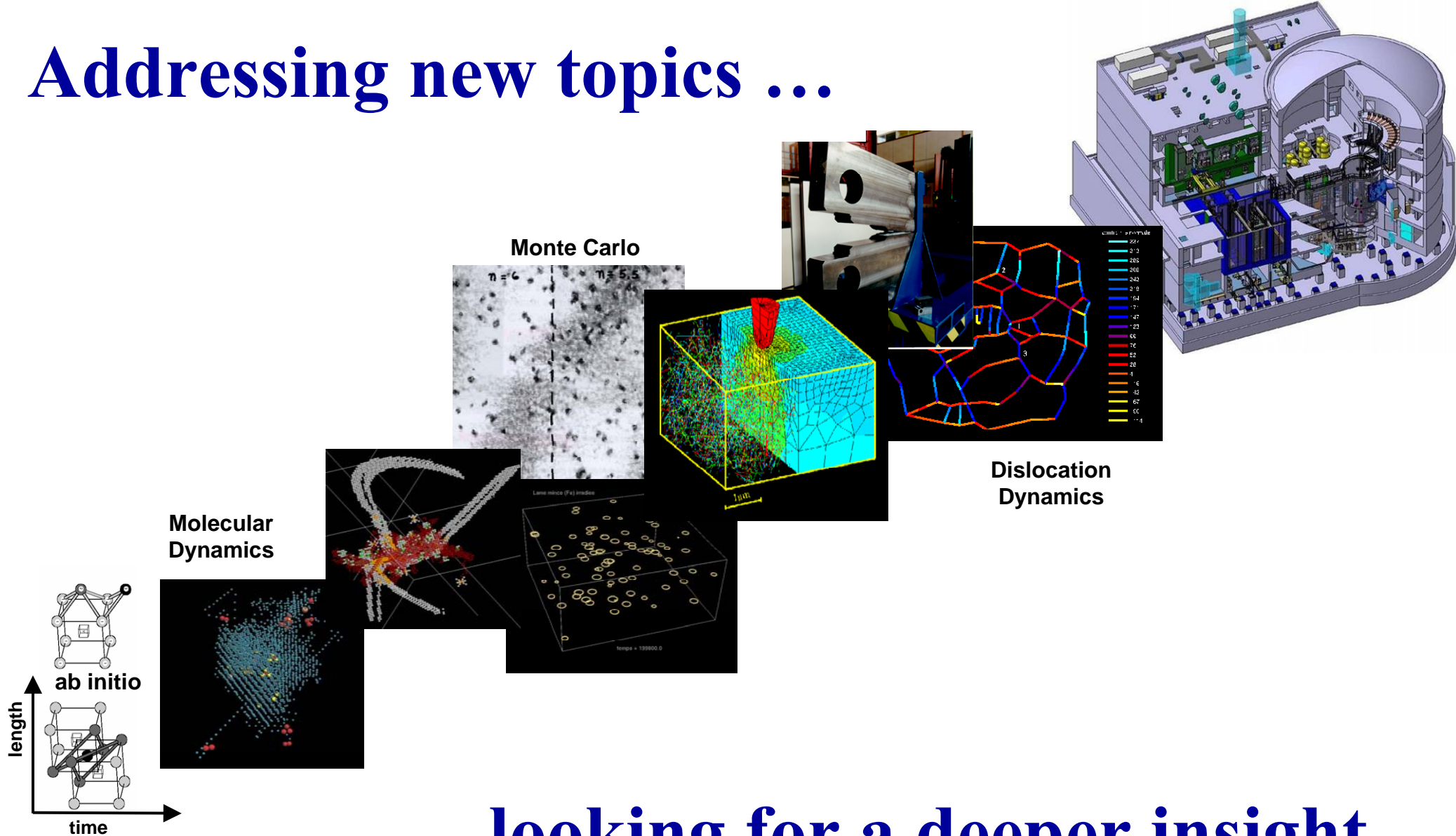


A unique experience :  
from Theory to Applied Science

D. Iracane & P. Chaix

# Addressing new topics ...



... looking for a deeper insight  
& getting into the machinery

# An ambitious program

- ↳ 1981: nucleon-nucleon interaction, looking for a deeper insight justification from Quantum Chromodynamics
- ↳ Using a powerful tool : variational methods and mean field theory
- ↳ An intricate topic with severe issues,
  - ✓ gauge invariance, renormalisation ...
- ↳ But interesting results

