursday Oct 3, 2013

Perturbative QCD

Not all QCD can be solved on the Lattice –

the number of lattice points fixes the UV/IR which can be resolved

→ QCD multi-loop calculation

- Relate renormalisation scheme on the lattice to the continuum

John Gracy

- Confinement for the Gluonpropagator

- Higher-order QCD corrections for parton evolution and hard processes

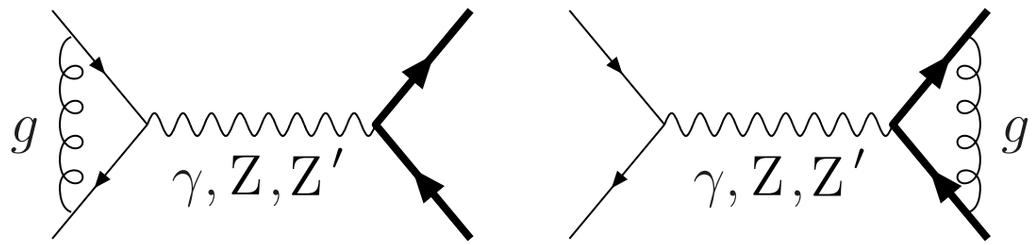
Andreas Vogt

- High-energy ("small-x") resummations of the perturbation series

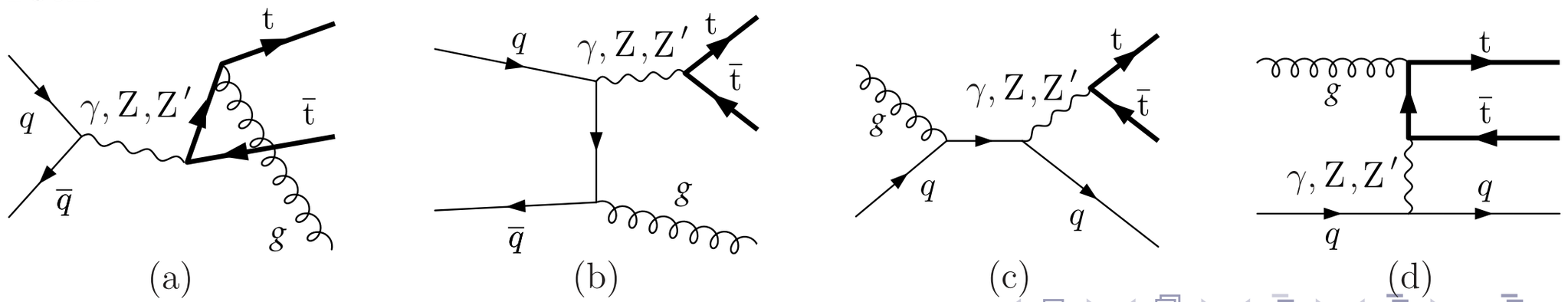
NLO QCD top-pair production in Shower Monte Carlos beyond SM

Tomas Jezo

- top-quark related observables likely sensitive to new physics
  - mass at the scale of EWSB ($m_t = 173.2 \pm 0.9$ GeV)
- new weakly coupled neutral gauge bosons enter s-channel top-pair production
- $\hat{\sigma}^{\mathrm{NLO}} = \hat{\sigma}(\alpha_S^2) + \hat{\sigma}(\alpha_W^2) + \hat{\sigma}(\alpha_S^3) + \hat{\sigma}(\alpha_S^2\alpha_W) + \hat{\sigma}(\alpha_S\alpha_W^2) + \hat{\sigma}(\alpha_W^3)$
  - $\hat{\sigma}(\alpha_S^3)$ not affected by the presence of Z′
  - $\hat{\sigma}(\alpha_S\alpha_W^2)$ most important contribution due to resonant role of Z′
- assuming flavour-diagonal Z′ couplings, $\hat{\sigma}(\alpha_S\alpha_W^2)$:
  - virtual:

