MORIOND Electroweak 2010

Theory Summary

Belen Gavela

UAM (Univ. Autónoma de Madrid) and IFT

The happiness

in the air

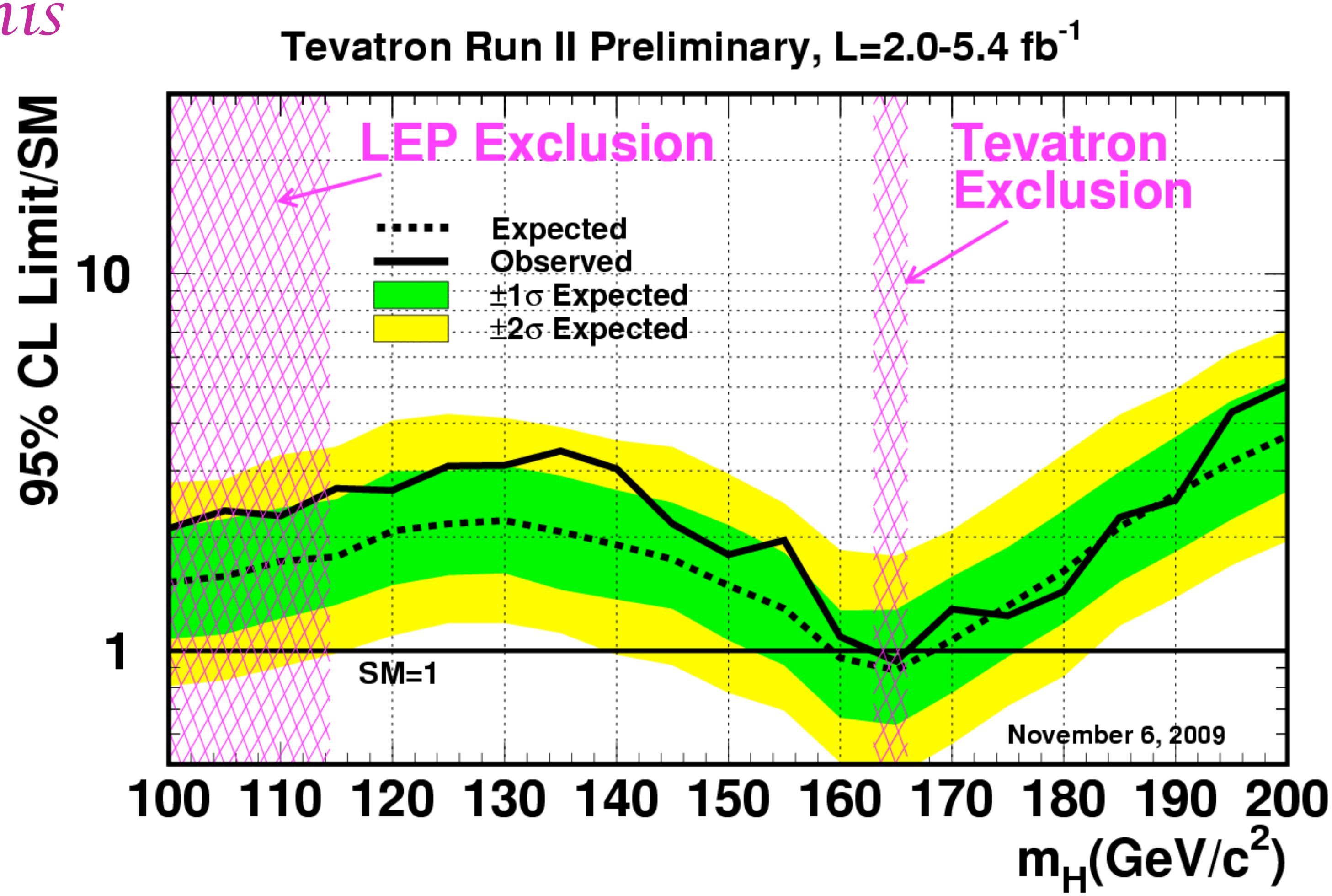
of the LHC era

… as we are almost “touching” the Higgs

The LHC & Tevatron may not be the only places in the universe where the Higgs is being produced today

Servant

St. Denis



SM Sensitivity: 159-169 GeV/c^2!

SM Exclusion: 162-166 GeV/c^2!

The happiness

in the air

of the LHC era

… as we are almost “touching” the vacuum

quantum numbers

$\boxed{SU(3) \times SU(2) \times U(1) \times \text{classical gravity}}$

We ~understand ordinary particles= excitations over the vacuum

We DO NOT understand the vacuum = state of lowest energy:

SU(3) x SU(2) x U(1) x classical gravity

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The Higgs excitation has the quantum numbers of the EW vacuum

SU(3) x SU(2) x U(1) x classical gravity

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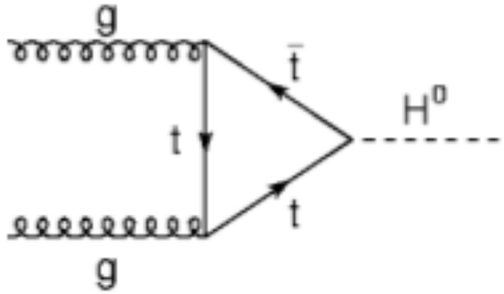
The (Tevatron->) LHC era will alllow us to explore it

The state of the art on our control

of the SM predictions

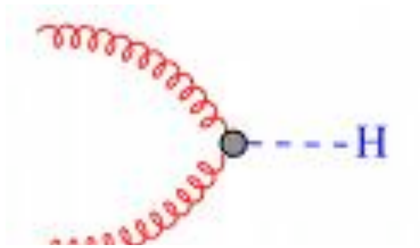
Harlander

Effective theory for gluon fusion



The effective theory in the infinite m_{top} limit matches finite m_{top} at %level

NNLO



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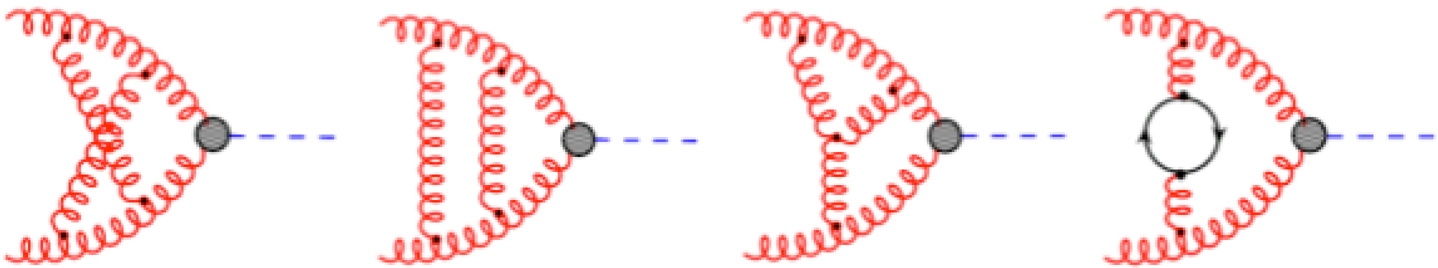

+…

Two-loop diagrams contributing to the process gg->H.

Are QCD corrections to gg fusion under control?

Harlander : **YES**

Harlander For Tevatron

Latest compilations[1]

Work for theorists

- NLO [Dawson '91], [Spira, Djouadi, Graudenz, Zerwas '91-'95]
  $\to$ +110% of LO
- NNLO [RH, Kilgore '02], [Anastasiou, Melnikov '02]
  $\to$ +60% of LO (30% of NLO)
- soft gluon resummation (or $\mu_F = \mu_R = m_H/2$) $\to$ +11%
  [Catani, de Florian, Grazzini, Nason '03]
- electro-weak $\to$ +6% of LO [Actis, Passarino, Sturm, Uccirati '08]
- π^2 resummation *not* included
- PDFs: MRST2006 $\to$ MSTW2008 $\to$ -13% (!)

[Anastasiou, Boughezal, Petriello '09], [de Florian, Grazzini '09]

Are QCD corrections to gg fusion under control?

Djouadi: **NO** because error in

Matching-scale (i.e. in truncation)

LARGE

Djouadi For Tevatron

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scale
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Djouadi

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PDF+$\Delta^{\exp}\alpha_s + \Delta^{\rm th}\alpha_s$----> ~20% Djouadi

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NNLL

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Djouadi:

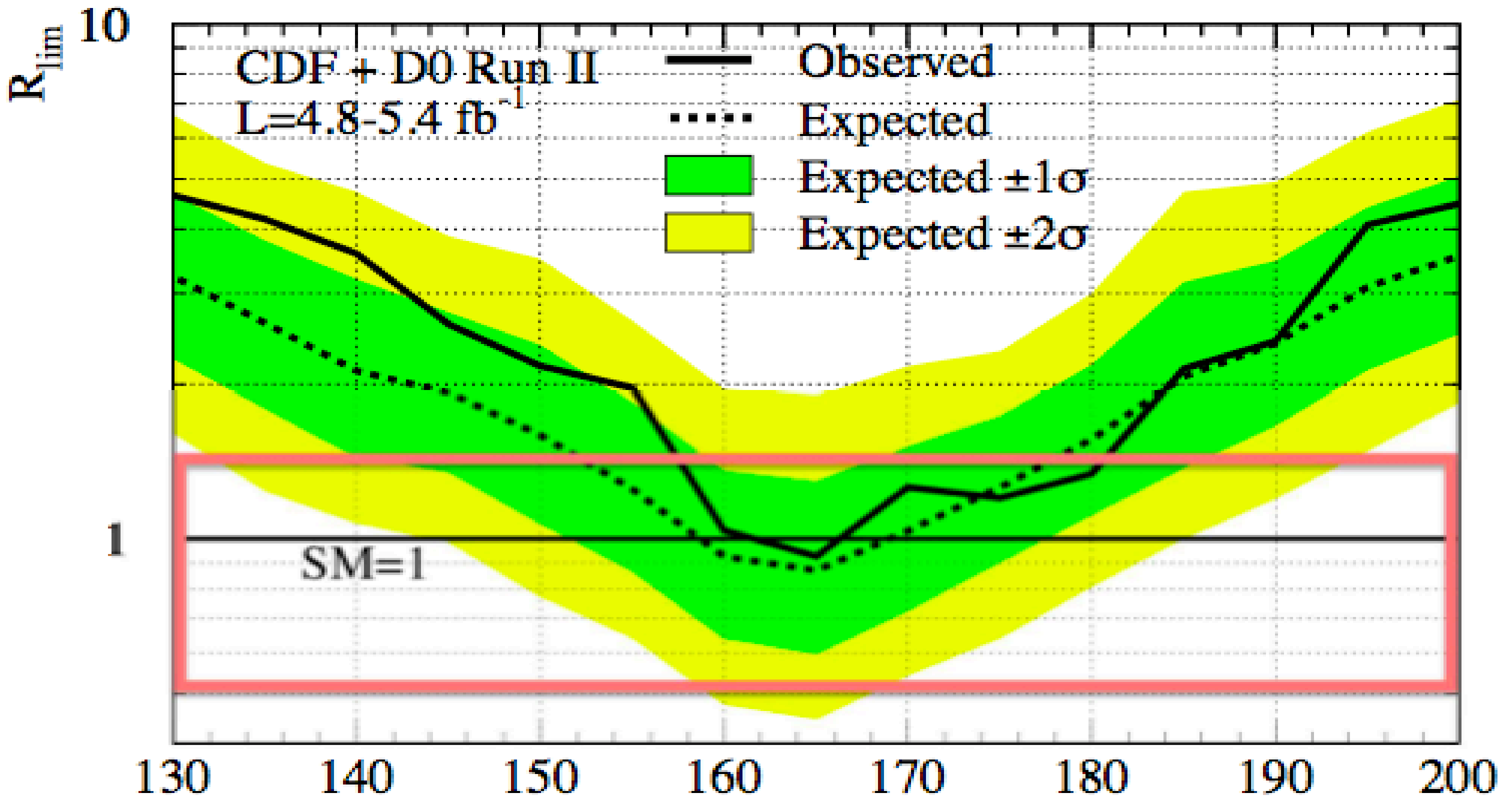
How to combine errors?

– **add scale and PDF not in quadrature**

– **exp+th error on α_s should be added**

-- **no NLLL** (if including them, error goes down)

adds ~40%error for M_H>150



95% CL CDF/D0 exclusion limit 162$\leq M_H \leq$166 GeV **not credible?**

Djouadi:

How to combine errors?

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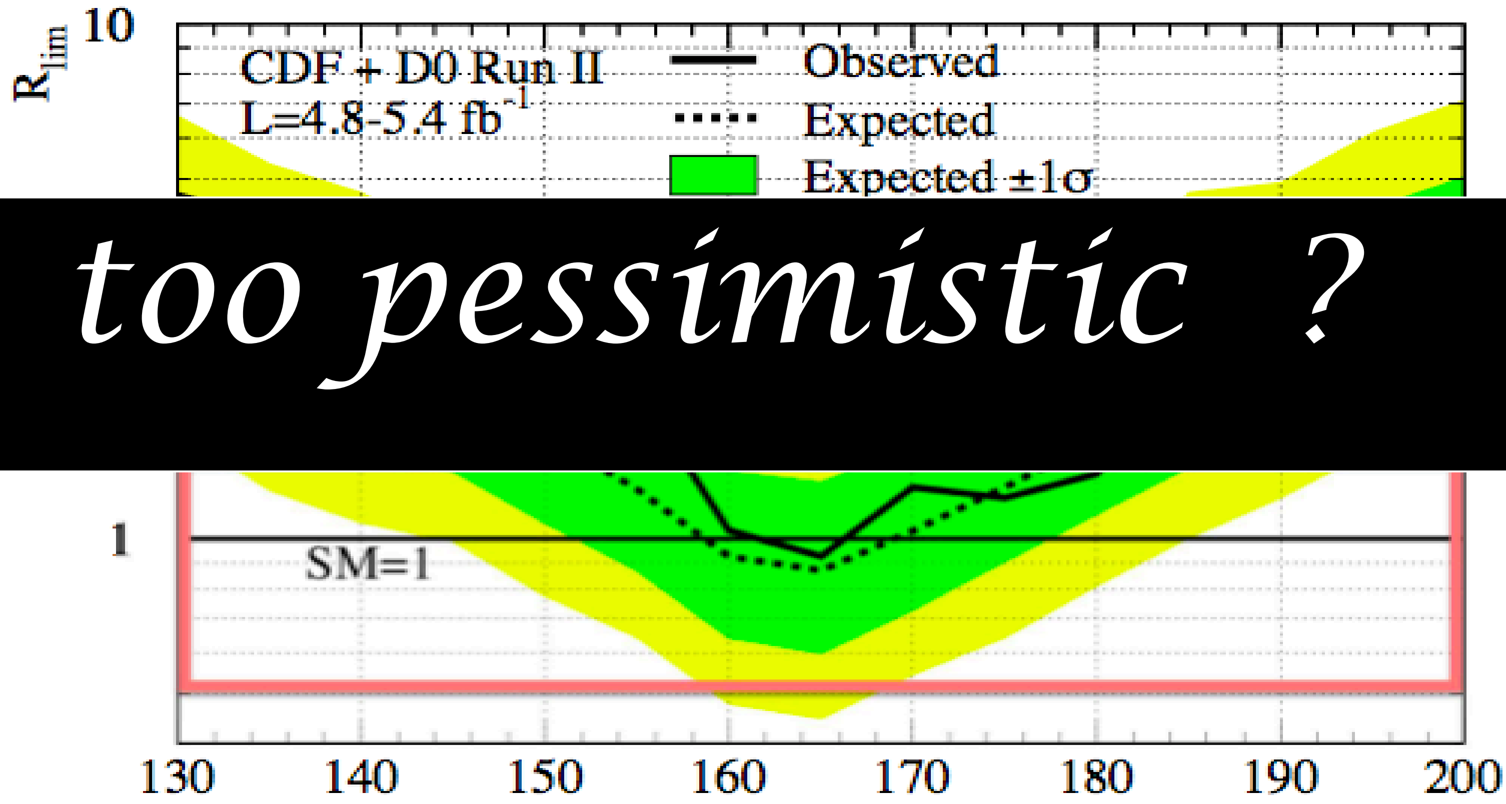

too pessimistic ?

