

R-parity Violation and 'All That'

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Oxford: 1990 - 1993

- I first saw Graham at Strings '89 at Texas A&M University, College Station, TX
- Jan., 1990: Oxford offered me a postdoc position: *saved my life!*
- We actually first met at CERN, in the Spring of 1990 for the LHC workshop (lead to Aachen meeting)
- Came to Oxford, Aug. 1990
- I spent three very happy and productive years in Oxford, mainly thanks to Graham

(In Dick Dalitz' former office, I had great office mates in Subir Sarkar and Steve Abel.)

(Graham gave me enough time off to regularly visit Heike in Hamburg and Columbus, OH in those 3 years)



1991 or 1992

Research

- In that time we published 3 papers together
 - **R-parity Violation at Hadron Colliders**
HKD, **Graham G. Ross**
Nucl.Phys. B365 (1991) 597-613
 - **Sphaleron Erasure of Primordial Baryogenesis**
HKD, **Graham G. Ross**
Nucl.Phys. B410 (1993) 188-216
e-Print: hep-ph/9207221
 - **Neutrino Masses from Gauge Symmetries**
HKD, G.K. Leontaris, S. Lola, **Graham G. Ross**, C. Scheich
Nucl.Phys. B436 (1995) 461-473
e-Print: hep-ph/9409369

Research II

- Graham also hooked me up with the experimentalists in Oxford
 - **R-parity Violation at HERA**
J. Butterworth, HKD
Nucl.Phys. B397 (1993) 3-34
e-Print: hep-ph/9211204
 - **Signals for Supersymmetry at HERA**
HKD, Peter Morawitz
Nucl.Phys. B428 (1994) 31-60
e-Print: hep-ph/9405253
- And with an excellent student
 - **R-parity Violation at a 500 GeV $e^+ e^-$ Collider**
HKD, S. Lola
ILC Workshop Proceedings, 1992

RPV at Colliders

- We took RPV seriously (well, I did 😊) and classified all *dominant* LHC signatures under the assumption of a neutralino LSP. We considered all 2 body production modes as well as the 2- and 3-body LSP decays.

$$\tilde{\chi}_1^0 \rightarrow \begin{cases} \ell_i^\pm \ell_k^\mp \nu, \ell_j^\pm \ell_k^\mp \nu, & L_i L_j \bar{E}_k \\ (\ell_i^\pm, \cancel{p}_T) + 2 \text{jets}, & L_i Q_j \bar{D}_k \\ 3 \text{jets}, & \bar{U} \bar{D} \bar{D} \end{cases}$$

- Really very simple, but became the basis for all pheno studies

Motivation for RPV: Cosmology

- *Bouquet & Salati; Campbell, Davidson, Ellis, Olive:*

Sphalerons, together with RPV can entirely wipe out the primordial baryon asymmetry

RPV out of equilibrium:

$$\lambda_{\text{RPV}} < 10^{-7}$$

[sphalerons satisfy B-L, RPV violates B or L]

- This encouraged us to rethink the problem

Sphalerons actually satisfy $\frac{1}{3}B - L_i$ separately.

Employing full set of chemical potential equations: as long as one L_i remains conserved, others can be large

- Included mass correction factor for the first time

$$\mu_i \longrightarrow \alpha(m_i/T)\mu_i, \quad \tilde{\alpha}(m_i/T)\mu_i,$$

- Leptogenesis:

$$B = \left(-16 + \frac{1344+1400\tilde{\alpha}}{144+270\tilde{\alpha}+125\tilde{\alpha}^2}\right) \frac{\Delta\tilde{\mu}}{15}$$

$$\Delta\mu \equiv \sum_i (1 - \alpha_i)\mu_i,$$

$\Delta\tilde{\mu}$: for SUSY

Rutherford Lab: 1996 – 2000

- Returned to Oxford; 2 days a week at Oxford
- Taught at Oxford physics department and University College, Oxford
- Became advisor to excellent Oxford Ph.D. students:

Peter Richardson, Marc Thormeier

- Worked on discrete symmetries, inspired by Graham and Luis



Aug. 2000

Discrete Gauge Symmetries

- Gauge symmetries safe from quantum gravity effects
- Discrete symmetry: remnant of broken gauge symmetry, also safe
- **Luis and Graham:** anomaly conditions on gauge symmetry translate into conditions on the low-energy discrete symmetry
- Classified all anomaly-free $\mathbf{Z}_{2,3}$ discrete symmetries, adding basic pheno requirements
- Only two remain: R_p and B_3

Discrete Gauge Symmetries II

- Extended this work with Christoph Luhn and Marc Thormeier to arbitrary \mathbf{Z}_N
- Extra solution P_6 , proton hexality; not GUT compatible
- Graham and collaborators (Hyun Min Lee, Stuart Raby, Michael Ratz, Roland Schieren, Kai Schmidt, Patrick Vaudravange) extended this work recently to discrete R-symmetries.
- They get a unique \mathbf{Z}_4^R symmetry for the MSSM, compatible with $SO(10)$.
- With Christoph Luhn and Marja Hanussek, we are extending this to the RPV case.