# SIMPLE MODEL FOR THE QCD VACUUM

Michael Danos

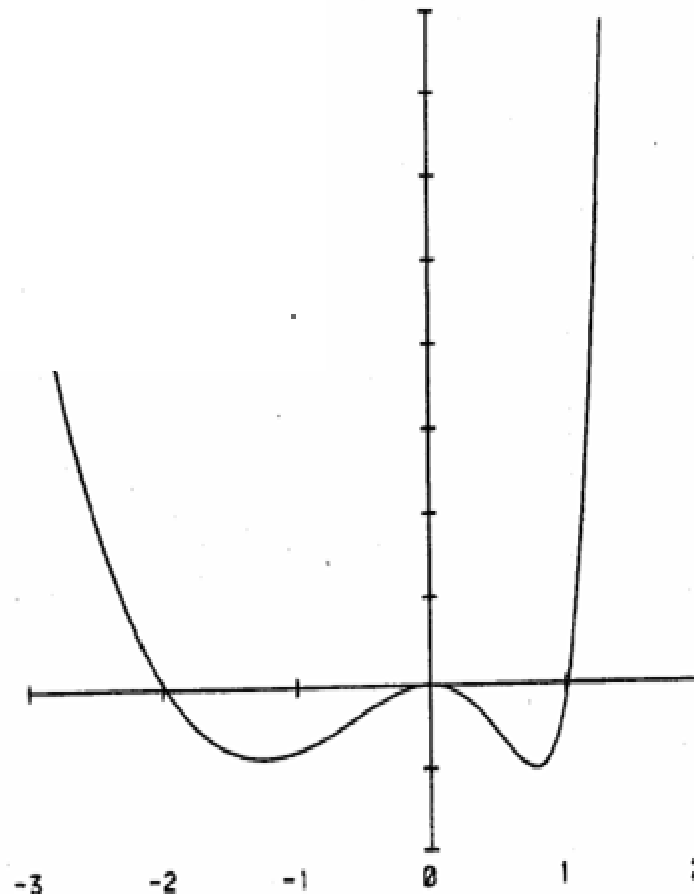
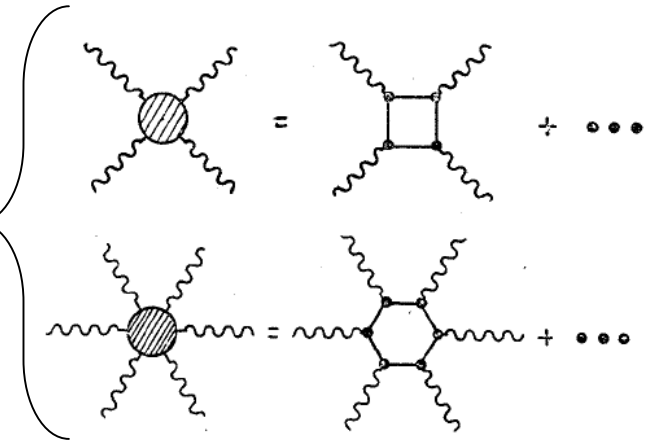
U.S. DEPARTMENT OF COMMERCE  
National Bureau of Standards  
Center for Radiation Research  
Washington, DC 20234

Daniel Gogny and Daniel Irakane

Centre d'Etudes de Bruyeres-le-Châtel  
92842 Montrouge  
CEDEX, France

**Gluon condensate study  
within Bogoliubov  
mean field theory:**

Looking for an  
attractive channel,  
the effective force,  
a tricky point



Mathematical, then  
numerical analysis exhibit  
a competition between 2  
phases

-a supra-conducting  
condensate with a non-zero  
gap ( $\rightarrow$  mass)

-a Bose-Einstein condensate

Addressing more “useful” topics ...