95% CL CDF/D0 exclusion limit 162 $\leq M_H \leq$ 166 GeV **not credible ?**

Djouadi

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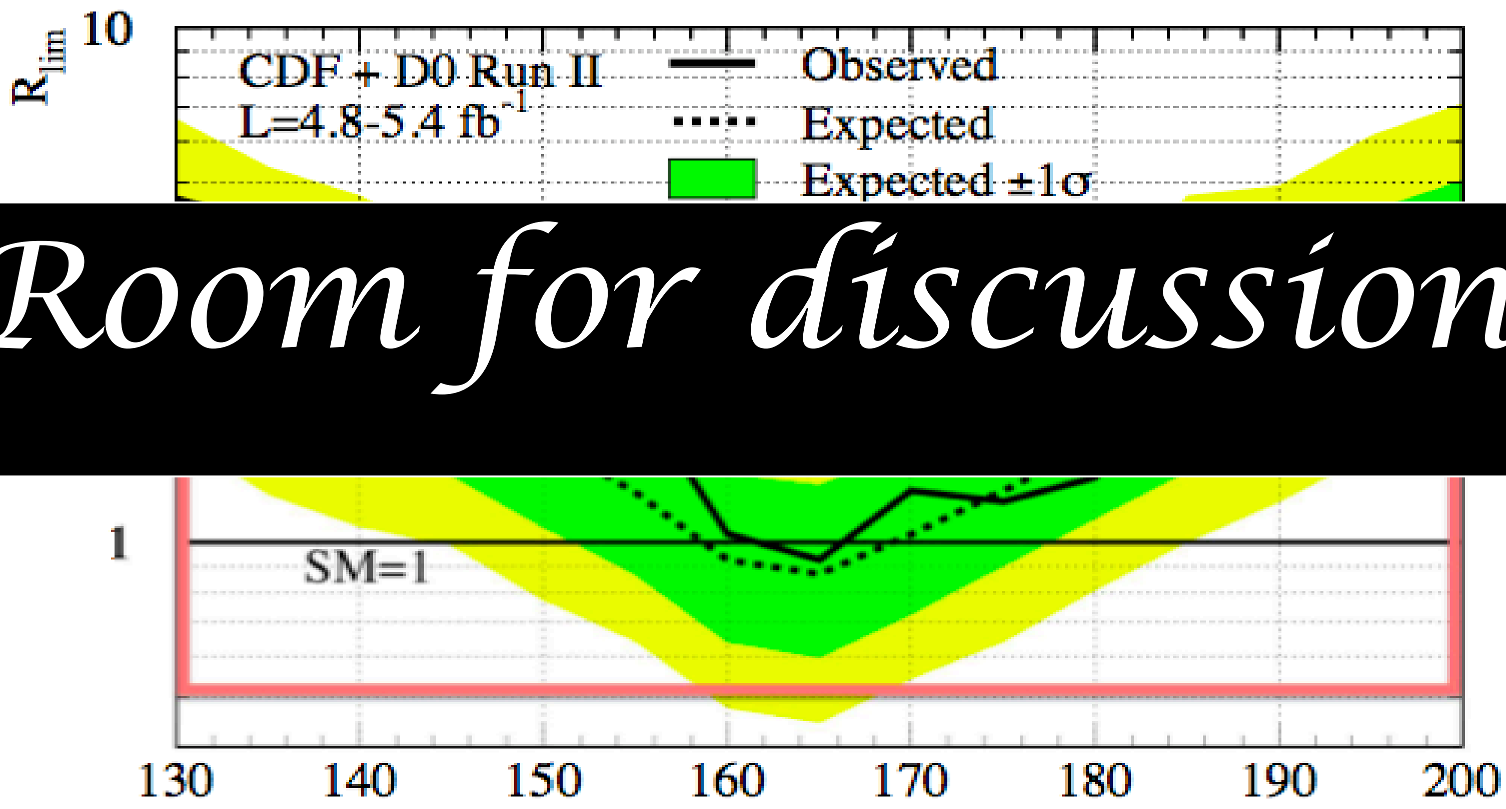

Room for discussion

reconsider 95% CL CDF/D0 exclusion limit 162$\leq M_H \leq$166 GeV ?

Djouadi

How to combine errors?

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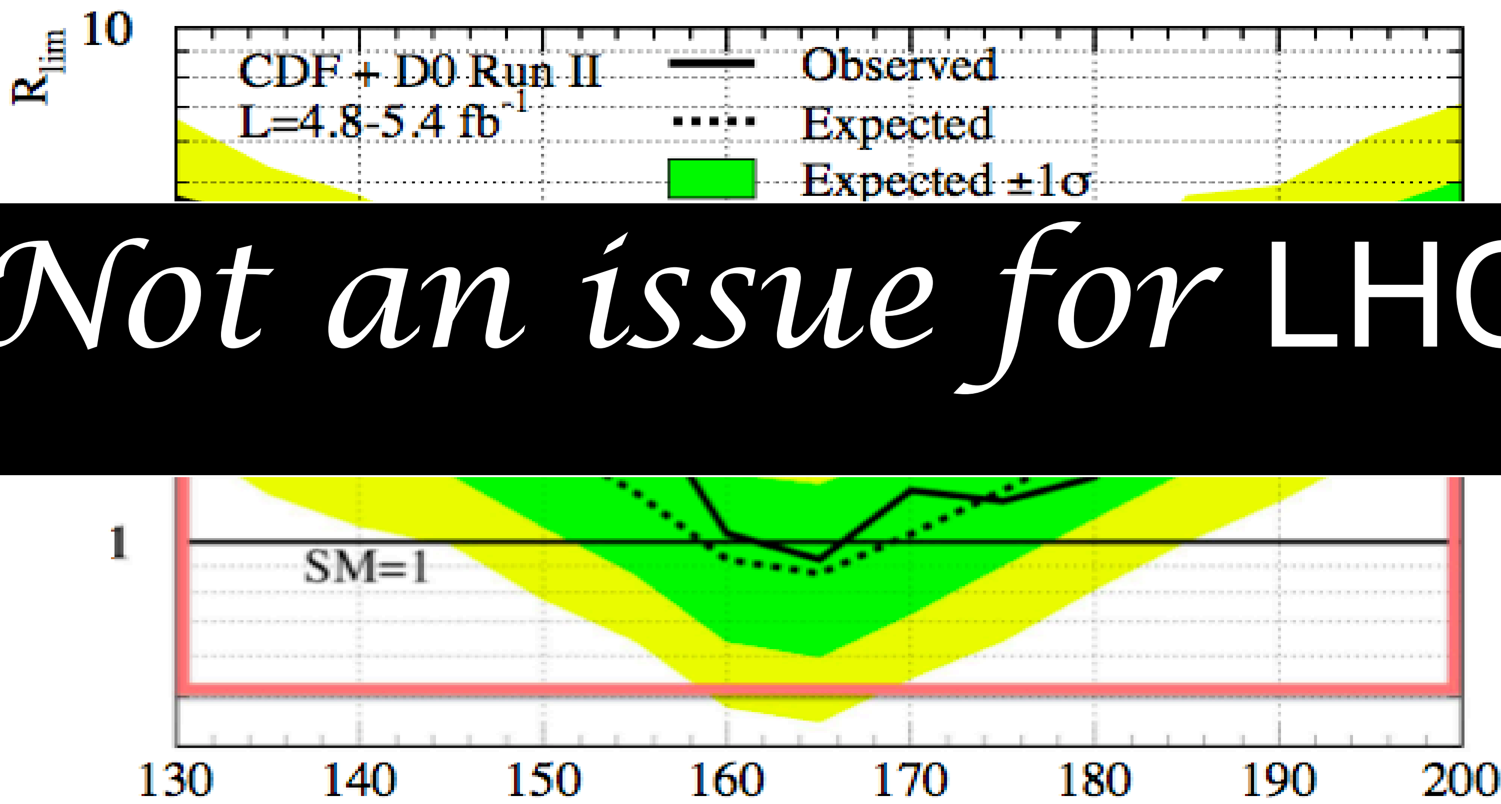


Not an issue for LHC

reconsider 95% CL CDF/D0 exclusion limit 162 $\leq M_H \leq$ 166 GeV ?

The mass of the top

Direct determination of the MS top mass

Using total cross section as a function of m_{top}

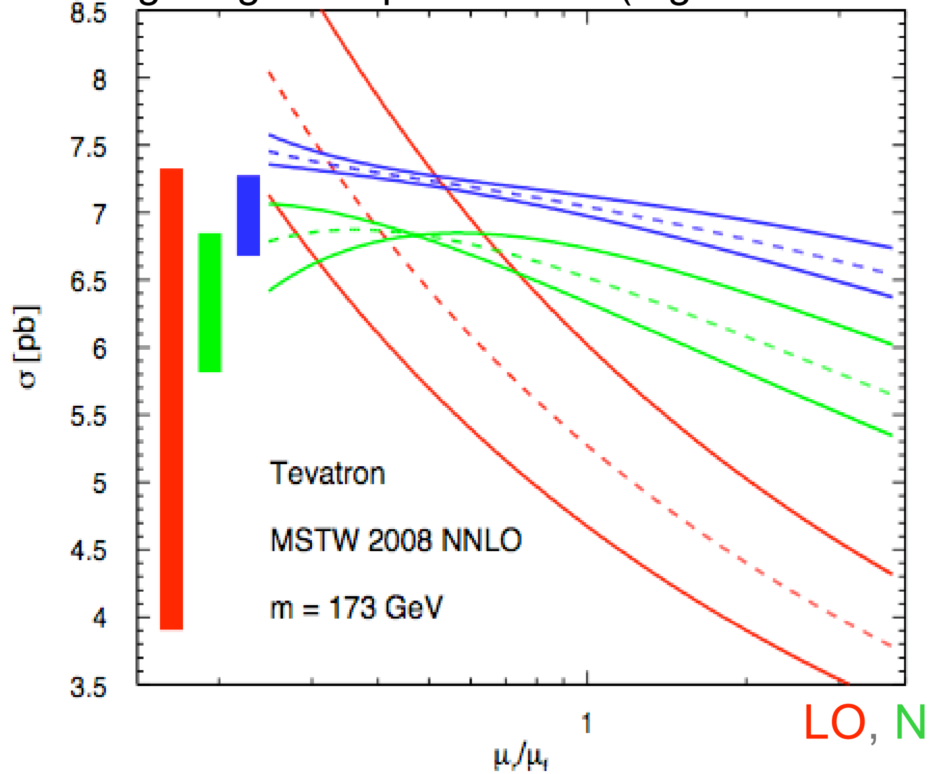
to minimize non-perturbative effects

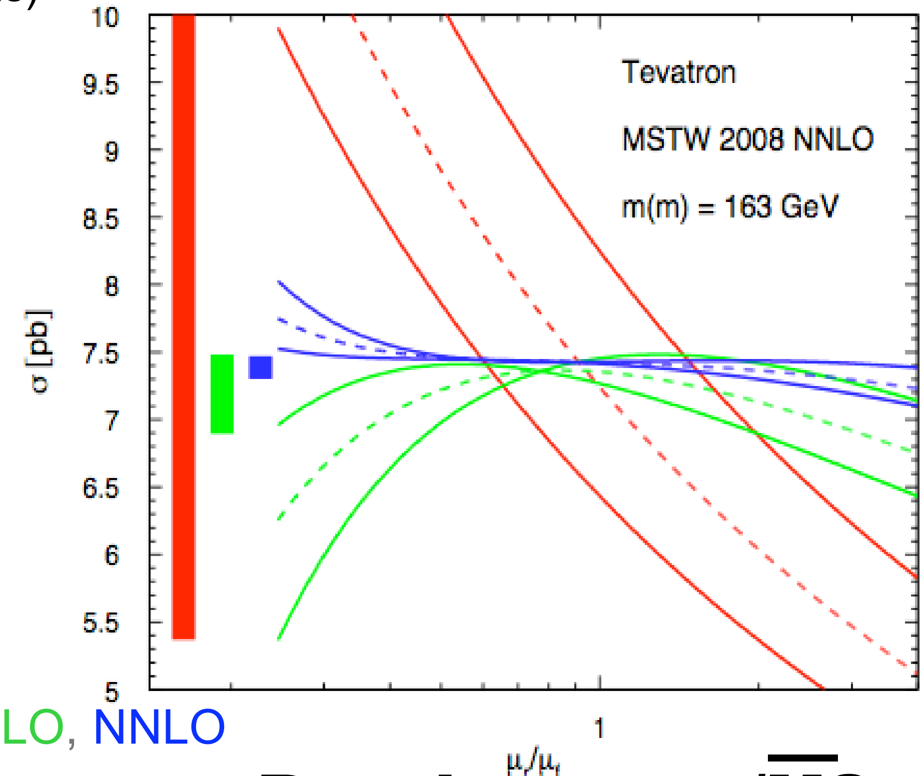
Uwer

- Include all threshold logarithms at 2-loop based on NNLL resummation + …

[Moch,P.U. 08]

long-range non-pert. effects (e.g. renormalons)