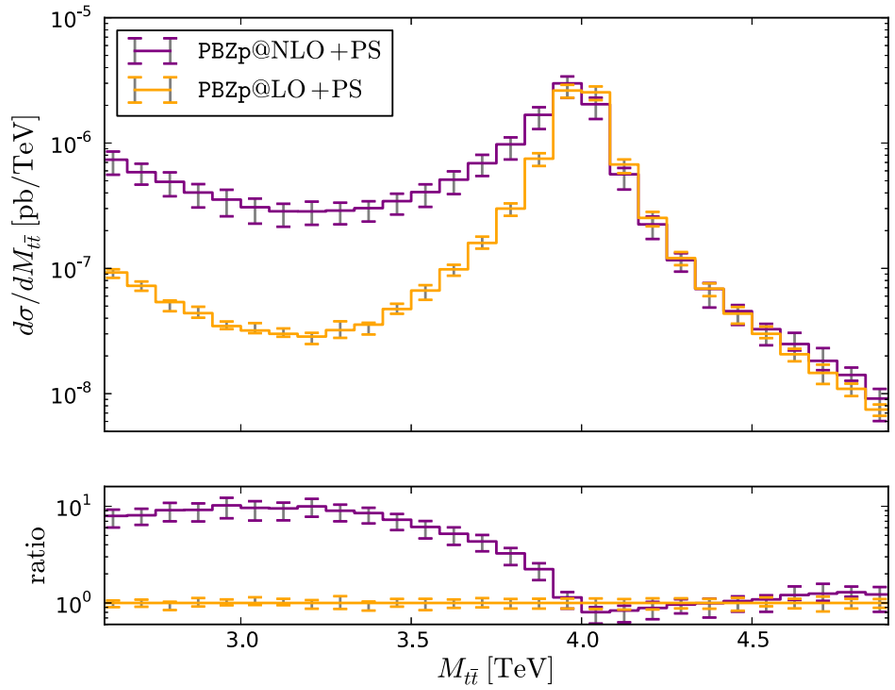


  - real:



NLO QCD top-pair production in Shower Monte Carlos beyond SM

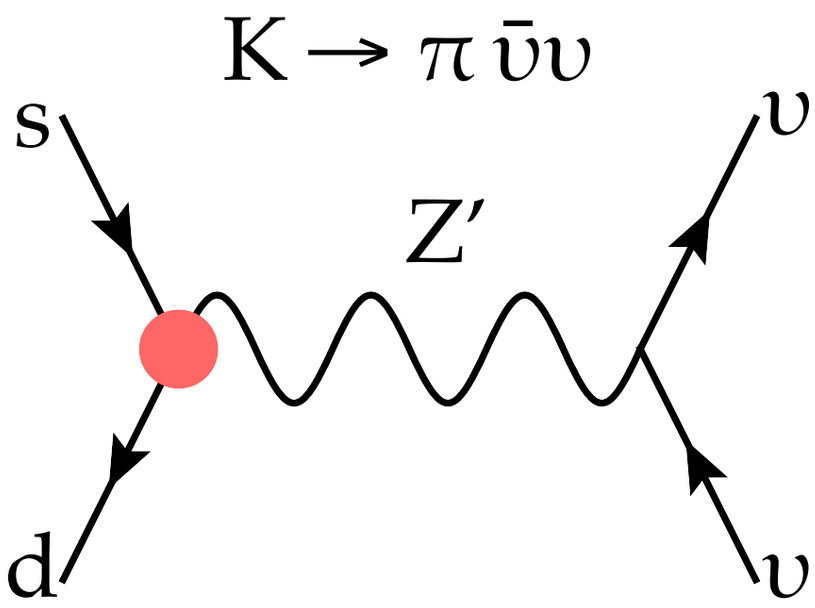
- we calculate corrections at $\mathcal{O}(\alpha_S \alpha_W^2)$
- develop an implementation in POWHEG-BOX Monte Carlo Event Generator Framework
  - treatment of IR QCD and QED singularities automatic
  - allows for consistent matching of NLO QCD calculation with the Parton Shower



Flavour Physics

- Flavour changing neutral current processes are highly suppressed in the Standard Model of particle physics

- $BR_{th}(K^+ \to \pi^+ \bar{\upsilon}\upsilon) = 8.2\ 10^{-11}$ & $BR_{th}(B_s \to \mu^+ \mu^-) = 3.7\ 10^{-9}$