↳ Getting deeper insight Relativistic mean field theory

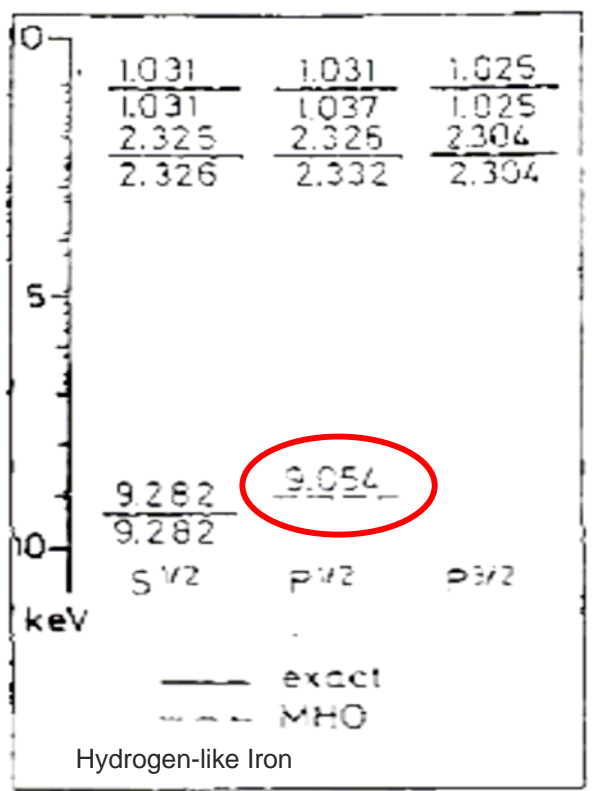
↳ In a domain

where forces are well known

with “clear operational stakes (1987...)”

COMPUTATION  
OF HEAVY IONS/ATOMS

# From relativistic atomic calculations...



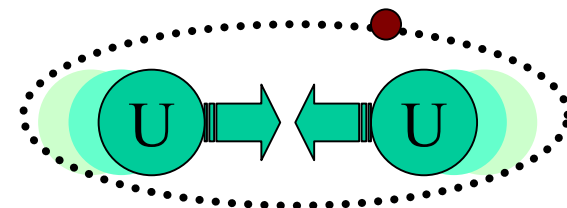
**From Density Functional method  
to basis expansion methods**

**Spurious eigenstates of the  
one-body Dirac Hamiltonian**

**The Dirac Hamiltonian  
with Coulomb interaction  
is not bounded from below**

- How to project out spurious state
- How to define the Fermi level with negative energy states ( $Z > 137 = 1/\alpha$ )?

e.g.:



J. Phys. B: At. Mol. Opt. Phys. **22** (1989) 3791–3814. Printed in the UK

J. Phys. B: At. Mol. Opt. Phys. **22** (1989) 3815–3828. Printed in the UK

**From quantum electrodynamics to mean-field theory:**

**I. The Bogoliubov–Dirac–Fock formalism** P Chaix and D Iracane

**II. Variational stability of the vacuum of quantum electrodynamics  
in the mean-field approximation** P Chaix , D Iracane and P L Lions

**What is the vacuum of QED  
for relativistic variational  
calculations of atoms?**

**Minimisation of energy in a  
Bogoliubov-Dirac-Fock variational space  
*Self-consistent Projection !***

**The QED vacuum is not stable if  $\alpha > 4/\pi$   
The BDF QED vacuum is stable if  $\alpha < 4/\pi$   
( $\alpha = 1/137 < 4/\pi$ , by chance ...)**

Meanwhile, the SDIO in USA ...

Large power FEL

operational capacities for Defence applications

?