LO, NLO, NNLO

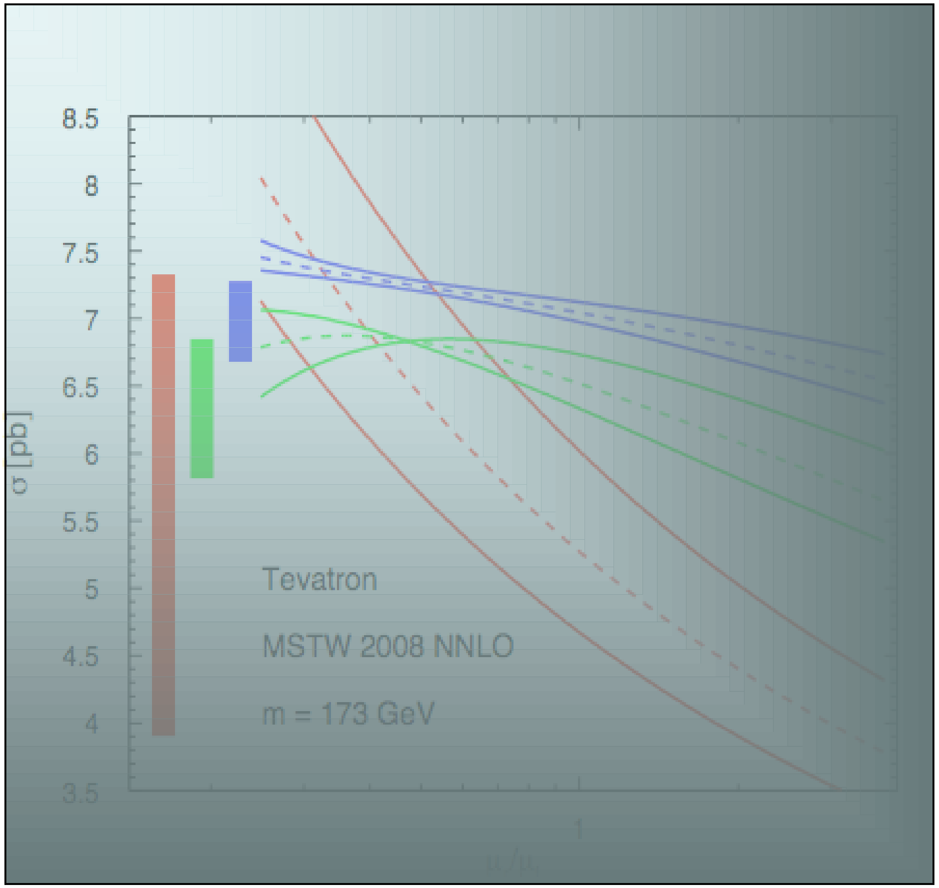
Pole-mass / on-shell

Running mass/$\overline{\text{MS}}$

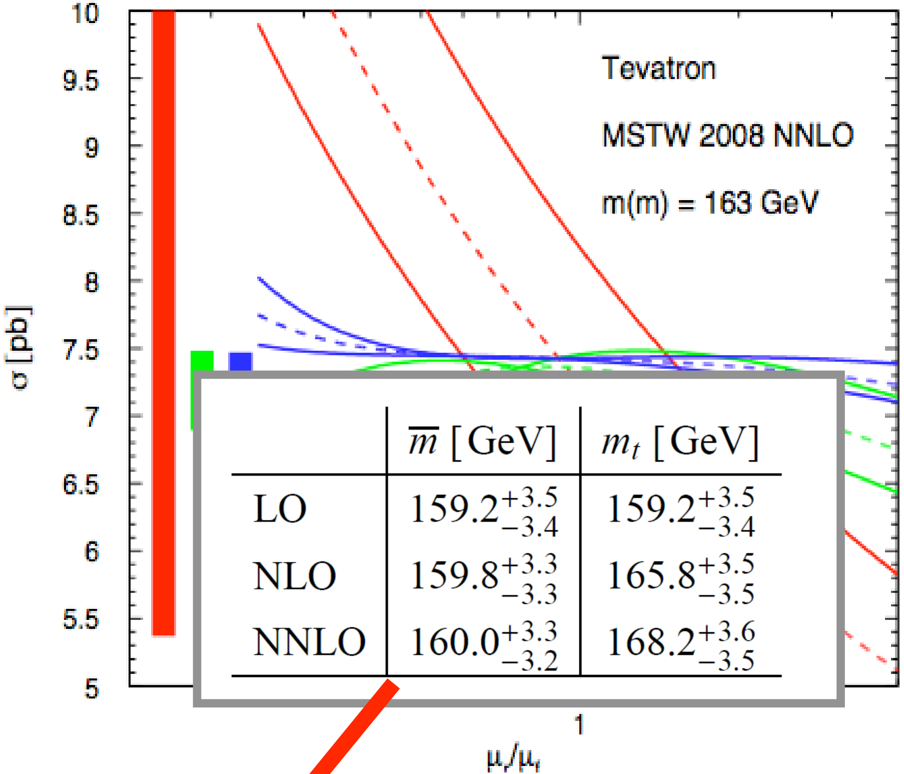
→ Perturbation theory better behaved !

Tevatron, D0

Uwer



Running mass/MS

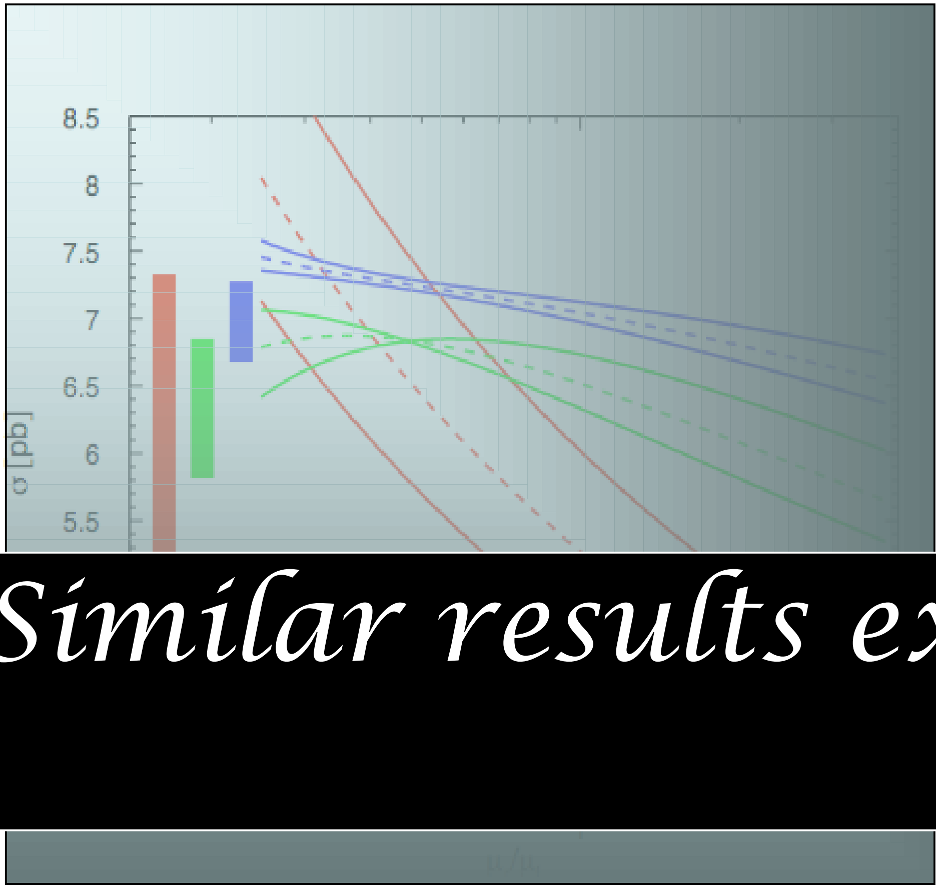


	$\overline{m}$ [GeV]	m_t [GeV]
LO	$159.2^{+3.5}_{-3.4}$	$159.2^{+3.5}_{-3.4}$
NLO	$159.8^{+3.3}_{-3.3}$	$165.8^{+3.5}_{-3.5}$
NNLO	$160.0^{+3.3}_{-3.2}$	$168.2^{+3.6}_{-3.5}$

Pole-mass $m_t = 168.9^{+3.5}_{-3.4}$

Tevatron, D0

Uwer



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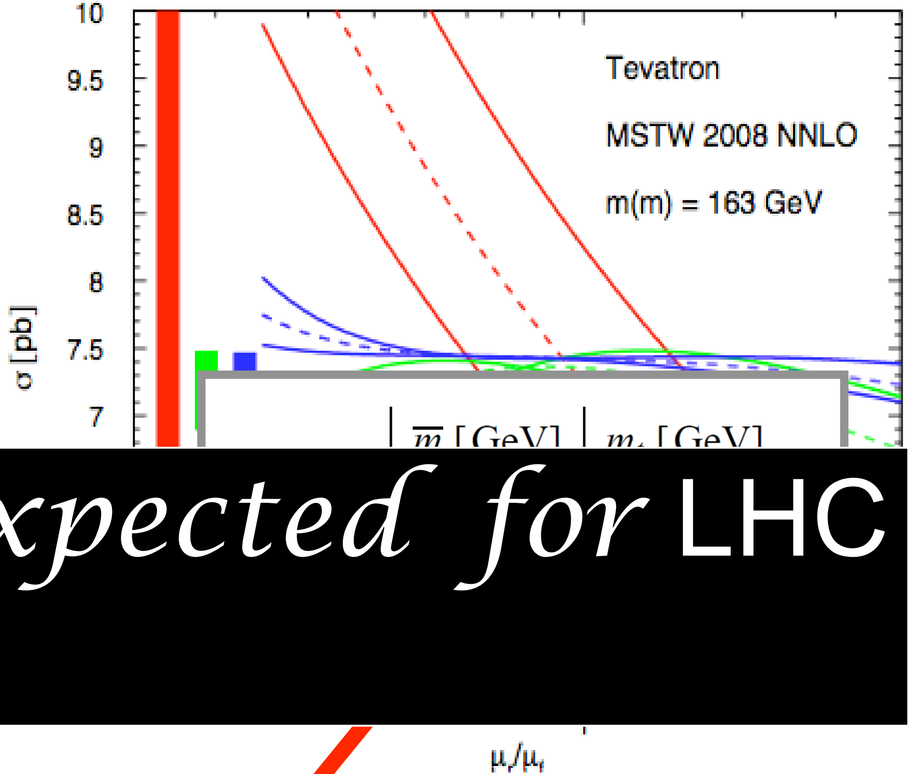

Similar results expected for LHC

Pole-mass $m_t = 168.9^{+3.5}_{-3.4}$

Tevatron, D0

Is the “Higgs signal” a SM Higgs ?

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* what QUANTUM NUMBERS? (spin, parity…) ?
pure state ?

* Even if it is a 0^+ , are COUPLING STRENGTHS as in SM?
i.e. SM Yukawa or gauge couplings?

….. and in a model independent way ?

Is the “Higgs signal” a SM Higgs?

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  i.e. SM **Yukawa** or gauge couplings?

i fermion masses may have
different origin than gauge boson masses

….. and in a model independent way ?

Rauch :

Assume your signal is a scalar "Higgs":
are its couplings SM ones?

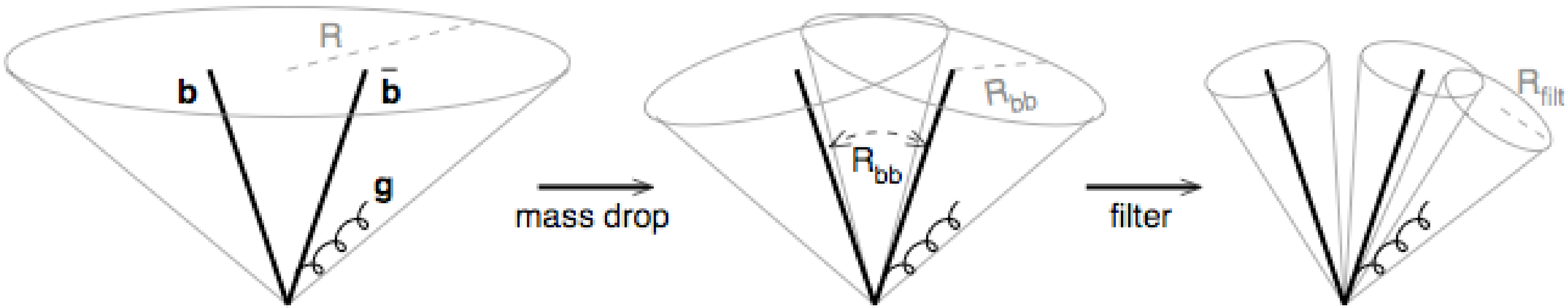
SM with deviations Δ_{ijH} allowed in Higgs coupling
(Yukawa´s, gauge, effective Higgs-gg,…).

SM tree-level → $g_{jjH} \longrightarrow g_{jjH}^{SM} \left(1 + \Delta_{jjH}\right)$

SM one-loop → $g_{jjH} \longrightarrow g_{jjH}^{SM} \left(1 + \Delta_{jjH}^{SM} + \Delta_{jjH}\right)$

Light Higgs , H --> bb

fat jets



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Rauch : SM with deviations Δ_{ijH} allowed in Higgs coupling

Errors obtained by 10,000 toy experiments:
SM hypothesis, $m_H = 120$ GeV, $\mathcal{L} = 30$ fb^{-1}
Fit with Gaussian of the central part within one standard deviation

Light Higgs

	no eff. couplings			with eff. couplings			ratio $\Delta_{ijH/WWH}$		
	σ_{symm}	σ_{neg}	σ_{pos}	σ_{symm}	σ_{neg}	σ_{pos}	σ_{symm}	σ_{neg}	σ_{pos}
Δ_{WWH}	±0.23	-0.21	$+0.26$	±0.24	-0.21	$+0.27$	—	—	—
Δ_{ZZH}	±0.36	-0.40	$+0.35$	±0.31	-0.35	$+0.29$	±0.41	-0.40	$+0.41$
Δ_{ttH}	±0.41	-0.37	$+0.45$	±0.53	-0.65	$+0.43$	±0.51	-0.54	$+0.48$
Δ_{bbH}	±0.45	-0.33	$+0.56$	±0.44	-0.30	$+0.59$	±0.31	-0.24	$+0.38$
$\Delta_{\tau\tau H}$	±0.33	-0.21	$+0.46$	±0.31	-0.19	$+0.46$	±0.28	-0.16	$+0.40$
$\Delta_{\gamma\gamma H}$	—	—	—	±0.31	-0.30	$+0.33$	±0.30	-0.27	$+0.33$
Δ_{ggH}	—	—	—	±0.61	-0.59	$+0.62$	±0.61	-0.71	$+0.46$
m_H	±0.26	-0.26	$+0.26$	±0.25	-0.26	$+0.25$			
m_b	±0.071	-0.071	$+0.071$	±0.071	-0.071	$+0.072$			
m_t	±1.00	-1.03	$+0.98$	±0.99	-1.00	$+0.98$			

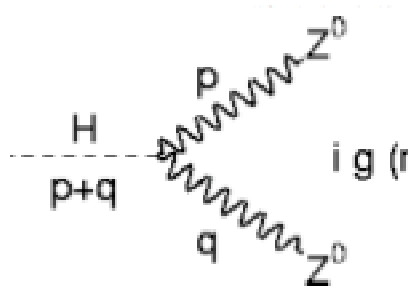
SFitter

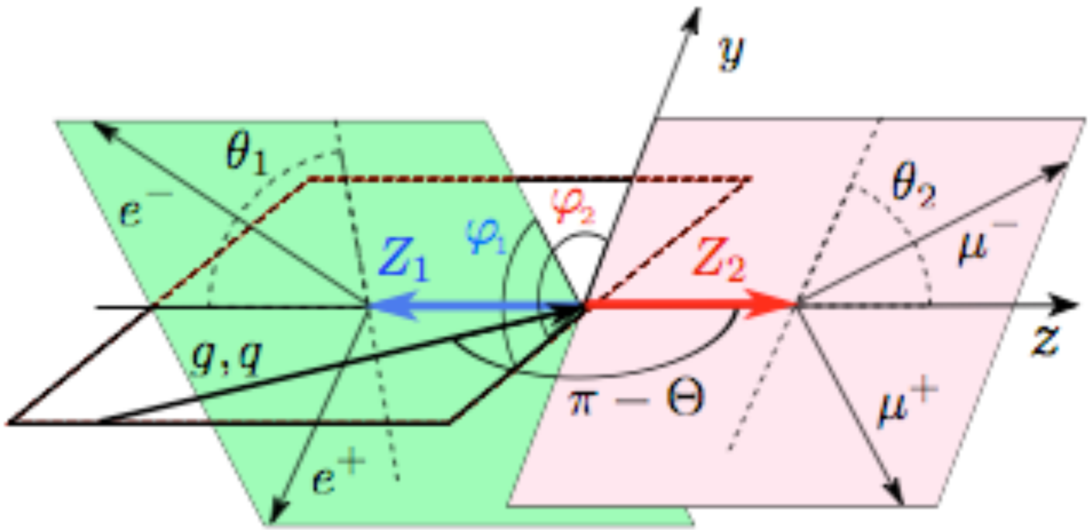
claims sensitivity to deviations of **#10%** with 30 fb^{-1}, m_H=120 GeV

* How to determine its QUANTUM NUMBERS? (spin, parity…) ?