$K^+ \propto |g_{sdZ'}|^2 (M_{Z'})^{-4}$

$K_L \propto (\mathrm{Im}\ g_{sdZ'})^2 (M_{Z'})^{-4}$

- using NNLO QCD and 2-loop EW the theory uncertainty is now at the 3% level

- $K^+ \to \pi^+ \bar{u}u$ would be sensitive to Z' of O(100 TeV) at tree level

- Generic formula for one-loop Z', W' interactions derived

- $K^+ \to \pi^+$ XX sets bounds on decays to new light neutral particles

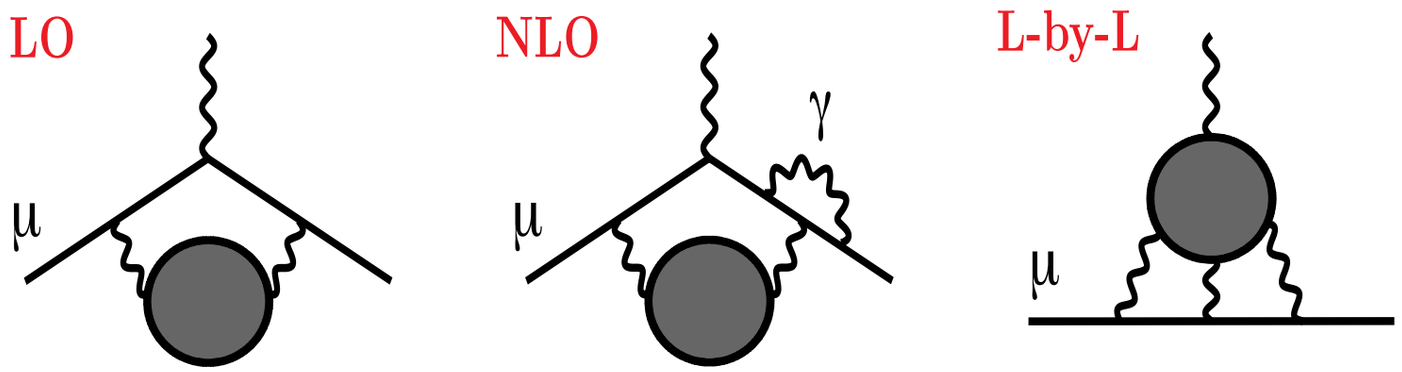
g-2: SM prediction

Thomas Teubner

$$a_\mu = a_\mu^{\mathrm{QED}} + a_\mu^{\mathrm{EW}} + a_\mu^{\mathrm{hadronic}} + a_\mu^{\mathrm{NP?}}$$

- QED: Kinoshita et al. 2012: 5-loop completed (12672 diagrams) ✓
- EW: 2-loop (got even better as Higgs mass now known) ✓
- Hadronic: the limiting factor of the SM prediction ✗

$$a_\mu^{\mathrm{had}} = a_\mu^{\mathrm{had,VP\ LO}} + a_\mu^{\mathrm{had,VP\ NLO}} + a_\mu^{\mathrm{had,Light-by-Light}}$$



L-by-L: - so far use of model calculations, pion form-factor data will help improving
- for the future: lattice QCD predictions

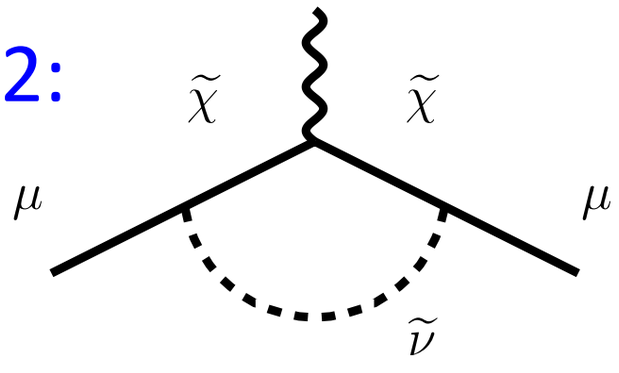
HVP: - precise prediction by using dispersion integral + e^+e^- hadronic cross section data

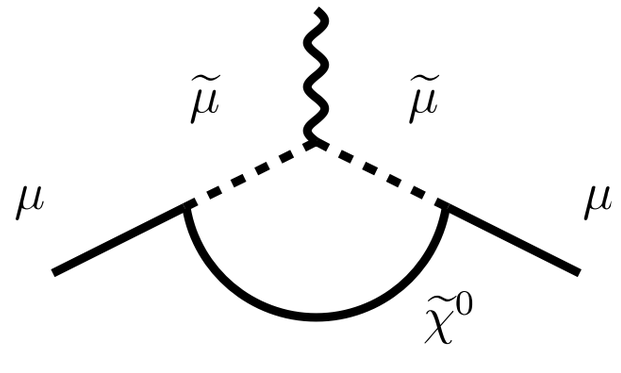
- Current situation: Exp – SM-TH: $(26\pm8).10^{-10}$ or 3.3σ

g-2, a sign for `new' physics?! SUSY?