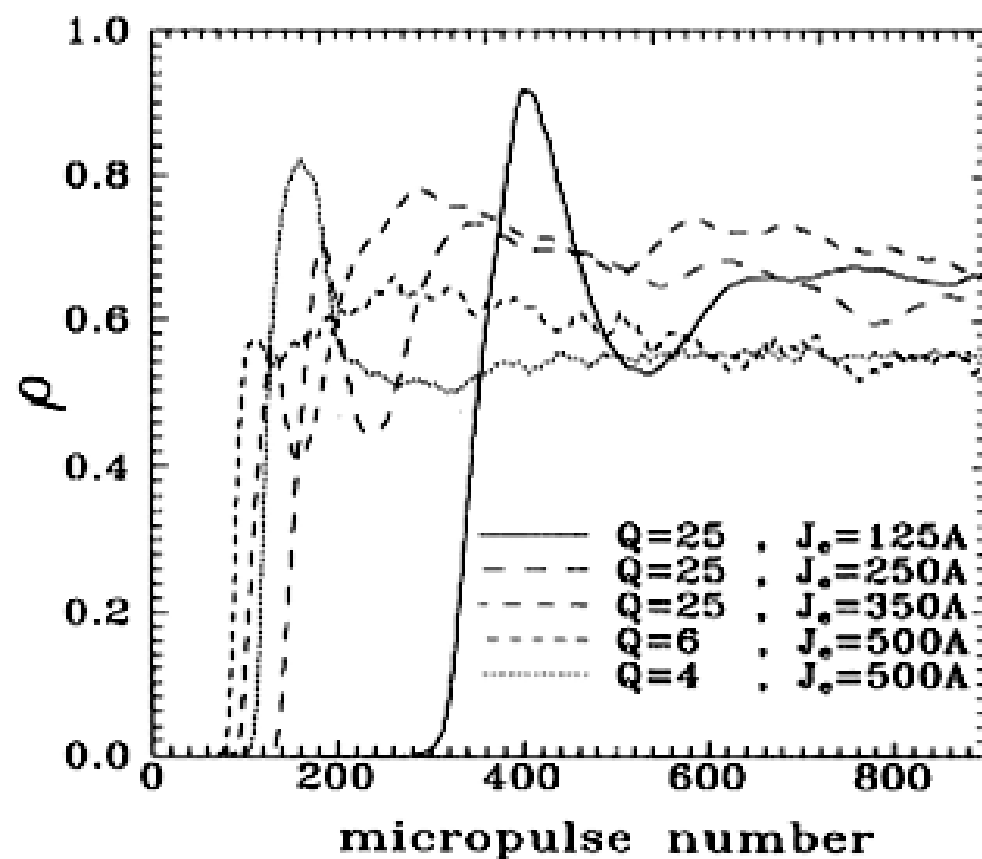
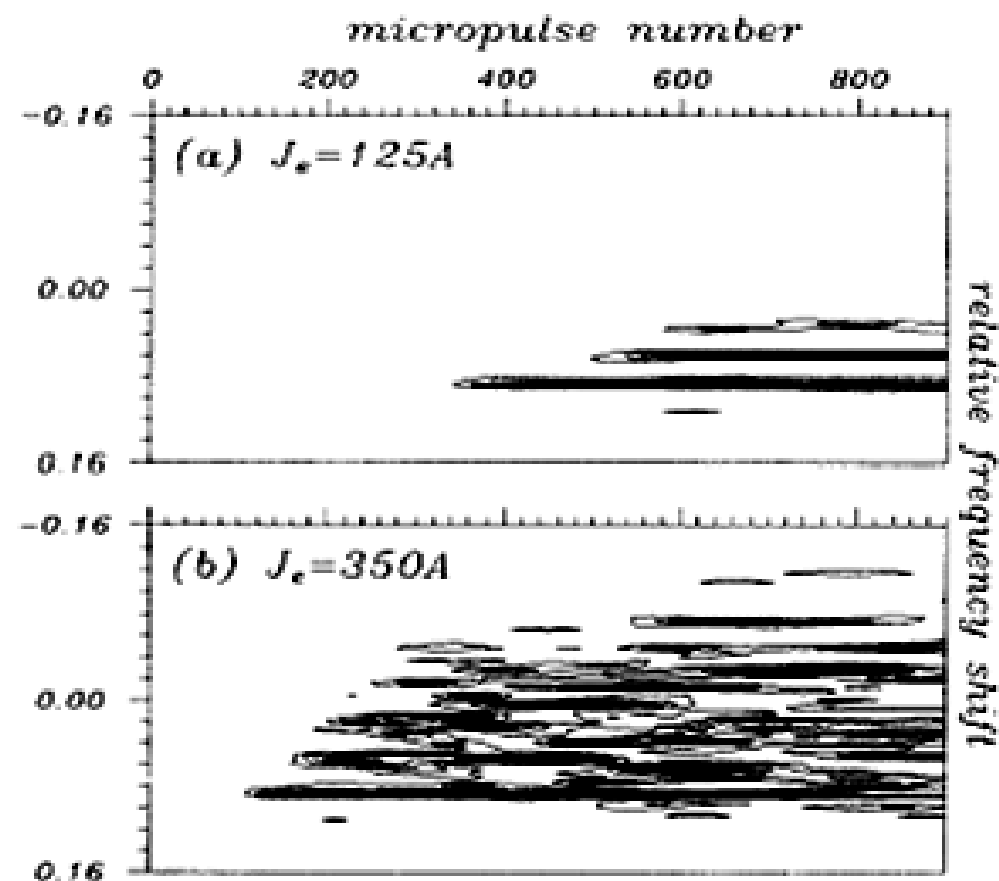


# Stability of a Free-Electron-Laser Spectrum in the Continuous-Beam Limit

D. Iracane and J. L. Ferrer

*Commissariat à l'Energie Atomique, B.P. No. 12, 91680 Bruyeres-Le-Chatel, France*