Rogan: exploit golden channel and angular correlations

$$H \to ZZ^* \to \ell_1^+ \ell_1^- \ell_2^+ \ell_2^-$$





“Higgs” Spin

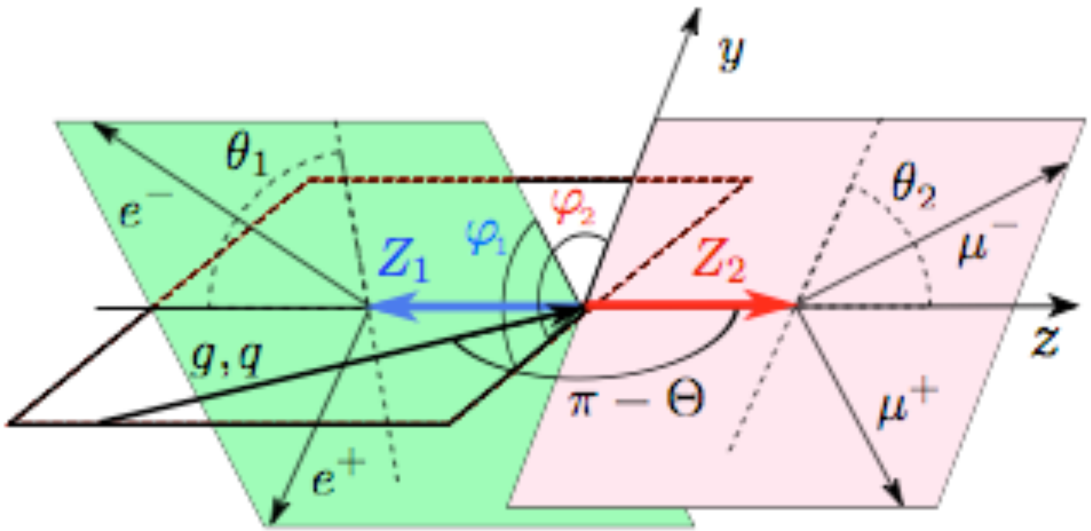
What are the quantum numbers?

SM: X=1

0 $$L_{\mu\alpha} = X\, g_{\mu\alpha} - (Y + i\,Z)\,\frac{k_\alpha k_\mu}{M_Z^2} + (P + i\,Q)\,\epsilon_{\mu\alpha}\frac{p_1 p_2}{M_Z^2}\,,$$

1 $$L^{\rho\mu\alpha} = X\,(g^{\rho\mu}\,p_1^\alpha + g^{\rho\alpha}\,p_2^\mu) + (P + i\,Q)\,\epsilon^{\rho\mu\alpha}(p_1 - p_2)$$

2^+ $$\begin{aligned} L^{\rho\sigma\mu\alpha} = \;& X_0\, m_H^2\, g^{\mu\rho}\, g^{\alpha\sigma} \\ & + (X_1 + i\,Y_1)\,(p_1^\alpha\, p_2^\rho\, g^{\sigma\mu} + p_1^\rho\, p_2^\mu\, g^{\sigma\alpha}) \\ & + (X_2 + i\,Y_2)\, p_1^\rho\, p_2^\sigma\, g^{\mu\alpha}, \end{aligned}$$

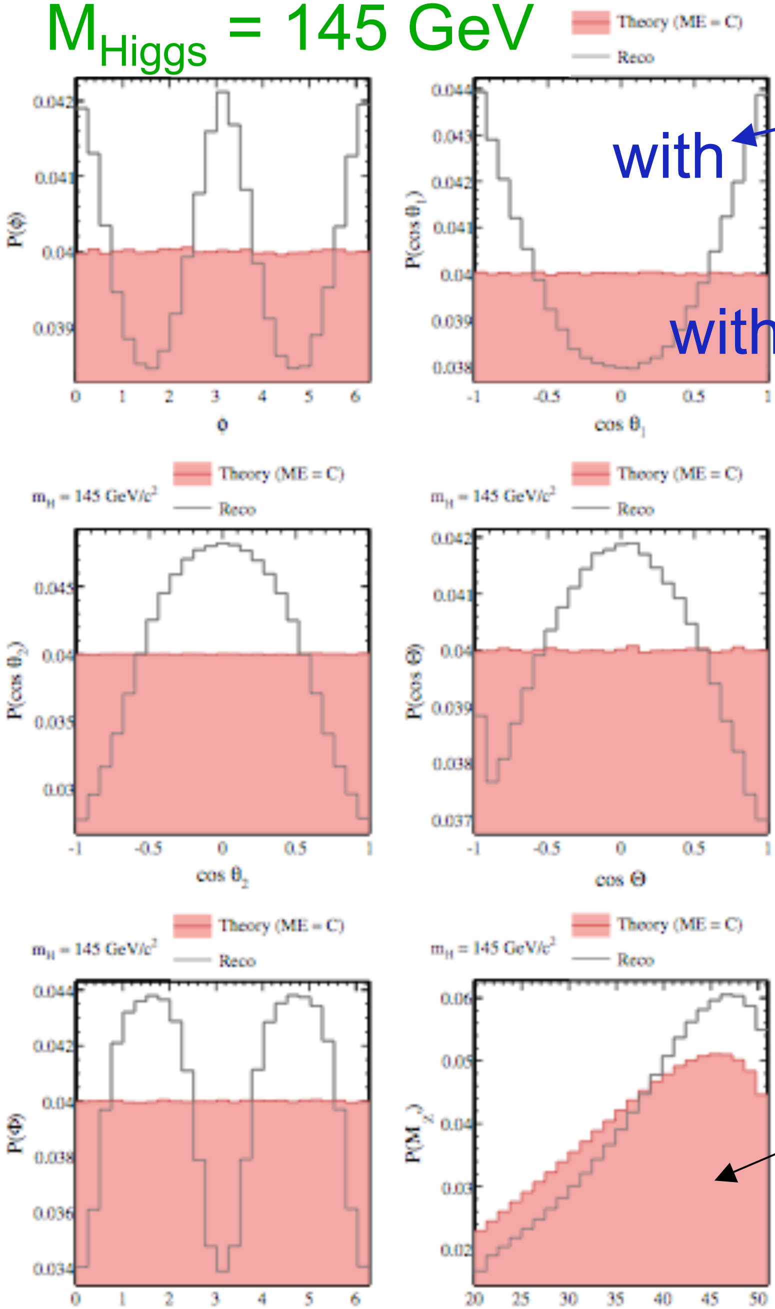


Five relevant angular variables

•Refine much previous analysis +detector phase-space acceptance (CMS)

•

M_{Higgs} = 145 GeV



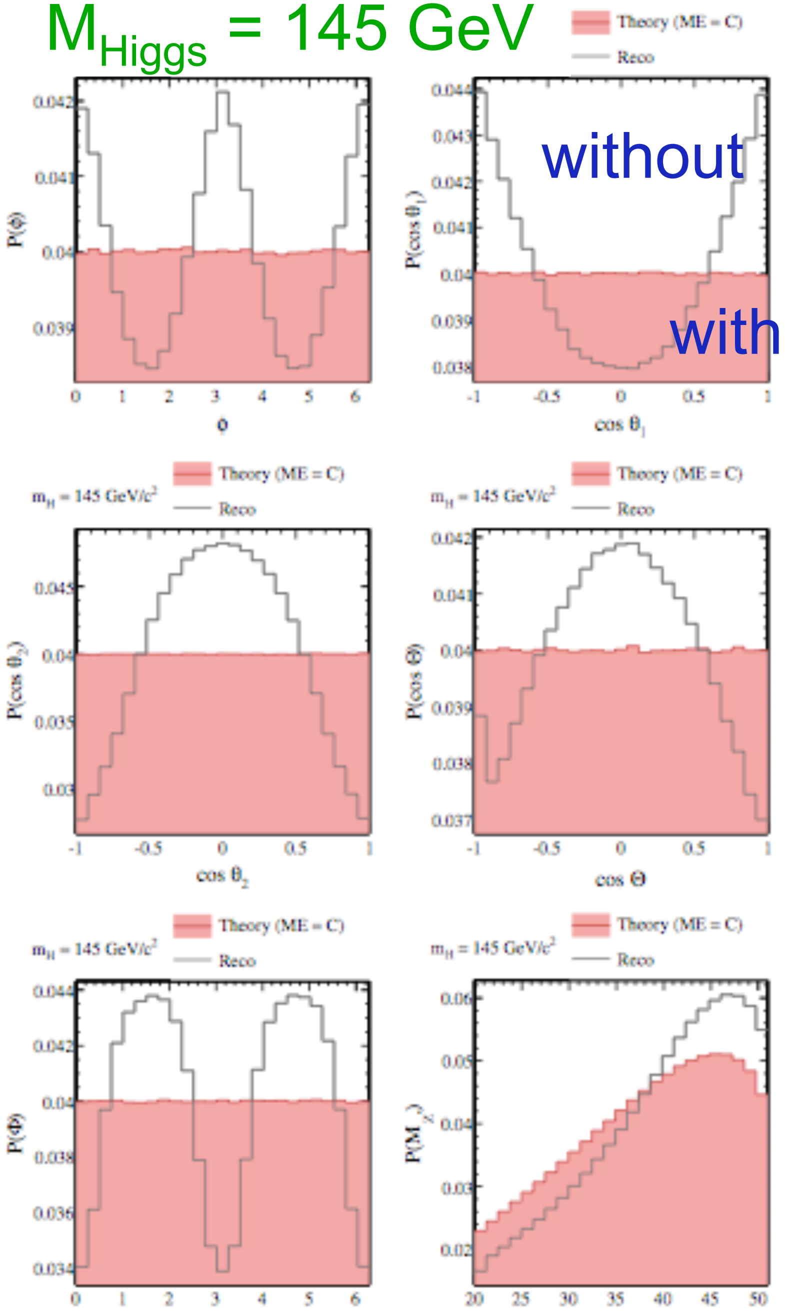
with

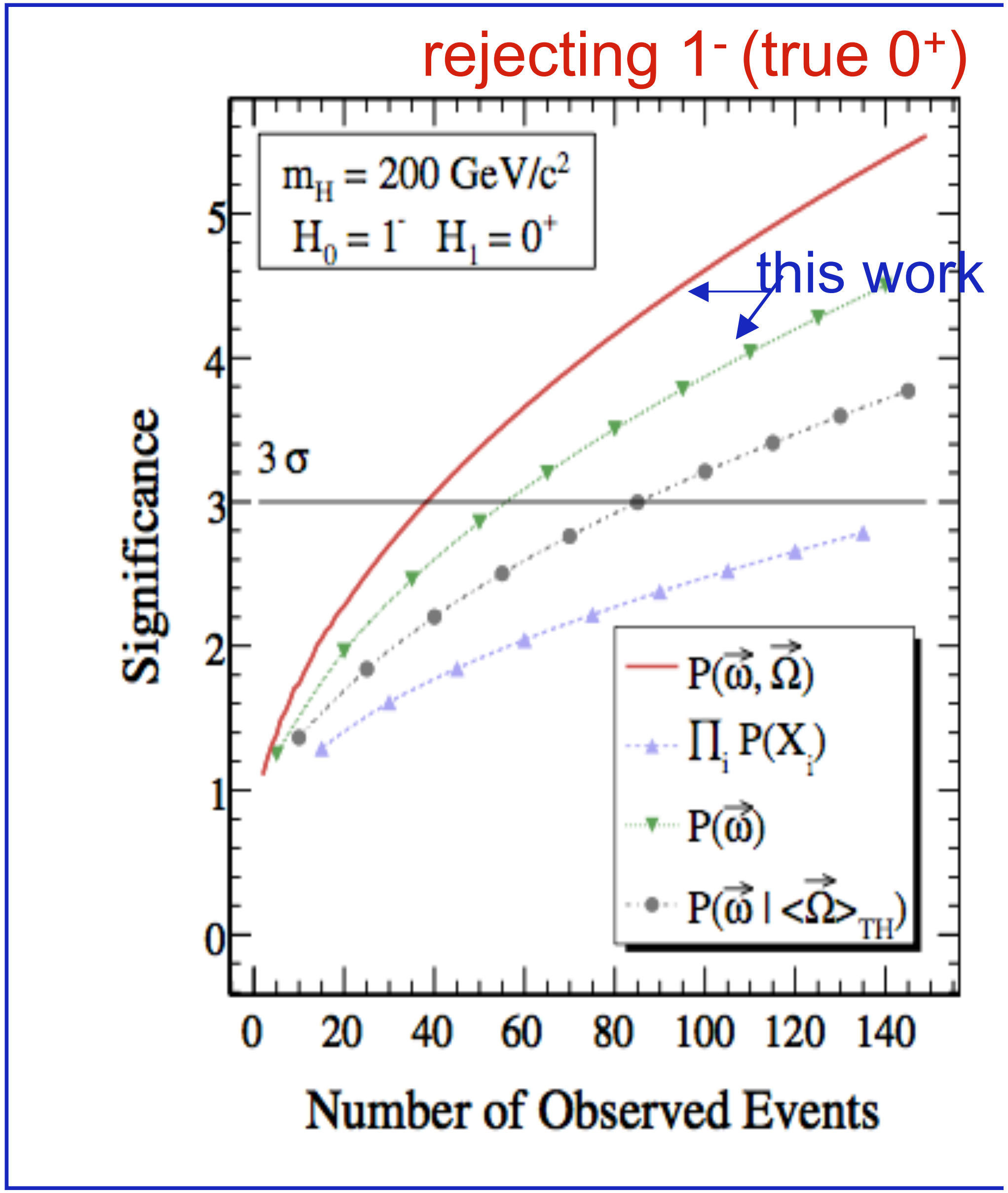
without

Detector sculpting of flat angular distributions

Detector sculpting of M(Z) distribution

- Refine much previous analysis +detector phase-space acceptance (CMS)
- M_{Higgs} = 145 GeV





Beyond the SM models

BSM because

1) **Experimental evidence** for new particle physics:

*** **Neutrino masses**
*** **Dark matter**

2) **SM fine-tunings/uneasiness**, i.e. in electroweak:

*** **Hierarchy problem**
*** **Flavour puzzle**

BSM electroweak

* **HIERARCHY PROBLEM**

fine-tuning issue: if BSM physics, why Higgs so light

Interesting mechanisms to solve it from SUSY;
strong-int. Higgs, extra-dim….

