

Where it all began...

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Geneviève Fest

*Talk based on our 40-year relationship
as collaborators, colleagues and friends.*

1985: Genève: postdoc at TRIUMF, me: postdoc at UBC.

Context: 2026 vs. 1985

Early 1980s: heterotic string $\implies E_6$ GUT. Rank 5 $\implies \exists$ 2 new Z' bosons.
Fundamental representation: **27**. First generation: 15 SM particles + a
RH neutrino + 11 exotic particles (a vector-singlet down-type quark, a
vector doublet of leptons, and a singlet neutrino):

$$\begin{pmatrix} u \\ d \end{pmatrix}_L, \quad u_R, \quad d_R, \quad \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L, \quad e_R^-, \\ \nu_R, \quad h_L, \quad h_R, \quad \begin{pmatrix} N \\ E^- \end{pmatrix}_L, \quad \begin{pmatrix} N \\ E^- \end{pmatrix}_R, \quad n_L.$$

\implies lots of new particles, masses and mixing with SM particles can take
any values we like \implies lots of things to measure.

Much of Geneviève's work in 1986-1987 is related to new particles in E_6 :

- 1 G.B. and S. Godfrey, "Asymmetries at e^+e^- Colliders from E_6 Grand Unified Theories;" D. London, G.B. and J.N. Ng, "Effects of Z^0 Mixing With an E_6 Gauge Boson at e^+e^- Colliders" and "Effects of an Extra Z^0 in Precision Neutrino-Electron Scattering Experiments." Properties of Z^0 not yet measured. If $\exists Z^0$ - Z' mixing, it will affect measurements at LEP/SLC. Observables: LR and FB asymmetries (paper #1), total and partial Z^0 widths (paper #2). Paper #3: cross sections for ν_e - e , $\bar{\nu}_\mu$ - e and ν_μ - e scattering.
- 2 D. London, G.B. and J.N. Ng, "Neutrino Masses and L Parity in E_6 Superstring Models." The **27** of E_6 the ν_L and lots of extra neutral particles. Here we construct the neutrino mass matrix and show that one can produce a very light Majorana neutrino using the various exotic neutrinos and the seesaw mechanism.
- 3 D. London, G.B. and J.N. Ng, "Lepton Vector - Lepton Mixings and Unitarity Bounds." We consider e - E mixing and show that, by examining the processes $E^+E^- \rightarrow E^+E^-$ and $E^+E^- \rightarrow E^+e^-$, we can get information about the mass and mixings of the E^\pm .

Speculative:

D. London, G.B. and J.N. Ng, “New Tests of Lepton Number Violation at Electron–Electron Colliders.”

Smoking-gun signal of lepton-number violation: neutrinoless double beta decay. There are two $n \rightarrow pe^- \bar{\nu}_e$ decays, the two $\bar{\nu}_e$ s annihilate because they are Majorana neutrinos. \implies internal process: $W^- W^- \rightarrow e^- e^-$. We turned this around: examine $e^- e^- \rightarrow W^- W^-$ at a future $e^- e^-$ collider (!?). Paper very well-received.

While Geneviève was at TRIUMF, the Lake Louise Winter Institute was born. From its web site: “The annual Lake Louise Winter Institute explores recent trends in particle physics in an informal setting. The institute is held at the Chateau Lake Louise in the Canadian Rocky Mountain range. Lectures are held in the morning and evening to allow the afternoon free for hiking, sightseeing, skiing and other activities.” Geneviève “attended” the LLWI in 1986 and 1987 while at TRIUMF, and again in 1990 while at the Université de Montréal. Why “attended?”

Geneviève was at TRIUMF from 1985 to 1987. She got a University Research Fellowship and was hired at the Université de Montréal (UdeM) at the end of her postdoc.

After going to UdeM, Geneviève hired a postdoc, C.Q. Geng, and began to work on kaon physics. E.g., from 1990-1992: G.B. and C.Q. Geng, “New range of mixing parameters and rare K decays,” P. Agrawal, J.N. Ng, G.B. and C.Q. Geng, “CP violation in $K^+ \rightarrow \pi^+ \ell \bar{\ell}$ decays,” G.B. and C.Q. Geng, “T-violating muon polarization in $K_{\mu 3}$ decays,” P. Agrawal, J.N. Ng, G.B. and C.Q. Geng, “A Study of T violation in $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ decays,” G.B., C.Q. Geng and P. Turcotte, “Direct CP-violating rare kaon decays with charged Higgs.” Fawzi Boudjema will probably give more details in his talk.

After UBC, I got another postdoc at DESY, but I kept in touch with Geneviève. (E.g., we met at the 1988 DPF Summer Study on High-energy Physics in the 1990s (Snowmass 88).) Towards the end of my postdoc, Geneviève strongly suggested that I apply for the same Fellowship she had, to be also held at UdeM. I did apply and I got it. I started at UdeM as a prof in 1989. Point: Geneviève essentially got me hired at UdeM. Thanks so much, Geneviève!

When I arrived at UdeM, C.Q. Geng was finishing up his postdoc. Geneviève had hired another postdoc, who arrived at roughly the same time. It was Fawzi Boudjema. This turned out to be important, as we will see.

Early 1990s: a hot topic was anomalous (non-standard) triple gauge-boson vertices. 1990: G.B., F. Boudjema and D. London, "Effects of an Anomalous ZWW Vertex at LEP." We show that, if anomalous TGVs exist, they can affect the branching ratios and asymmetries of the Z^0 to be measured at LEP.

I told you about the role that Geneviève played in me getting my faculty position at UdeM. But there's more. So, although she was not directly responsible for it, Geneviève was involved in me meeting my wife. Thanks again, Geneviève!

Fawzi will talk more about the various topics that Geneviève worked on in the 1990s. One paper (1993): G.B., D. London and H. Nadeau, "Single leptoquark production at e^+e^- and $\gamma\gamma$ colliders." So Geneviève, my wife (then a postdoc at McGill) and I wrote a paper about searching for a new type of particle at a new type of collider.

1994: for personal reasons, Geneviève decided to move to France. By this time, Fawzi had taken a position at Annecy. I don't know the details (maybe Fawzi can tell you), but Geneviève also ended up going to Annecy.

Summer 1995: my wife, my daughter and I visited Annecy. The four of us wrote a followup article to the paper we had written at TRIUMF: G.B., F. Boudjema, D. London and H. Nadeau, "Inverse neutrinoless double beta decay revisited." Also had a big impact.

After that, Geneviève and I stayed in touch, but we didn't collaborate on any physics projects until 2021: G.B., J. Kumar, D. London and A. Pukhov, "The B anomalies, the U_1 leptoquark and dark matter." That is, we wrote a paper that combined her area of expertise (DM) and mine (B physics).

Recap: I have tried to give you an idea of what Geneviève worked on in the early years. I have also summarized the work we did together, as well as the role she played in my professional and personal life. We wrote our last paper together in 2022. I'm sure it won't be our last.