(Received 9 July 1990)



Two-Frequency Wiggler for Better Control of Free-Electron-Laser Dynamics

D. Iracane and P. Bamarac

PHYSICAL REVIEW E

VOLUME 48, NUMBER 5

NOVEMBER 1993

Stochastic electronic motion and high-efficiency free-electron lasers

P. Chaix, D. Iracane, and C. Benoist

Commissariat à l'Energie Atomique

VOLUME 72, NUMBER 25

PHYSICAL REVIEW LETTERS

20 JUNE 1994

Experimental Evidence for High-Efficiency, Low-Brightness Behavior in Free-Electron Lasers

D. Iracane, V. Fontenay, P. Guimbal, S. Joly, S. Striby, and D. Touati

Commissariat à l'Energie Atomique, D 12 01690 D.

Theory

$$\mathcal{B} = \frac{E_L}{QE_e \Sigma} \leq \mathcal{B}_M = \frac{\sqrt{3}}{2} \simeq 0.86 ,$$

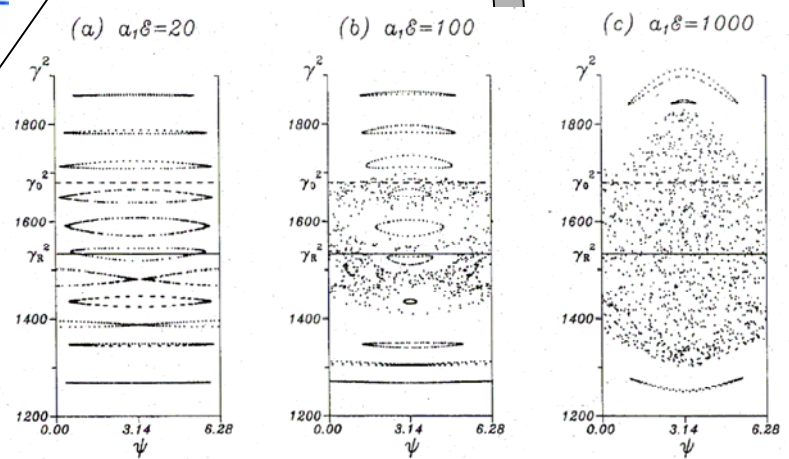
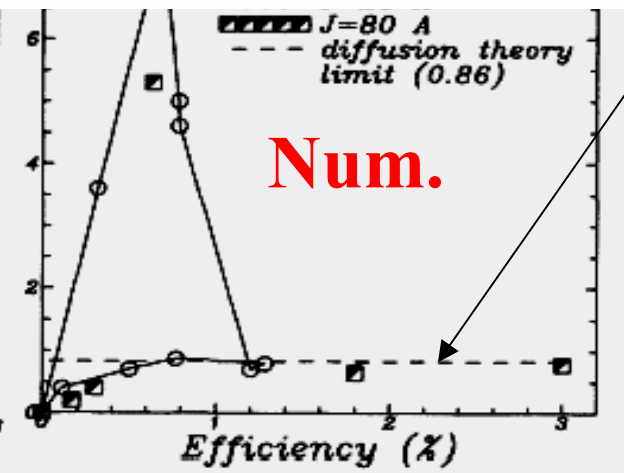
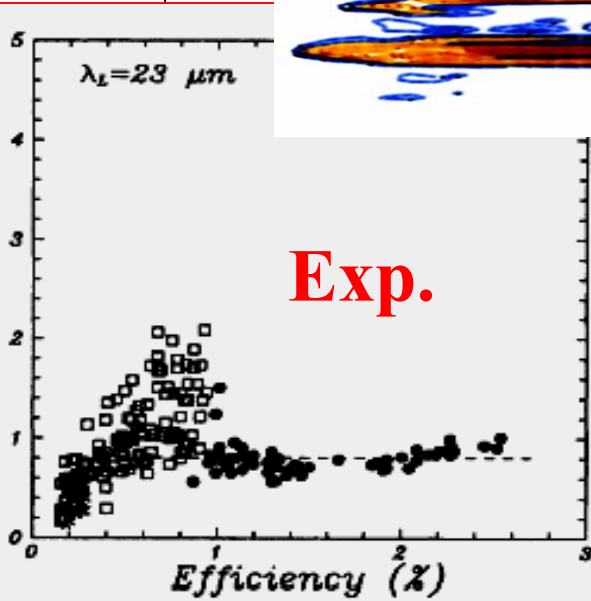
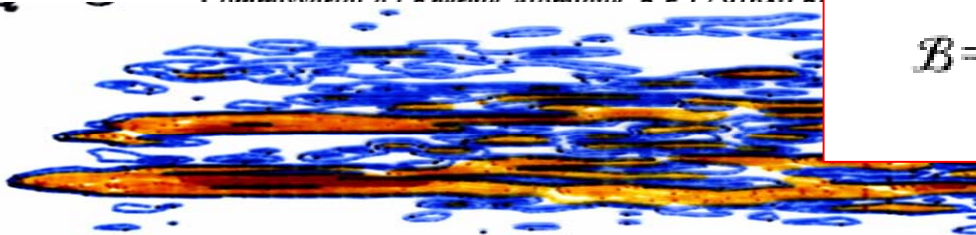