In practice, none without further fine-tunings

• **FLAVOUR PUZZLE**: no progress

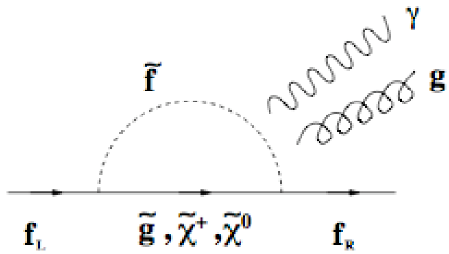
BSMs tend to make it worse

understanding stalled since 30 years,
Only new B physics data AND neutrino masses and mixings

The FLAVOUR WALL for BSM

i) Typically, BSMs have **electric dipole moments** at one loop

i.e susy MSSM:

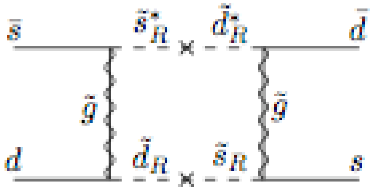


< 1 loop in SM ---> **Best (precision) window of new physics**

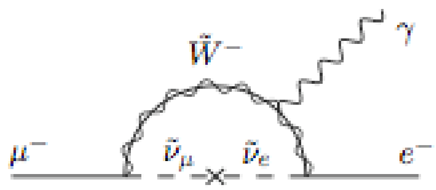
ii) **FCNC**

i.e susy MSSM:

$K^0 - \overline{K}^0$ mixing



$\mu \to e\gamma$



competing with SM at one-loop

Facing the FLAVOUR WALL in MSSM

Susy Flavour problem

Lavignac

culprit: susy breaking

$$\begin{aligned}
\mathcal{L}_{\rm soft}^{\rm MSSM} \;=\; & -\frac{1}{2}\left(M_3\,\tilde{g}\tilde{g} + M_2\,\tilde{W}\tilde{W} + M_1\,\tilde{B}\tilde{B} + \text{h.c.}\right) \\
& -\left(A_u\,\tilde{Q}\tilde{\bar{u}}H_u - A_d\,\tilde{Q}\tilde{\bar{d}}H_d - A_e\,\tilde{L}\tilde{\bar{e}}H_d + \text{h.c.}\right) \\
& -\tilde{Q}^\dagger m_Q^2\,\tilde{Q} - \tilde{L}^\dagger m_L^2\,\tilde{L} - \tilde{\bar{u}}^\dagger m_{\bar{u}}^2\,\tilde{\bar{u}} - \tilde{\bar{d}}^\dagger m_{\bar{d}}^2\,\tilde{\bar{d}} - \tilde{\bar{e}}^\dagger m_{\bar{e}}^2\,\tilde{\bar{e}} \\
& -m_{H_u}^2\,H_u^\dagger H_u - m_{H_d}^2\,H_d^\dagger H_d - \left(B\mu\,H_u H_d + \text{h.c.}\right)
\end{aligned}$$

One way to avoid dangerous FCNC

is $\boxed{\text{universal soft terms: } (m_Q^2)_{ij} \approx m^2 \delta_{ij}}$

magic
recipee

MSSM -------------------------------> cMSSM

~100 free parameters -------------> a few

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constrained

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MSSM ---------------------------------> cMSSM

~100 free parameters --------------> a few

You can view this as $\left\{ \right.$ a) Inspired from mSUGRA

Quantifying tuning and probability

Assuming **c**MSSM (= mSUGRA), how fine-tuned/probable is the model? We heard:

i) A quantification of the remaining little hierarchy fine-tuning

Cassel

---> some regions with light Higgs still allow ~ 10% fine-tunning

ii) A thorough improved Bayesian sweep over the **c**MSSM parameter space.

Bayesian statistics quantifies one's degree of belief in inputs and results

Cabrera

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ii) A thorough improved Bayesian sweep over the **c**MSSM parameter space.

Cabrera

* again, light Higgs favored
* "sizeable probability of not discovering susy at LHC" (i.e. 50% with 1 fb^{-1})

… if it is there at all

One way to avoid dangerous FCNC

is **universal soft terms:** $(m_Q^2)_{ij} \approx m^2\delta_{ij}$

magic recipee

MSSM --------------------------------> **c**MSSM

~100 free parameters -------------> a few

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b) Put by hand

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Where did naturalness go?

One way to avoid dangerous FCNC

is $\boxed{\text{universal soft terms: } (m_Q^2)_{ij} \approx m^2 \delta_{ij}}$ magic recipee

MSSM ---------------------------------> **c**MSSM

~100 free parameters -------------> a few

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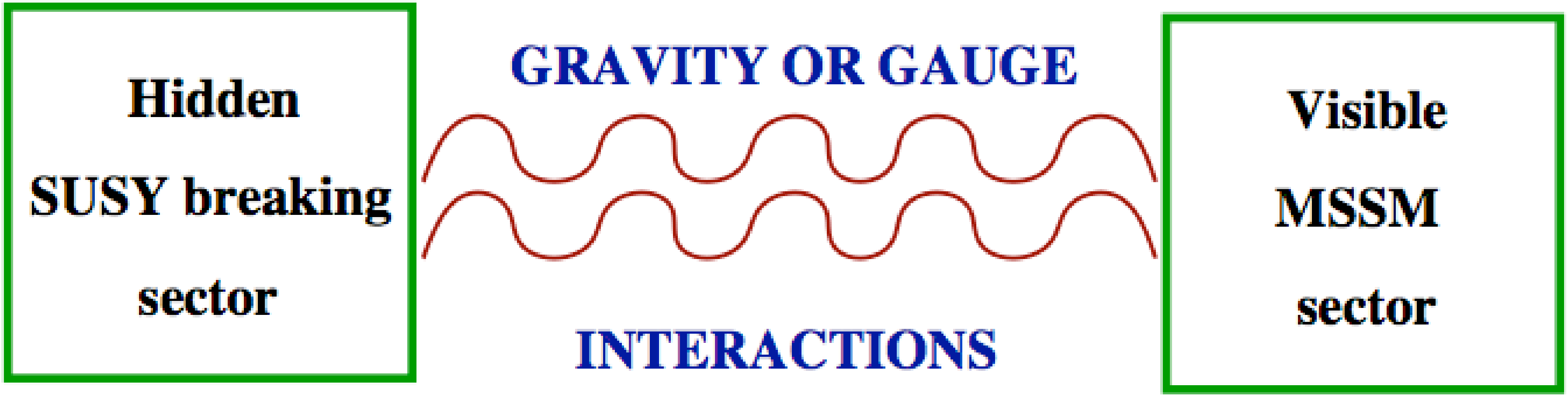
Do you have a better way ?

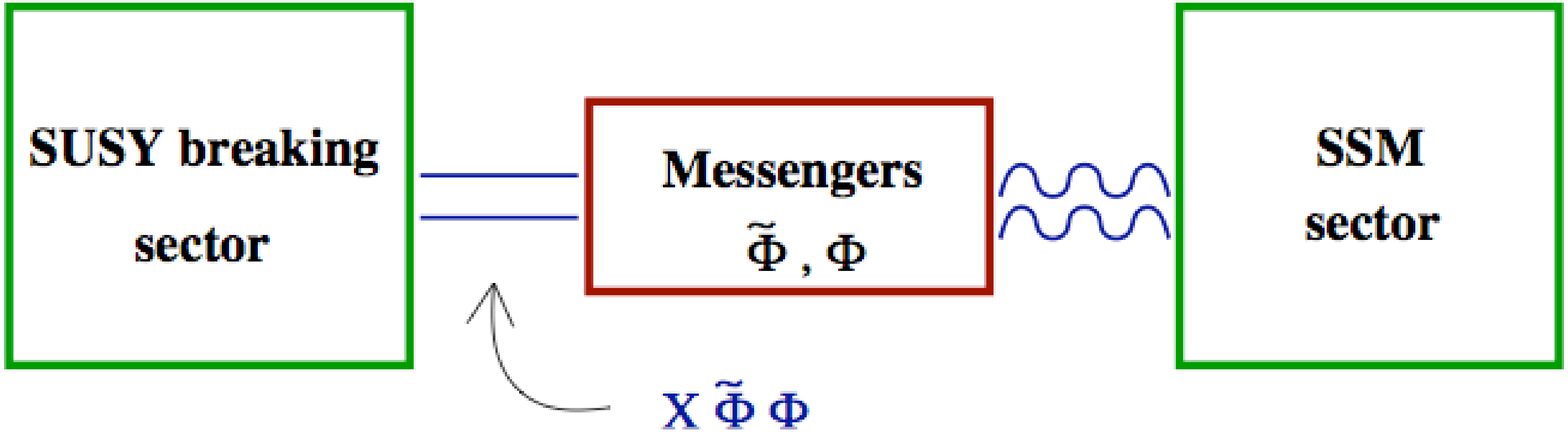
GAUGE MEDIATION



Mariotti,

Facing the FLAVOUR WALL in MSSM

GAUGE MEDIATION



Loop suppressed FLAVOUR transitions and other advantages

Nevertheless: μ, $B\mu$ and other problems remain/worsen

* LSP in gauge mediation: gravitino

Lavignac: Combining gauge mediation with unification

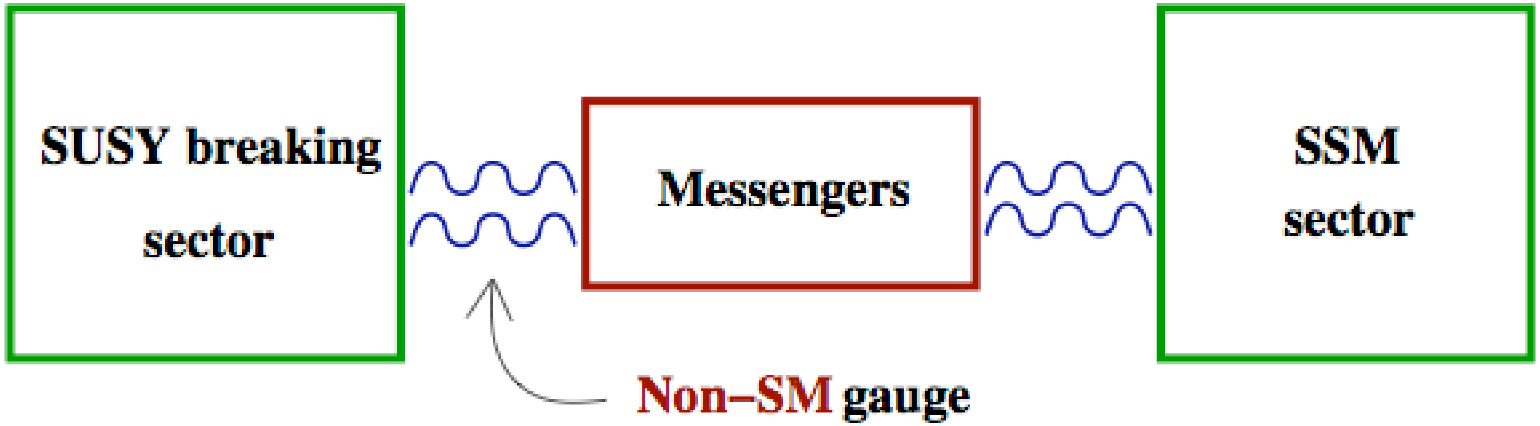
* LSP may be neutralino (bino)

  - NLSP may be gravitino or gluino

Mariotti,

Facing the FLAVOUR WALL in MSSM

SEMI-DIRECT GAUGE MEDIATION



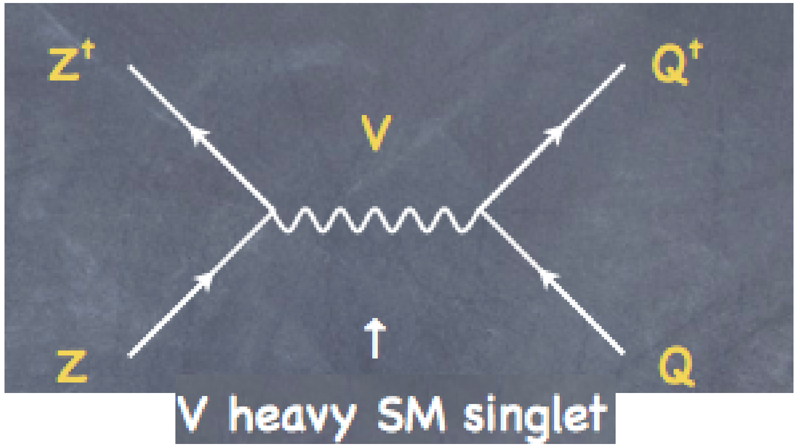
More loop suppressed FLAVOUR transitions and other advantages

Nevertheless: μ, $B\mu$ and other problems remain/worsen

Nardecchia

Facing the FLAVOUR WALL in MSSM

TREE-LEVEL GAUGE MEDIATION...... possible!



Suppressed FLAVOUR transitions and other advantages

μ, $B\mu$ and other problems perhaps ameliorate ?

Facing the FLAVOUR WALL in MSSM

GAUGE MEDIATION

Is this better ?

Facing the FLAVOUR WALL in MSSM

GAUGE MEDIATION

Did naturalness survive ?

Facing HIERARCHY in MSSM

The great attractive of weak scale susy:

*** The Higgs mass is protected from quadratic dependences on new heavy physics scales**

(also provides dark matter candidates….. nice)

The rest is not so bright….

“little hierarchy” problem ~1%, and more

Ellwanger **Facing HIERARCHY in MSSM**

* You need to add a crossed term $B\mu\, H_u\, H_d$ with $\mu \sim$ 100 GeV

NMSSM: justify μ as $\mu = \langle S \rangle$

* This could help too with the "little hierarchy" problem ~1% ->
i.e. It has **singlet** scalars:

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i) **adjust** CP-odd scalar A_1 H --> A_1 A_1, m_{A1} ~10 GeV

Singlino LSP — $\sim 4\ \tau$'s per Susy event
— possibly displaced vertices from stau-decays!

"No Higgs" at the LHC can be a signal

Domingo : η_b-A_1 mixing also possible

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SIGNALS

"N

S

until this Tuesday... *Cranmer* : LEP data

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SIGNALS

Cranmer : LEP data

Forget τ signals … and charmed ones *(Grivaz)*

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But NMSSM also has to face the Flavour wall:

NMSSM ----------- > **c**NMSSM

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* **mSUGRA ?**
or
* **BY HAND ?**

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Where did naturalness go??

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Do you have a better model?

ii) **adjust** CP-even scalar and account for Lep excess-hints

But NMSSM also has to face the Flavour wall:
NMSSM ----------- > **c**NMSSM

* **mSUGRA ?**

or

* **BY HAND ?**

Antoniadis : **NOT QUITE**

rather try something else: stay away from preconceived models

Facing HIERARCHY in MSSM

- Effective actions with higher-dim/hdo:

  appropriate tools to parametrize our ignorance about new physics

guided by symmetries

Antoniadis **Facing HIERARCHY in MSSM**

- Effective actions with higher-dim/hdo:

  appropriate tools to parametrize our ignorance about new physics

•Sticks to MSSM to soften the large hierarchy gap

Adds effective operators to compensate the little hierarchy problem ~1% :

Antoniadis **Facing HIERARCHY in MSSM**

- Effective actions with higher-dim/hdo:

  appropriate tools to parametrize our ignorance about new physics

•Sticks to MSSM to soften the large hierarchy gap

Adds effective operators to compensate the little hierarchy problem ~1% :

* From singlet S, as in NMSSM but heavy-->

BSH_uH_d --> $\lambda\,(H_uH_d)^2$: extra free term to shift m_H

• Adds effective operators up to d=6

Antoniadis

Facing HIERARCHY in MSSM

- Effective actions with higher-dim/hdo:

  appropriate tools to parametrize our ignorance about new physics

•Sticks to MSSM to soften the large hierarchy gap

Adds effective operators to compensate the little hierarchy problem ~1% :

•Enhanced H → bb decays

•Enhanced squark pair production

•Heavier Higgs

•Lighter stop

Antoniadis **Facing HIERARCHY in MSSM**

- Effective actions with higher-dim/hdo:

  appropriate tools to parametrize our ignorance about new physics

•Sticks to MSSM to soften the large hierarchy gap

Adds effective operators to compensate the little hierarchy problem ~1% :

$\downarrow$

•With tunings, it is possible to lift the Higgs mass to

$$\boxed{\Rightarrow m_h \simeq 103 - 119 \text{ GeV}}$$

But FLAVOUR WALL : i.e. the induced corrections to Yukawa couplings are made flavour diagonal by hand

Bernal

Same than Antoniadis et al., but it is enough for them to

stop at $(H_uH_d)^2$ operators, in order to solve the little hierarchy

WHY?:

They do not impose positivity of the potential (unlike Antoniadis)

…. or not so strictly… (ok e.g. in models with 2 vaccua

… light stops, heavy sleptons

---> prospects for dark matter detection

In these MSSM+ effective approaches…

Aren't we trading the **little hierarchy** by the new distinct scale(s)

$M \neq M_{susy}$

which weight down the effective ops.?

while the whole point of susy EW was to avoid adjusting EW scales…

Are these examples alike to simply add
(heavy) scalar singlets ??