SUSY could easily explain g-2:

Main 1-loop contributions:





Simplest case:

$$a_\mu^{\mathrm{SUSY}} \simeq sgn(\mu)\, 130 \times 10^{-11}\, \tan\beta \left(\frac{100\,\mathrm{GeV}}{\Lambda_{\mathrm{SUSY}}}\right)^2$$

- Needs μ>0, `light' SUSY-scale Λ and/or large tan β to explain 260 x 10^{-11}

- This is already `excluded' by LHC searches in the simplest SUSY scenarios (like CMSSM); causes large χ^2 in simultaneous SUSY-fits with LHC data and g-2

- However note: SUSY does not have to be minimal (w.r.t. Higgs), could have large mass splittings (with lighter sleptons), or corrections (to g-2 and Higgs mass) different from simple models, or not be there at all

- g-2 constrains params, distinguishes between NP models `degenerate' for LHC

Tim Jones

- Non-minimal coupling to gravity
  - Theories of the general form

$$S_J = \int d^4x\sqrt{-g}\left\{ -\tfrac{1}{2}(M_P^2 + \xi\phi^2)R + L(\text{matter}) \right\}$$

lead to novel inflationary models, for example using the SM Higgs as the inflaton. Marty Einhorn and I were the first to generalise this idea to the supersymmetric case.

MSSM $\leftarrow$? $\rightarrow$ Inflation

- Currently we are exploring scale invariant versions, where $M_P = 0$ above and the Einstein term arises from $\langle\phi\rangle$ via

Dimensional Transmutation

- Mark Hindmarsh and I developed the MHISSM, which has the following features
  - Low energy MSSM (with massive neutrinos)
  - F-term hybrid inflation $T_{\rm rh} \sim 10^{15}$ GeV

    $W_I = \lambda_1 \Phi \overline{\Phi} S - M^2 S$

  - Dynamical explanation of μ-term and RH neutrino masses

    $W_X = \frac{1}{2}\lambda_2 N N \Phi - \lambda_3 S H_1 H_2$

  - Second period of Higgs-driven "thermal" inflation $T_{\rm rh} \sim 10^9$ GeV
  - Reduced amount of F-term inflation: $n_s \simeq 0.976$
  - Dark matter (neutralino from gravitino decays/freeze-out, or gravitino)
  - Leptogenesis from RH neutrino decays (if $M_{N_1} \lesssim 10^9$ GeV)
  - Cosmic strings, $G\mu_{\rm cs} \simeq 10^{-7}$, consistent with CMB
- I am currently performing a detailed exploration of the sparticle spectrum, in the part of parameter space including a 125GeV SM-like Higgs boson.

Ian Jack Head of our theoretical physics group

- Superconformal Chern-Simons theories beyond leading order
- 4-loop ADM for a general a N=2 SUSY Chern Simons theory in 3-dimensions
- Working on the a-theorem, i.e. a 4 dimensional version of the c-theorem

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String Theory (Radu Tatar)

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String Theory (Radu Tatar)

- Geometry of 3-dimensional Chern-Simons theories
- Brane Configurations, Geometric Engineering and Supersymmetric Field Theories
- F-theory phenomenology
- Generalization of String Theory compactifications on non Kahler manifold
- Seiberg-like dualities in 2 and 3 dimensions

Issues in unification and String theory (Alon Faraggi)

- Phenomenological studies of string models (Sonmez)

(also with Kounnas, Partouche and Rizos)

Projects: Thresholds in TeV scale Scherk-Schwarz SUSY breaking; Classifcation of Flipped SU(5) vacua (Sonmez)

- (Non)–Perturbative Dualities (Athanasopoulos)

Projects: Spinor–vector duality in heterotic Gepner models

- PHYSICS BEYOND THE STANDARD MODEL: (Mehta)

e.g. SUSY; neutrinos; Z′; FCNC; dark matter; Cosmic rays

Projects: Stringy Z′ at the LHC (Mehta)

- FOUNDATIONS OF QUANTUM GRAVITY Quantum mechanics from an equivalence postulate

(with Marco Matone)

Projects: Mobius symmetry and the compact universe.