Fig. 2. Poincaré sections of the electronic phase space in a TFW for a monochromatic laser field, for increasing values of the intensity.



# A part of the heritage: How to identify the most important texts

676.

## PARTICLE PHYSICS: INTERACTIONS

Hermitian fields, which is equivalent to two spin-0 complex fields. The simplest way is to put these two complex fields,  $\phi_1$  and  $\phi_2$ , into a single two-dimensional representation under the  $SU_2 \times U_1$  transformations. We write

$$\phi = \begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix}$$

and assume it to be of the form

$$T' = \frac{1}{2}$$

so that, because of (22.53),

$$L^\dagger R \phi$$

is of

$$T = T' = 0$$

The Lagrangian density of this system of leptons, gauge fields and  $\phi$  is

$$\mathcal{L} = -\frac{1}{4} \vec{B}_{\mu\nu}^2 - \frac{1}{4} C_{\mu\nu}^2 - R^\dagger \gamma_4 \gamma_\mu D_\mu R - L^\dagger \gamma_4 \gamma_\mu D_\mu L - (\bar{D}_\mu \phi^\dagger) D_\mu \phi - U(|\phi|) - f(L^\dagger \gamma_4 R \phi + R^\dagger \gamma_4 L \phi^\dagger)$$

where  $|\phi|^2 = \phi^\dagger \phi$ ,

$$D_\mu L = \left[ \frac{\partial}{\partial x_\mu} - i g \frac{1}{2} \vec{\tau} \cdot \vec{B}_\mu - i \left(-\frac{1}{2}\right) g' C_\mu \right] L,$$

$$D_\mu R = \left[ \frac{\partial}{\partial x_\mu} - i \left(-\frac{1}{2}\right) g' C_\mu \right] R,$$

$$D_\mu \phi = \left[ \frac{\partial}{\partial x_\mu} - i g \frac{1}{2} \vec{\tau} \cdot \vec{B}_\mu - i \left(\frac{1}{2}\right) g' C_\mu \right] \phi,$$

$$\bar{D}_\mu \phi^\dagger = \left[ \frac{\partial}{\partial x_\mu} + i g \frac{1}{2} \vec{\tau} \cdot \vec{B}_\mu + i \left(\frac{1}{2}\right) g' C_\mu \right] \phi^\dagger$$

in which the numerical value inside the parenthesis denotes the field.

## WEAK AND ELECTROMAGNETIC GAUGE THEORY

677.

Exercise. Prove that the above Lagrangian density is invariant under the local  $SU_2 \times U_1$  transformations:

$$C_\mu \rightarrow C_\mu + \frac{1}{g'} \frac{\partial a}{\partial x_\mu},$$

$$L \rightarrow \exp(i a T_L') u L,$$

$$R \rightarrow \exp(i a T_R') R$$

$$\phi \rightarrow \exp(i a T_\phi') u \phi$$

where  $a(x)$  is an arbitrary real function,  $u(x)$  is any  $2 \times 2$  unitary matrix function with  $\det u = 1$ ,

$$B_\mu \equiv \frac{1}{2} \vec{\tau} \cdot \vec{B}_\mu,$$

$$T_L' = -\frac{1}{2}, \quad T_R' = -1$$

3. Spontaneous symmetry breaking

Similarly to (22.5), we assume

$$U(|\phi|) = \frac{\mu^2}{4\rho^2} (\phi^\dagger \phi - \rho^2)^2;$$

the shape is again of the form given by Figure 22.1. The minimum of  $U$  is at  $|\phi| = \rho$ . Just as in (22.7), this means  $\langle \text{vac} | \phi | \text{vac} \rangle = \rho$ .