Facing the hierarchy problem without susy

To protect the Higgs mass -----> use a symmetry other than susy

• **i.e a global symmetry:** i.e. Technicolor

if it has a Higgs, it can be its ~Goldstone boson:

little Higgs, composite, some extra-dim…

Strong dynamics is good to give masses to W, Z

i.e. Technicolor , etc.

So is susy at the electroweak scale

Strong dynamics is good to give masses to W, Z

i.e. Technicolor , etc.

The main trouble also here used to be the FERMION WALL

Strong dynamics is good to give masses to W, Z

i.e. Technicolor , etc.

The main trouble also here used to be the FERMION WALL

Gripaios: Composite + Kaplan's idea…. FCNC could be OK;
predicts 50% deviations in Yukawa and gauge couplings

-->*Rauch's* talk

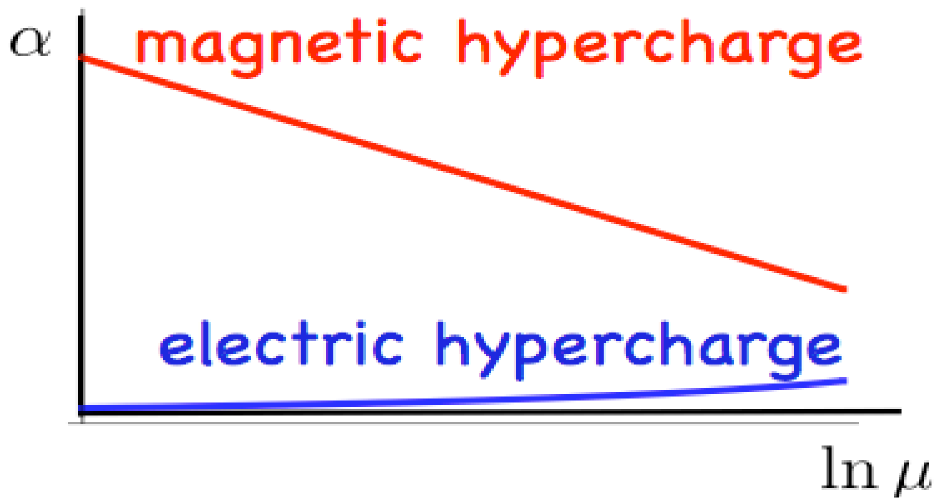
A Moriond scoop

Terning

Facing the hierarchy problem without susy

Magnetic Monopoles

a fourth generation with
magnetic charges?



Csaki, Terning, Shirman

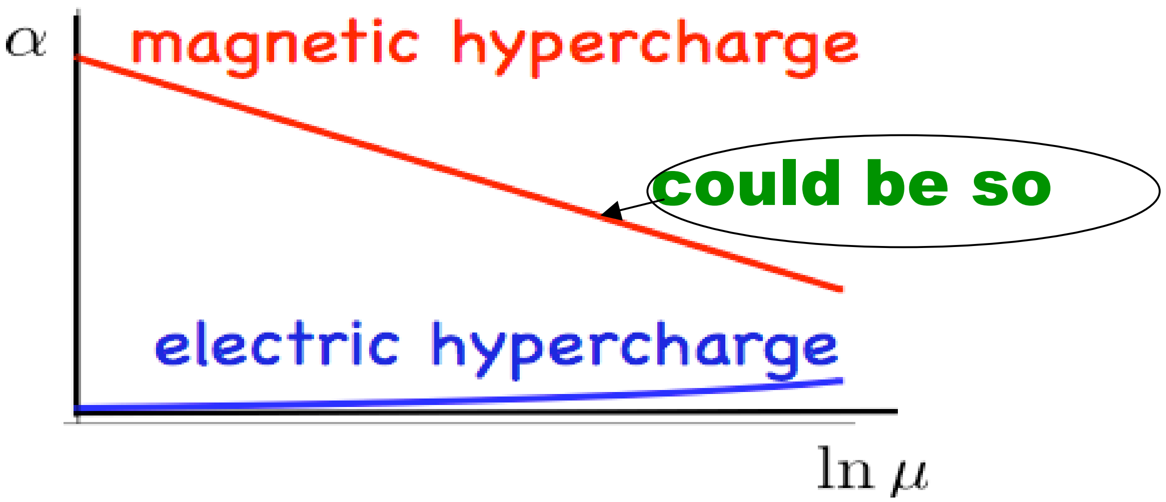
Facing the hierarchy problem without susy

Magnetic Monopoles

SM

a fourth generation with magnetic charges?

Strong dynamics →



Csaki, Terning, Sherman

→ it is as if you would be doing technicolor, but with gauge group U(1)

→ **it is as if you would be doing technicolor, but with gauge group U(1)**

-> At least one heavy up-type fermion: **heavy top built-in !** (Callan-Rubakov effect)

→**Neutrinos come out with zero mass**… this needs extension

→ Why other up-type quarks not so heavy as top quarks?

Even if no real monopole field theory… it is **stimulating**

?

→ **it is as if you would be doing technicolor, but with gauge group U(1)**

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→ Why other up-type quarks not so heavy as top quarks?

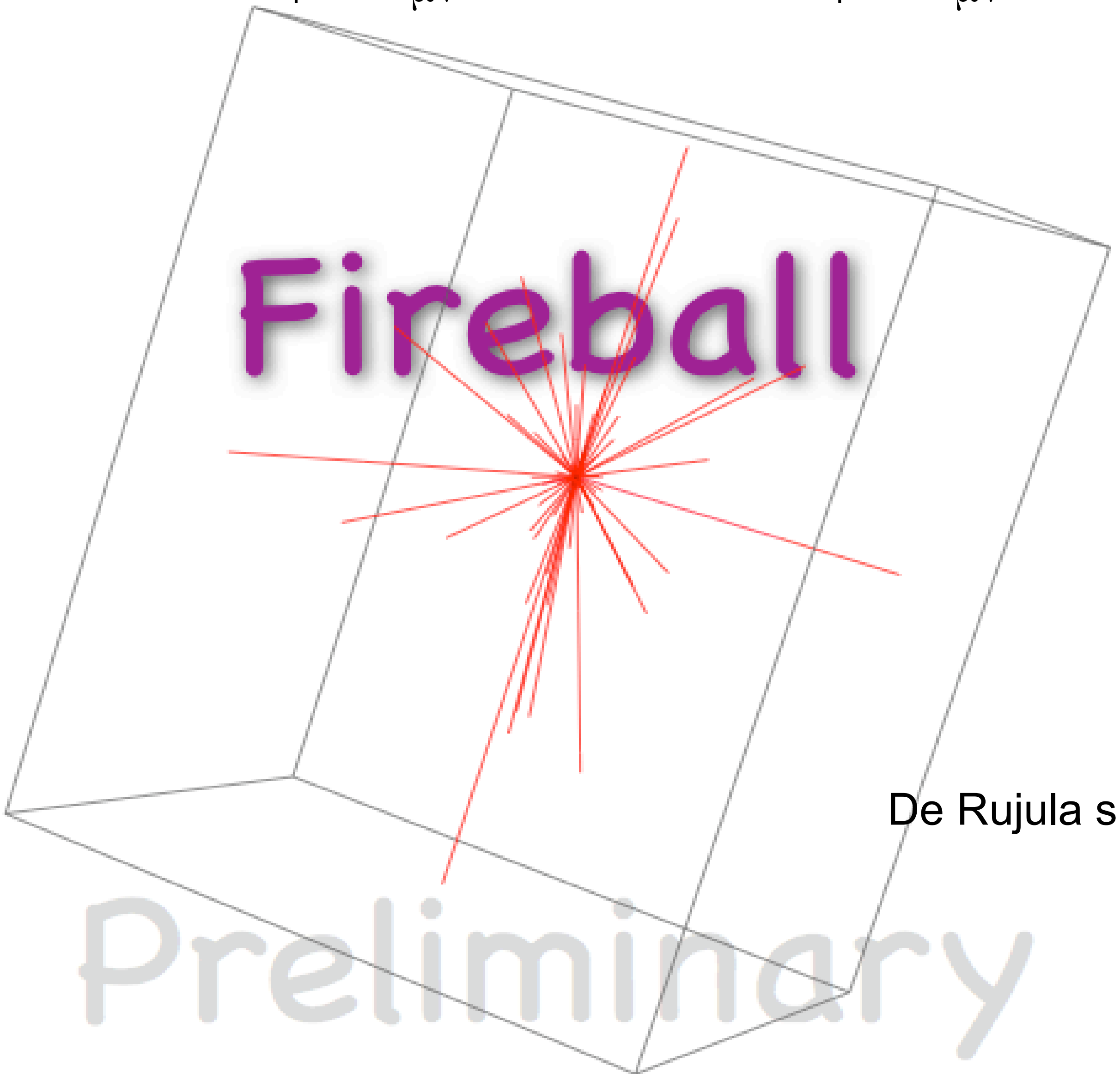
?

Even if no real monopole field theory… it is **stimulating**

Two fewer parameters than SM:

There is no Higgs

(maybe) SIGNAL ~ $1/M^n_{monopole}(F_{\mu\nu}F^{\mu\nu})^n, \quad 1/M^n_{monopole}(F_{\mu\nu}\tilde{F}^{\mu\nu})^n$

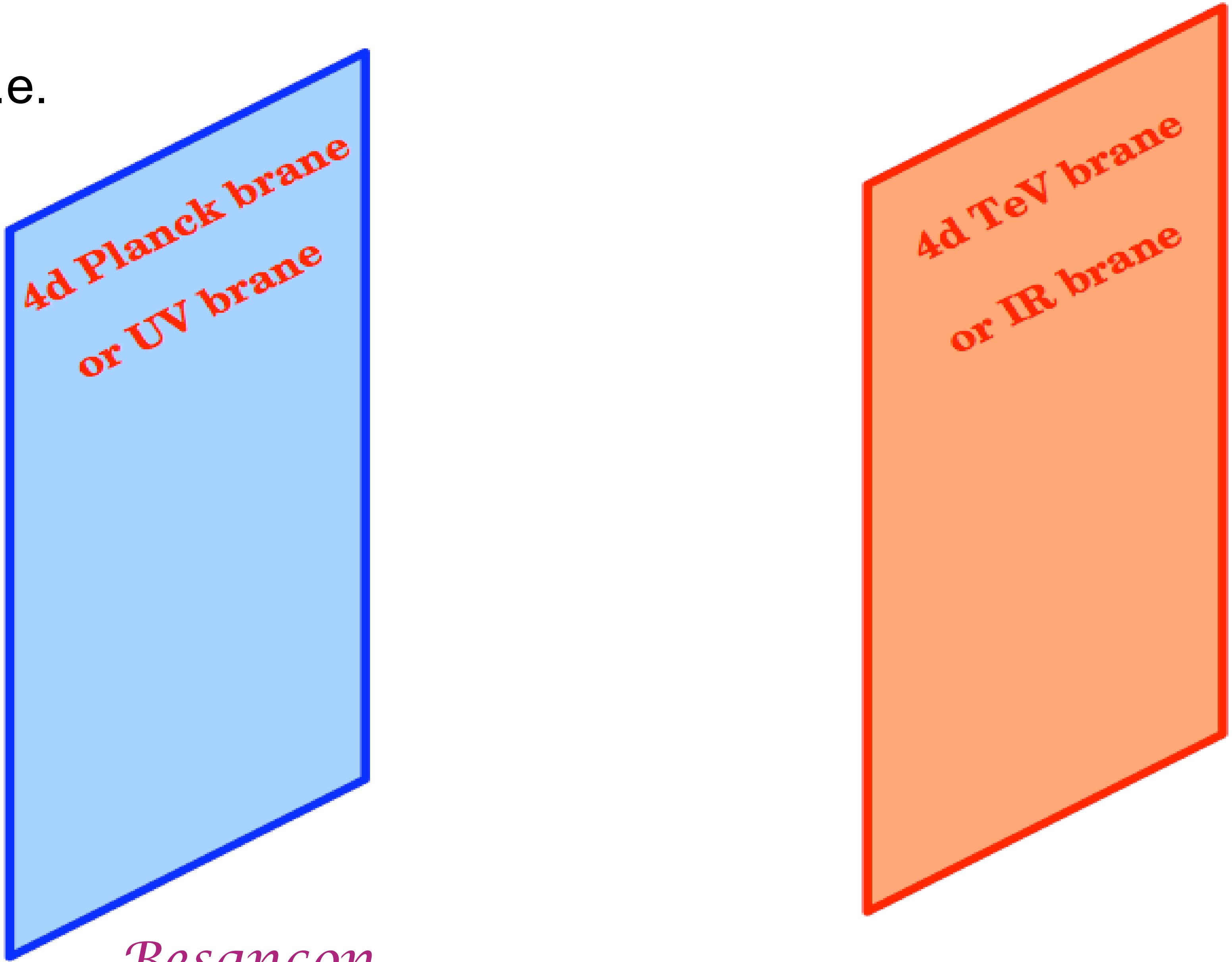


De Rujula signals

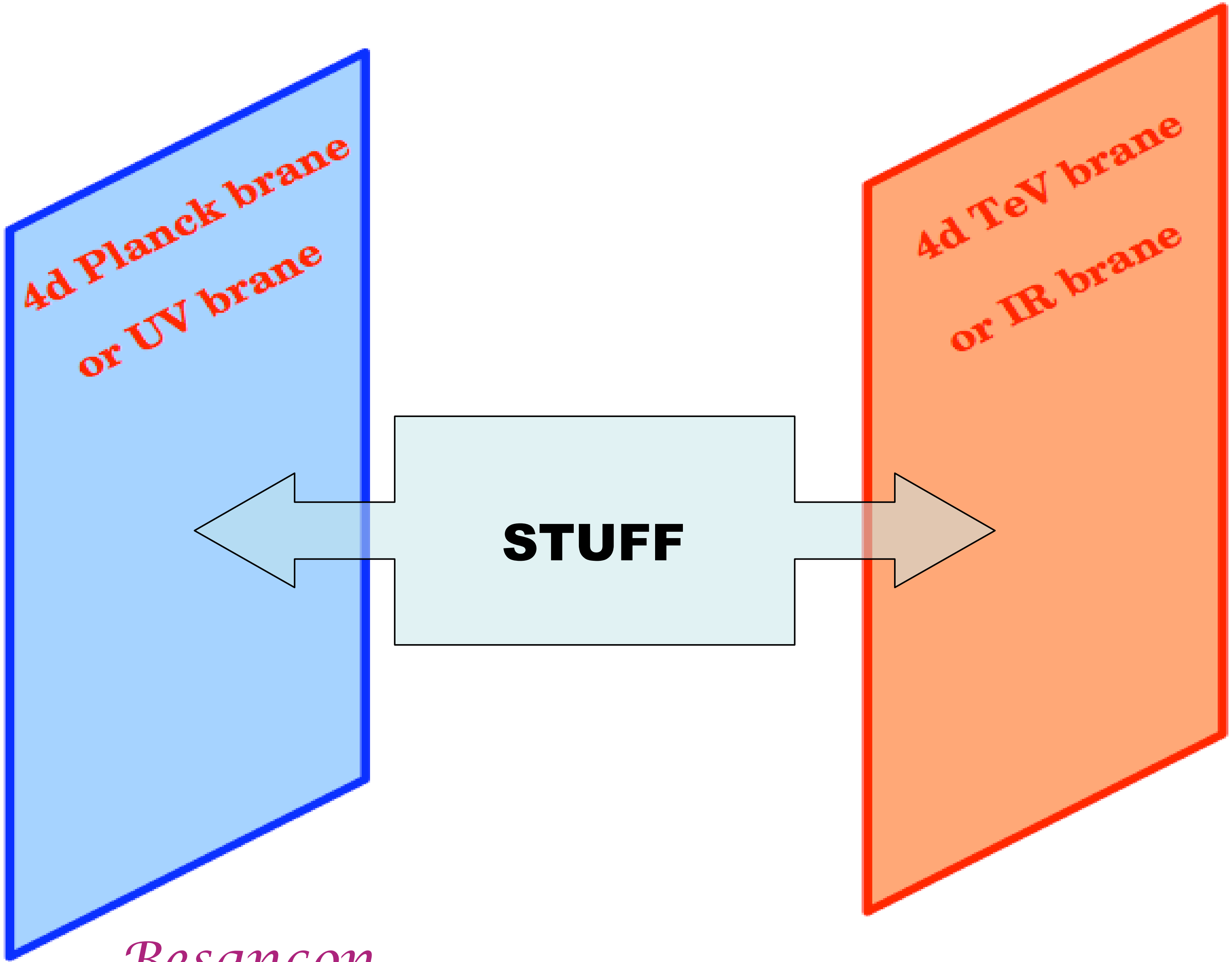
Grojean, Weiler, JT

Facing the hierarchy with extra dimensions

i.e.