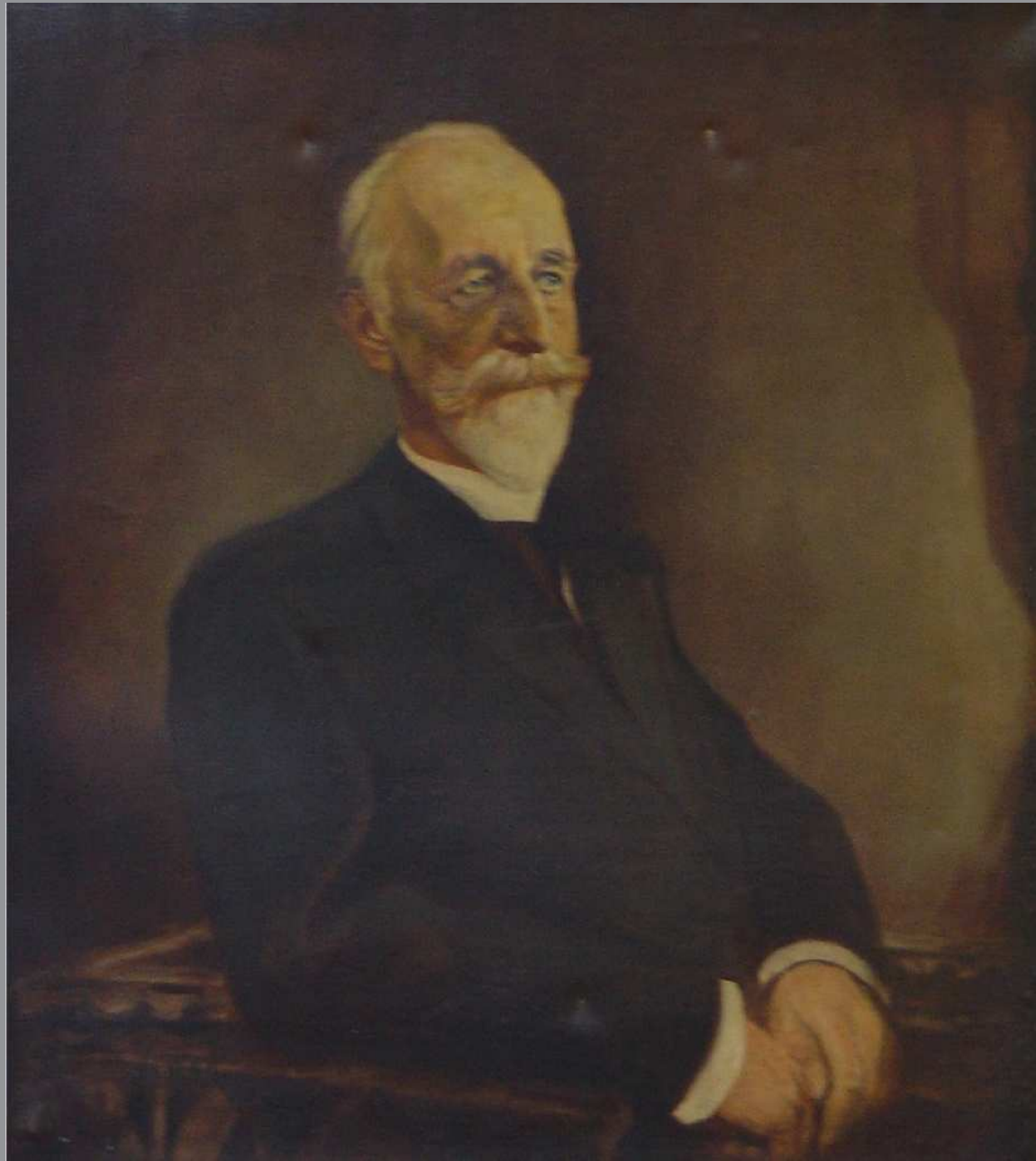
(Note R-parity is not (necessarily) an R-symmetry.)