Black Holes and Geometrical Structures in String Theory (Thomas Mohaupt)

- Black holes in string theory
  - Construction of explicit solutions in supergravity and string theory
  - Study of general properties of black hole solutions
  - Black hole entropy and its relation to string and brane states
- Geometrical structures in string theory and supergravity, in particular
  - special real and Kähler geometry of vector multiplets
  - quaternion-Kähler geometry of hypermultiplets
  - special geometry of time-reduced and Euclidean supergravity theories
  - non-supersymmetric generalisations of special geometry

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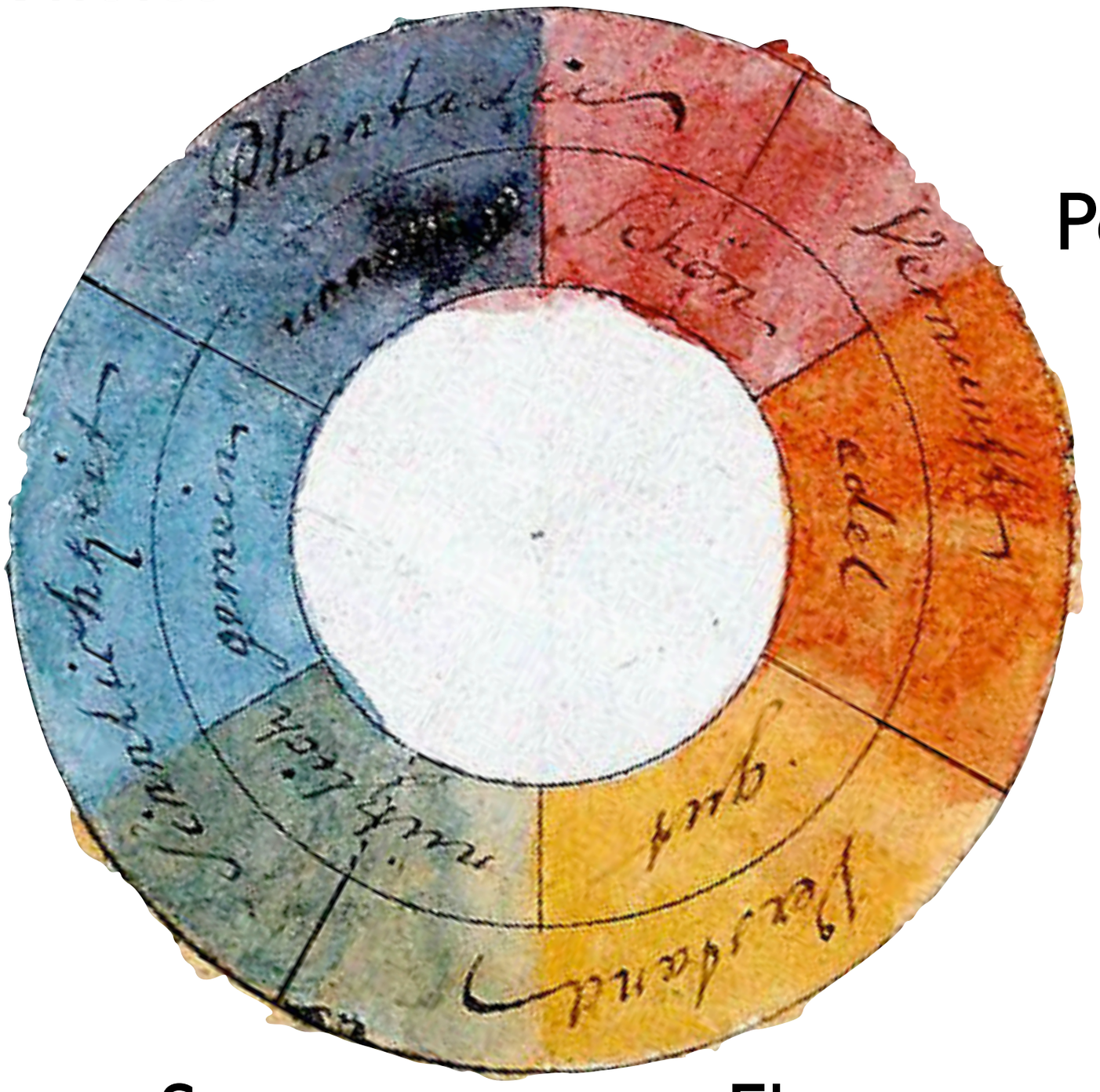