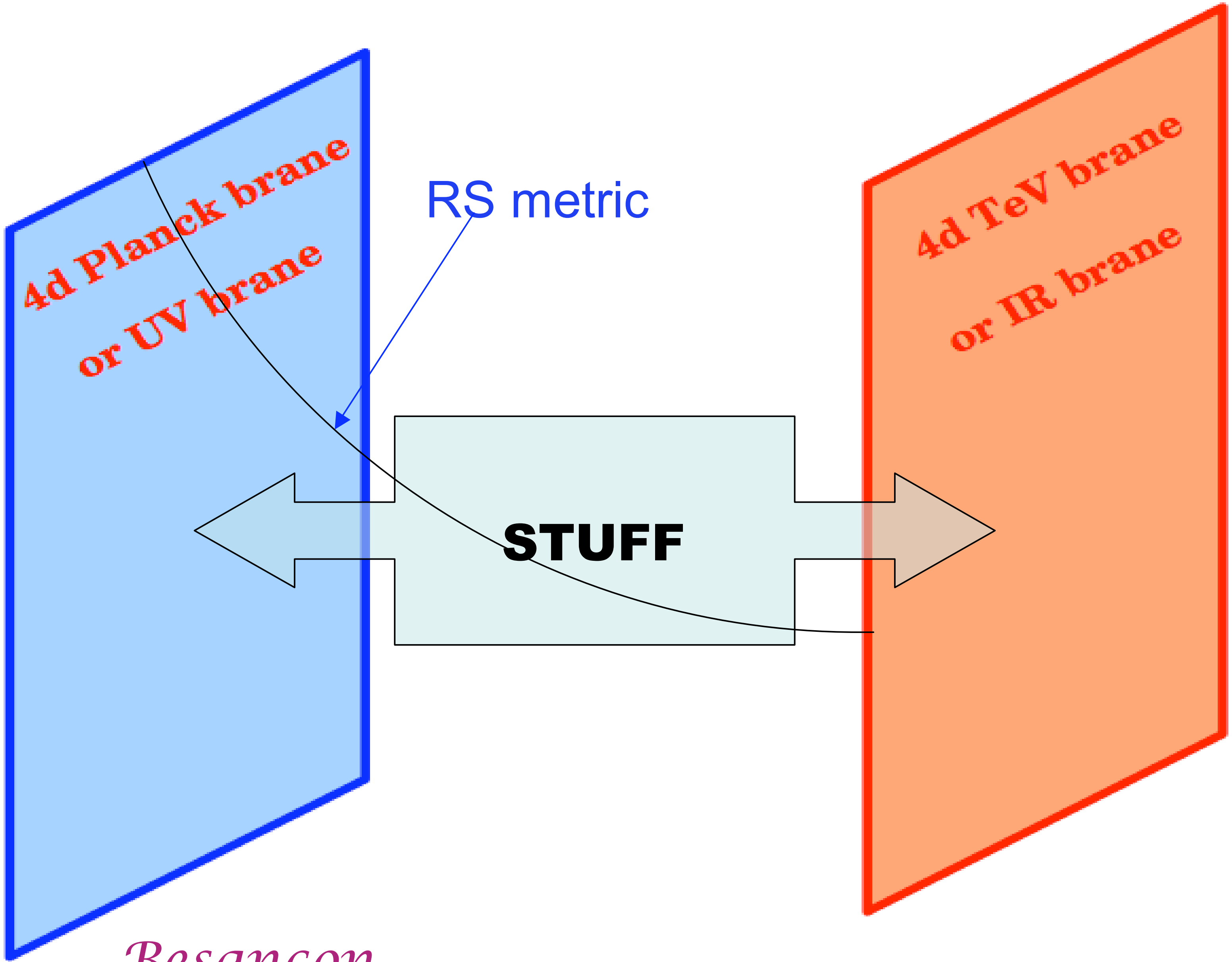


Facing the hierarchy with extra dimensions



Besancon

Facing the hierarchy with extra dimensions



Besancon

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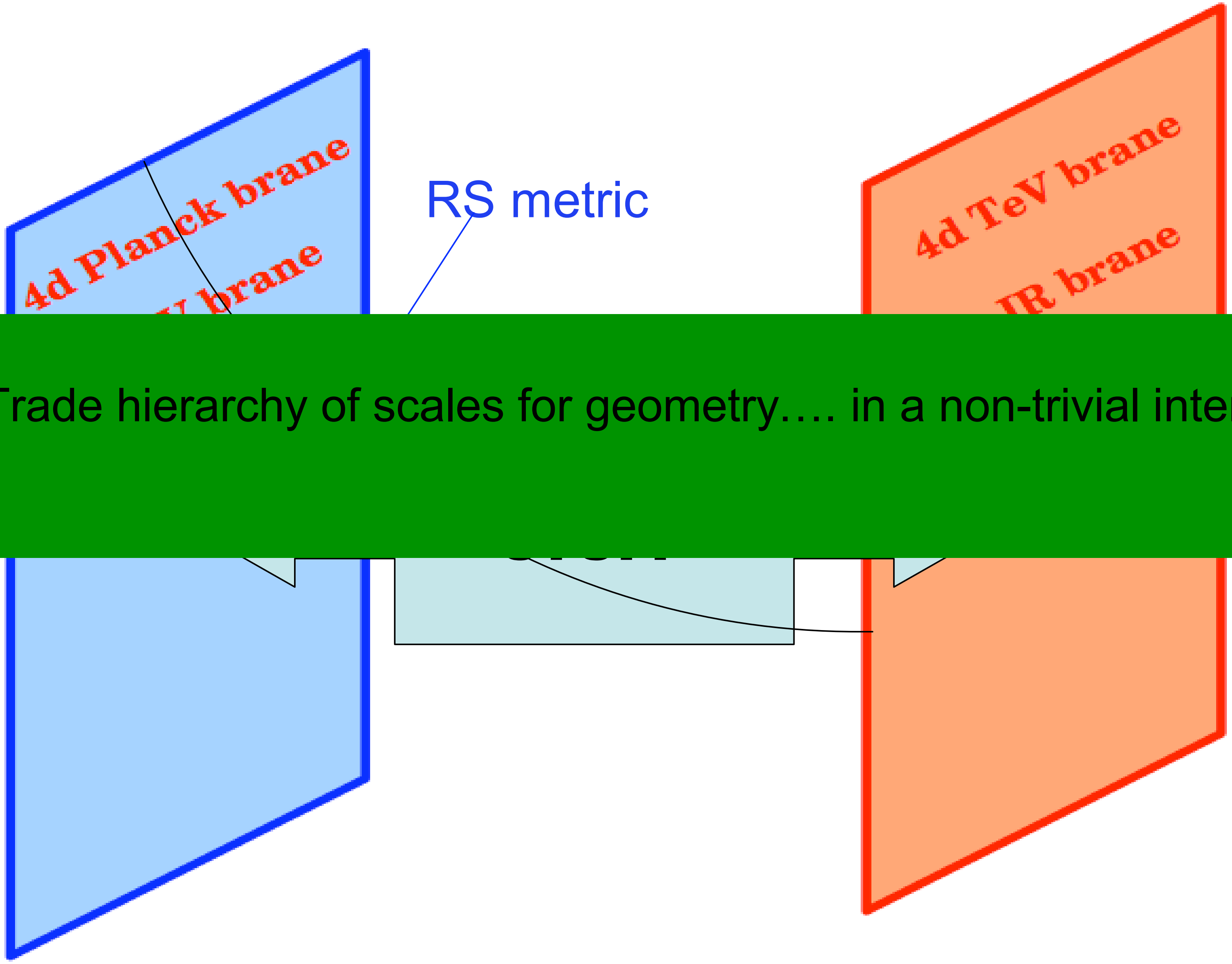


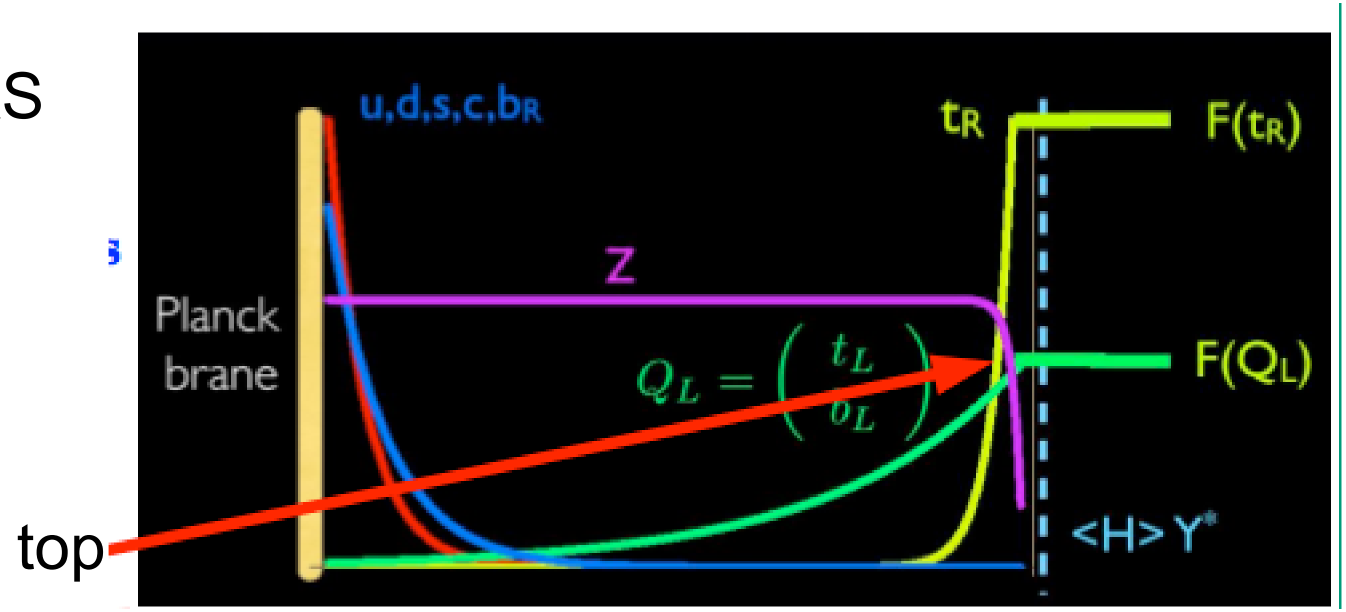
Trade hierarchy of scales for geometry…. in a non-trivial interesting way

But extra-dim model stumble on the FLAVOUR WALL

FCNC…

flavour spectrum

i.e. RS

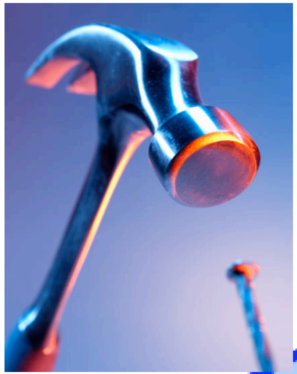


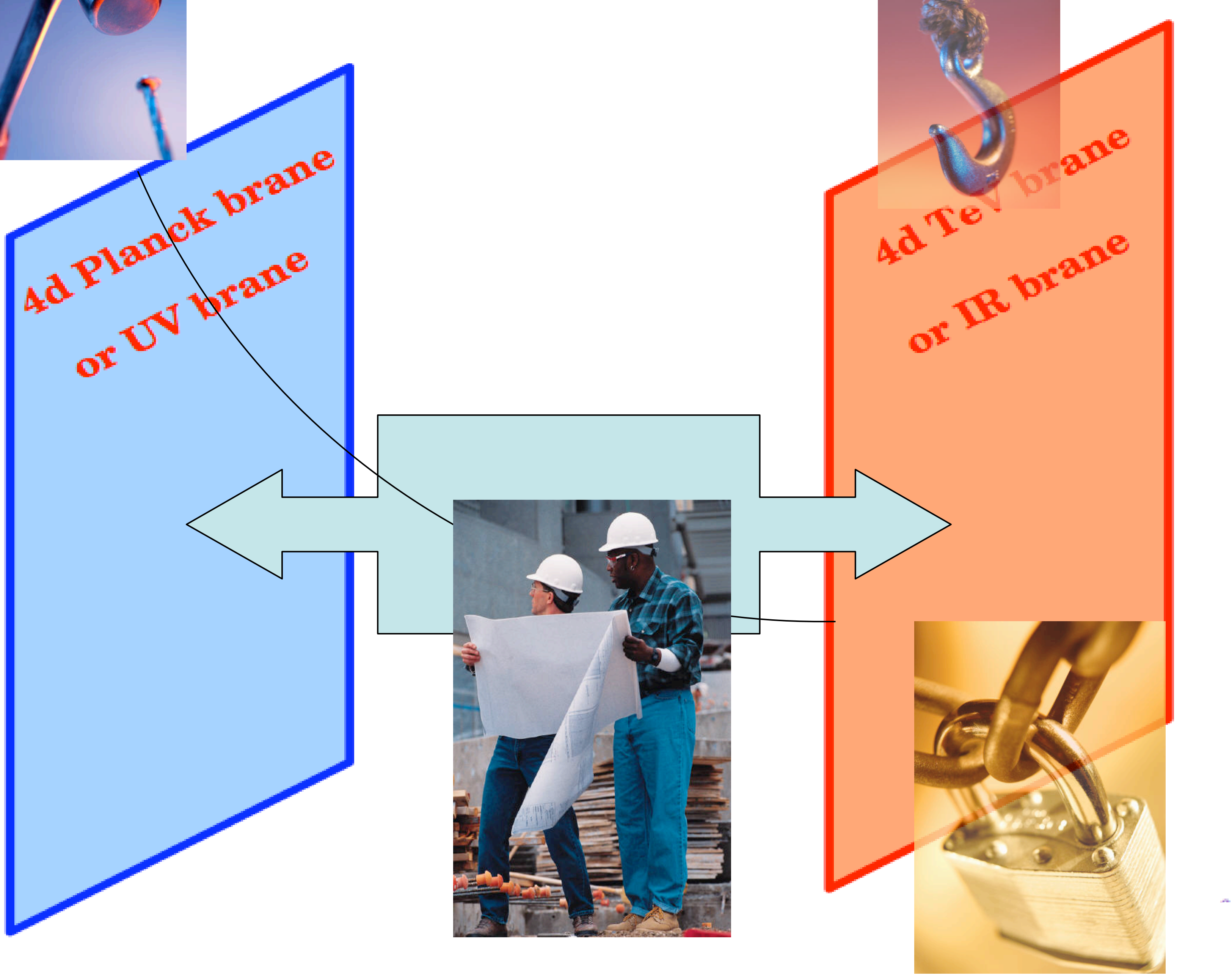
Neutrino masses are a challenge:

all scales are at most TeV…. even Majorana scale

?