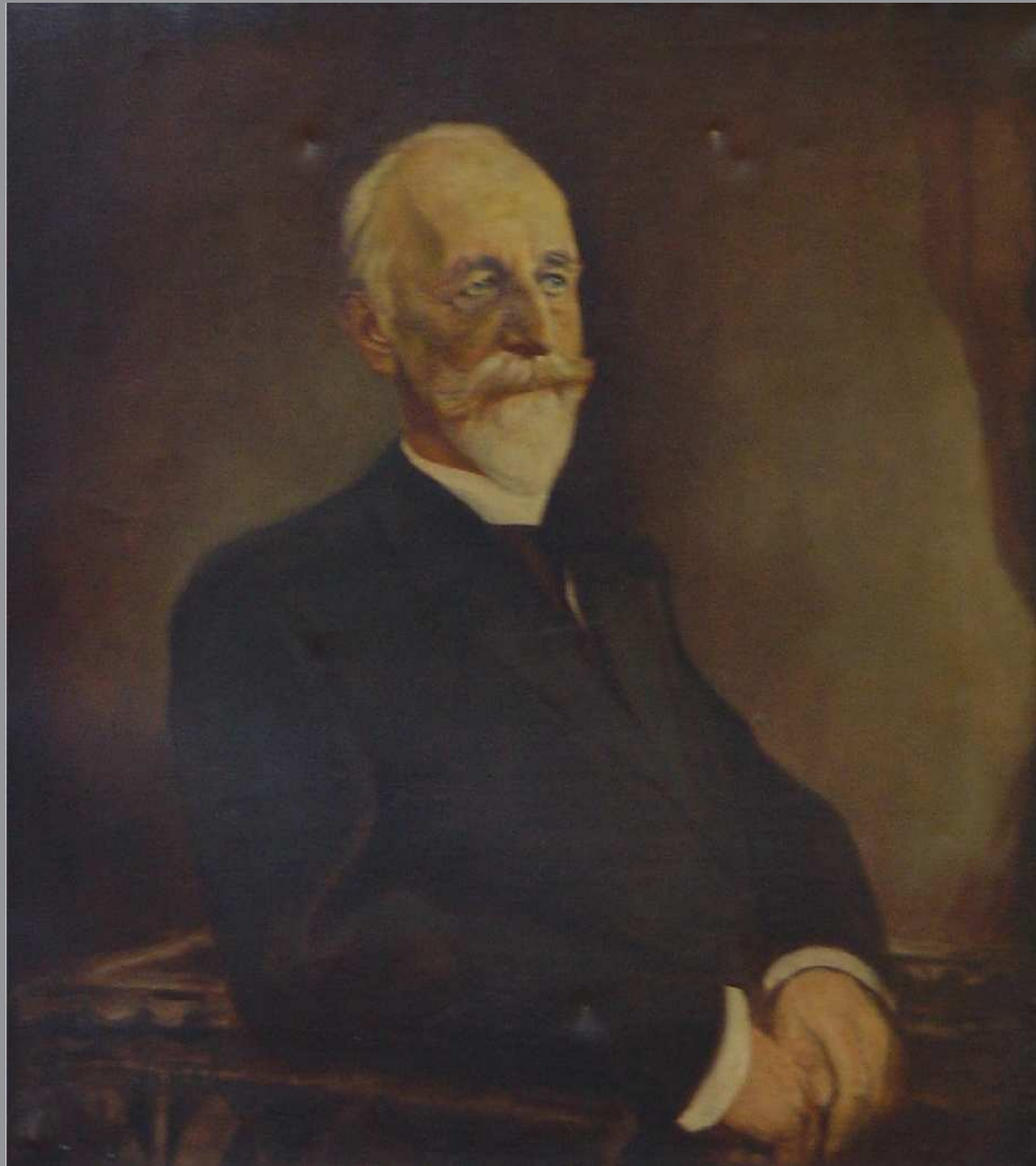
A Few words on RPV

- Worked for me, but over the years kind of a pariah status
- **However**, suddenly have become very popular, with the lack of evidence for “conventional” SUSY at the LHC
- They even have RPV discussions within ATLAS and CMS now
- **Quote:** “Can explain any experimental anomaly with RPV”
- **Proof:** HERA anomaly, Karmen time anomaly, light bottom squark, NuTeV dimuon events, solar neutrinos via FV

- **Exception that proves the Rule: Opera, FTL* neutrinos**

* FTL = faster than light





Heinrich Gustav Johannes Kayser *1853 Bingen, † 1940 Bonn