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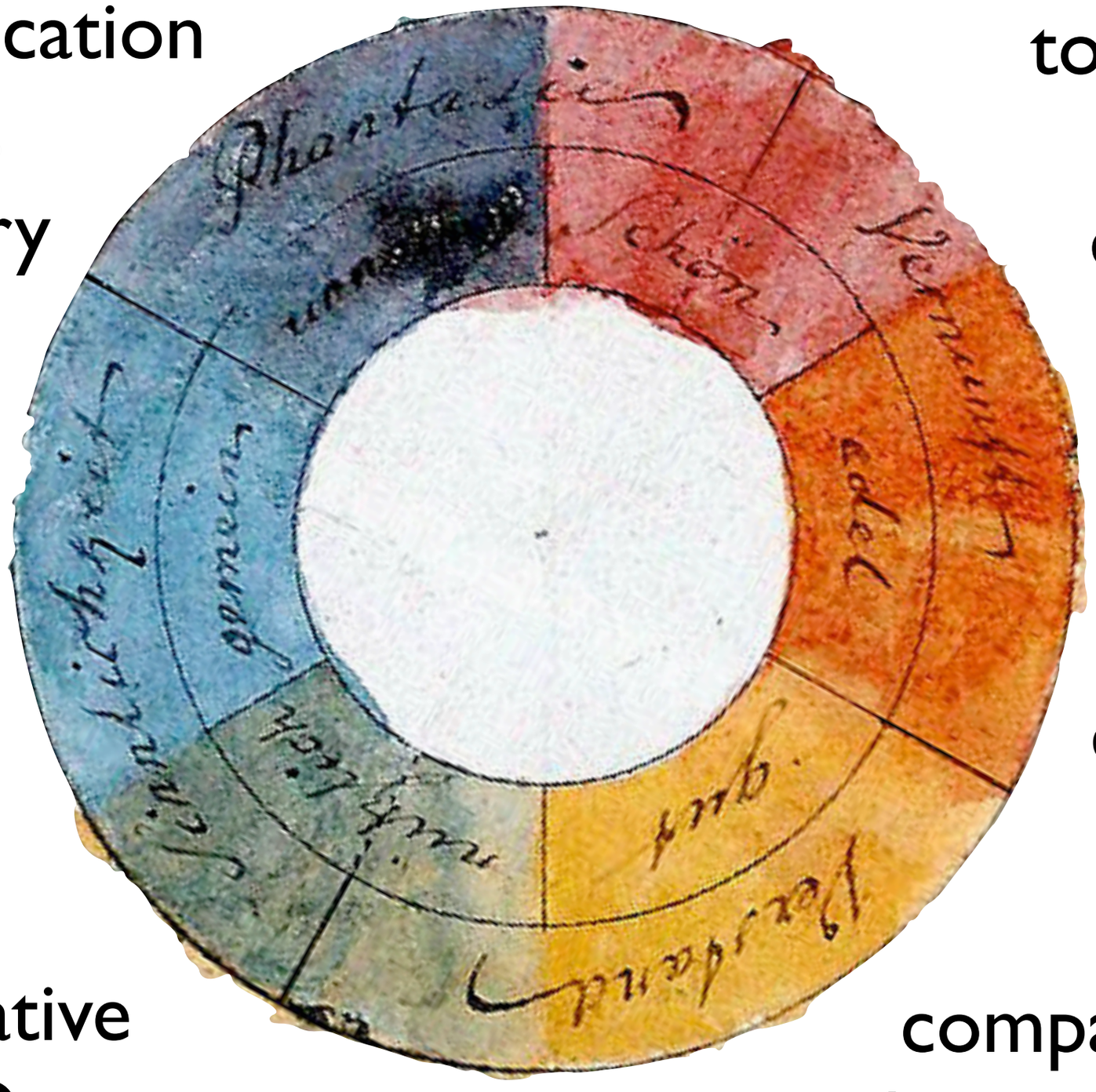

Connected
to physics
at large
distance
scales

Inflation
dark matter
dark forces
UHECR
compact universe
perturbative calculations