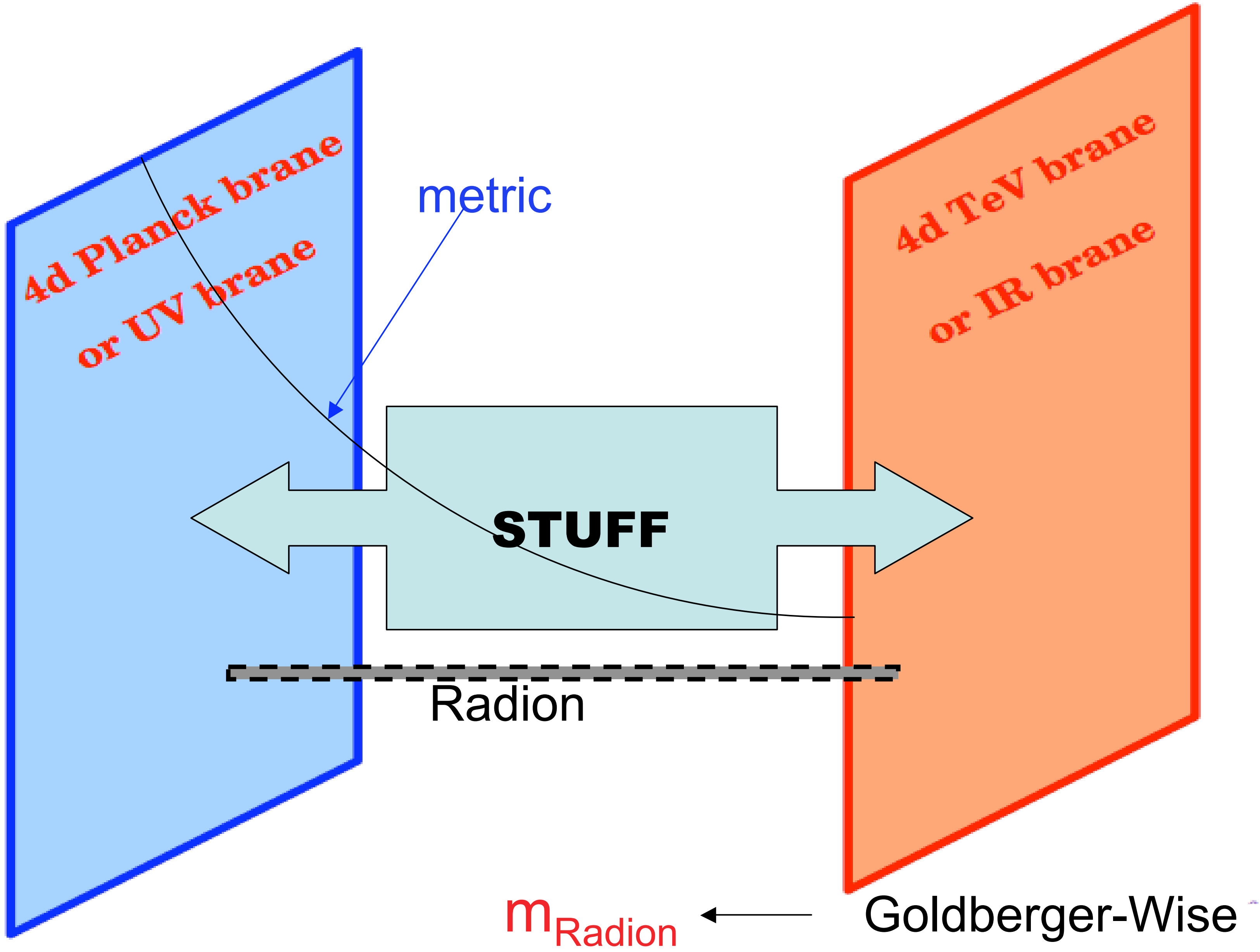
Also need to stabilize the distance



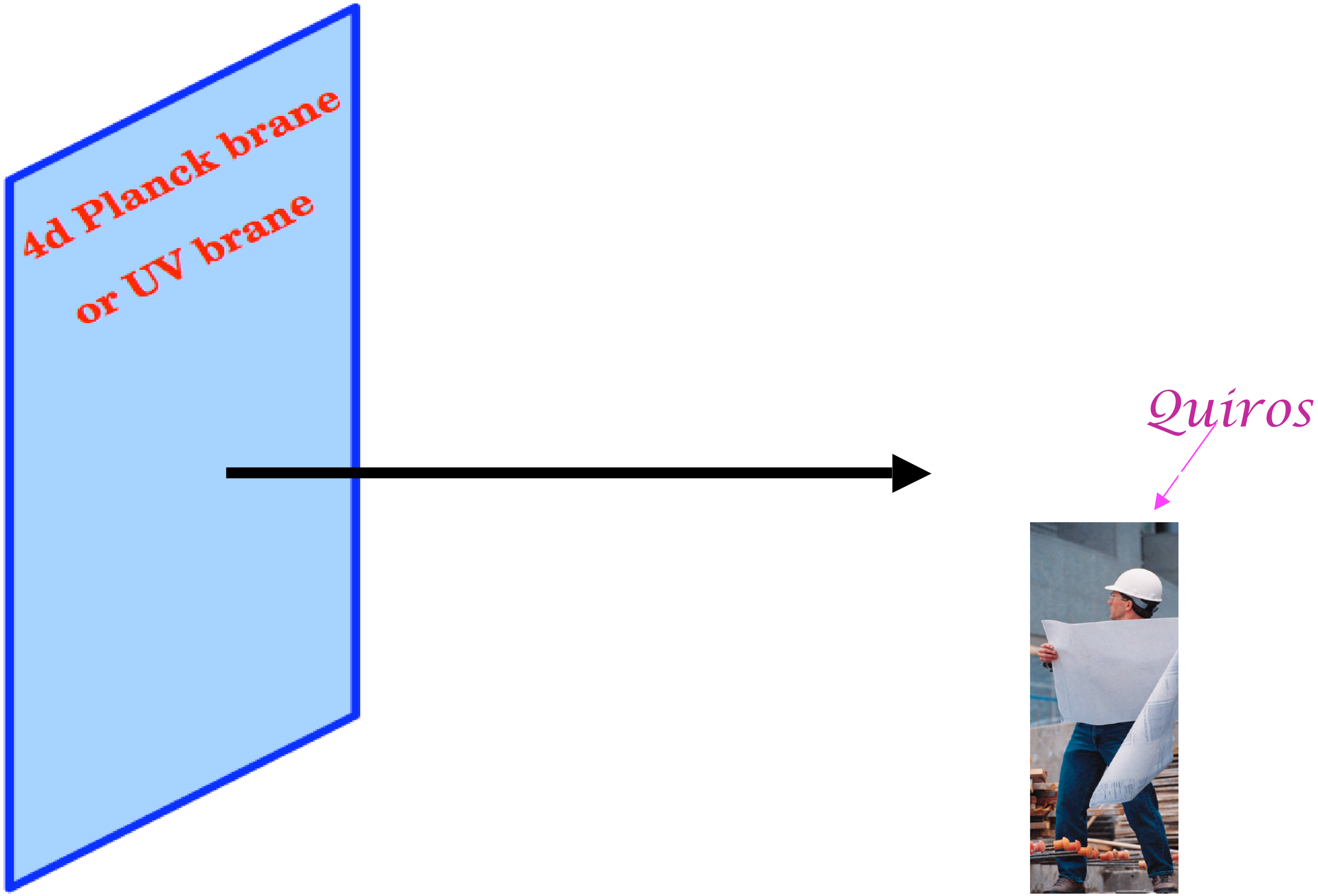


Also need to stabilize the distance

To stabilize the distance (radion): add a scalar field

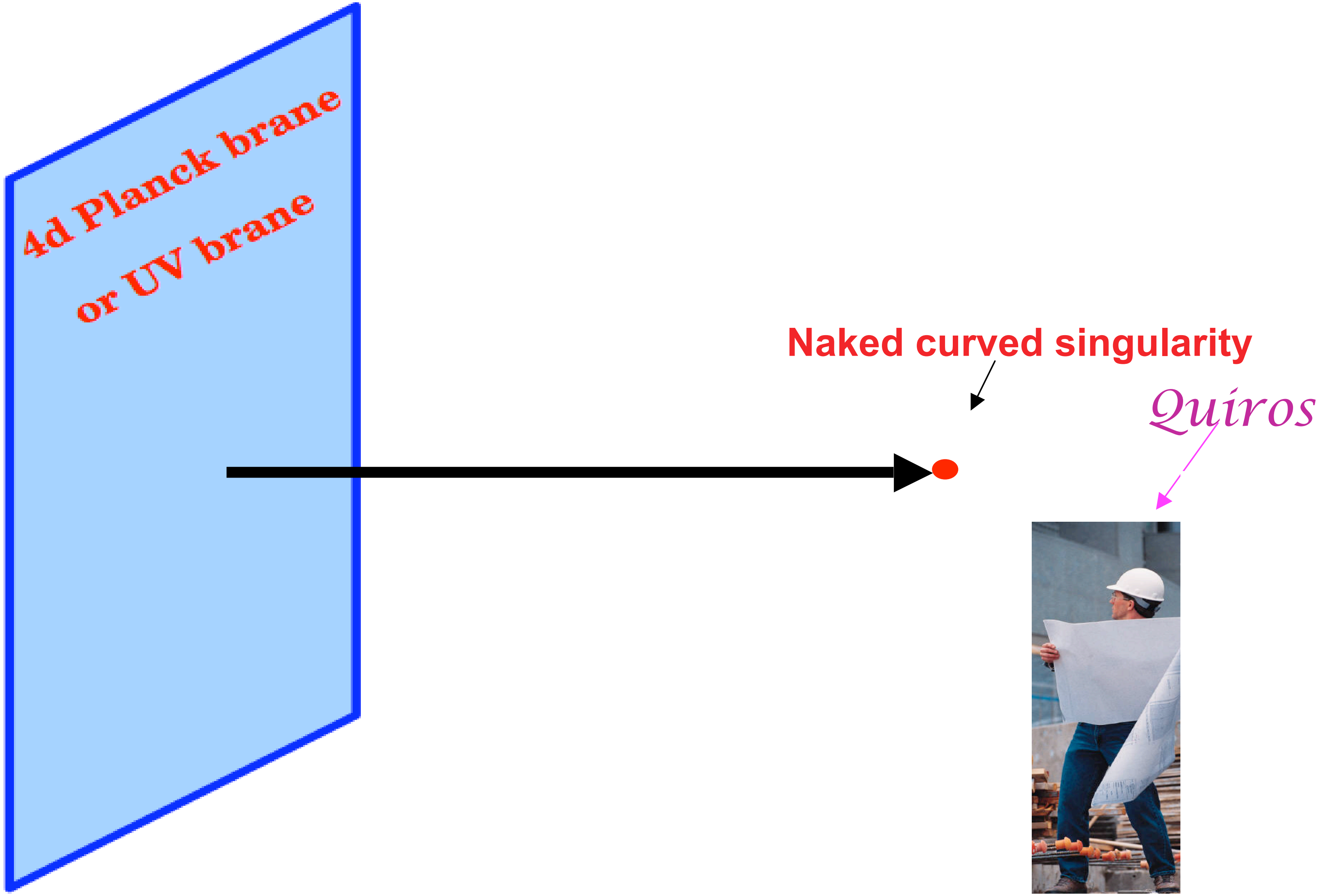


Soft wall



Quiros

Soft wall



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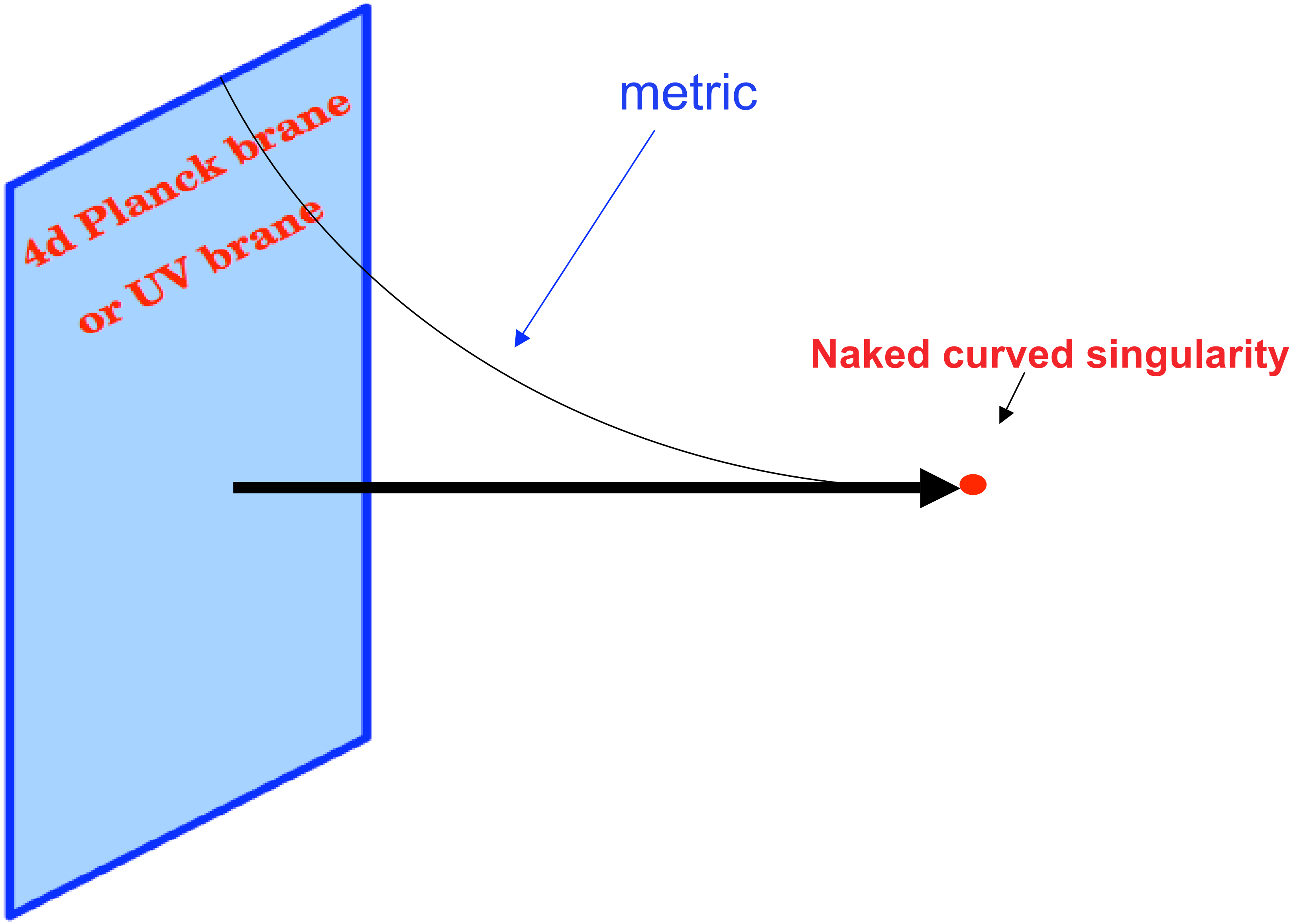
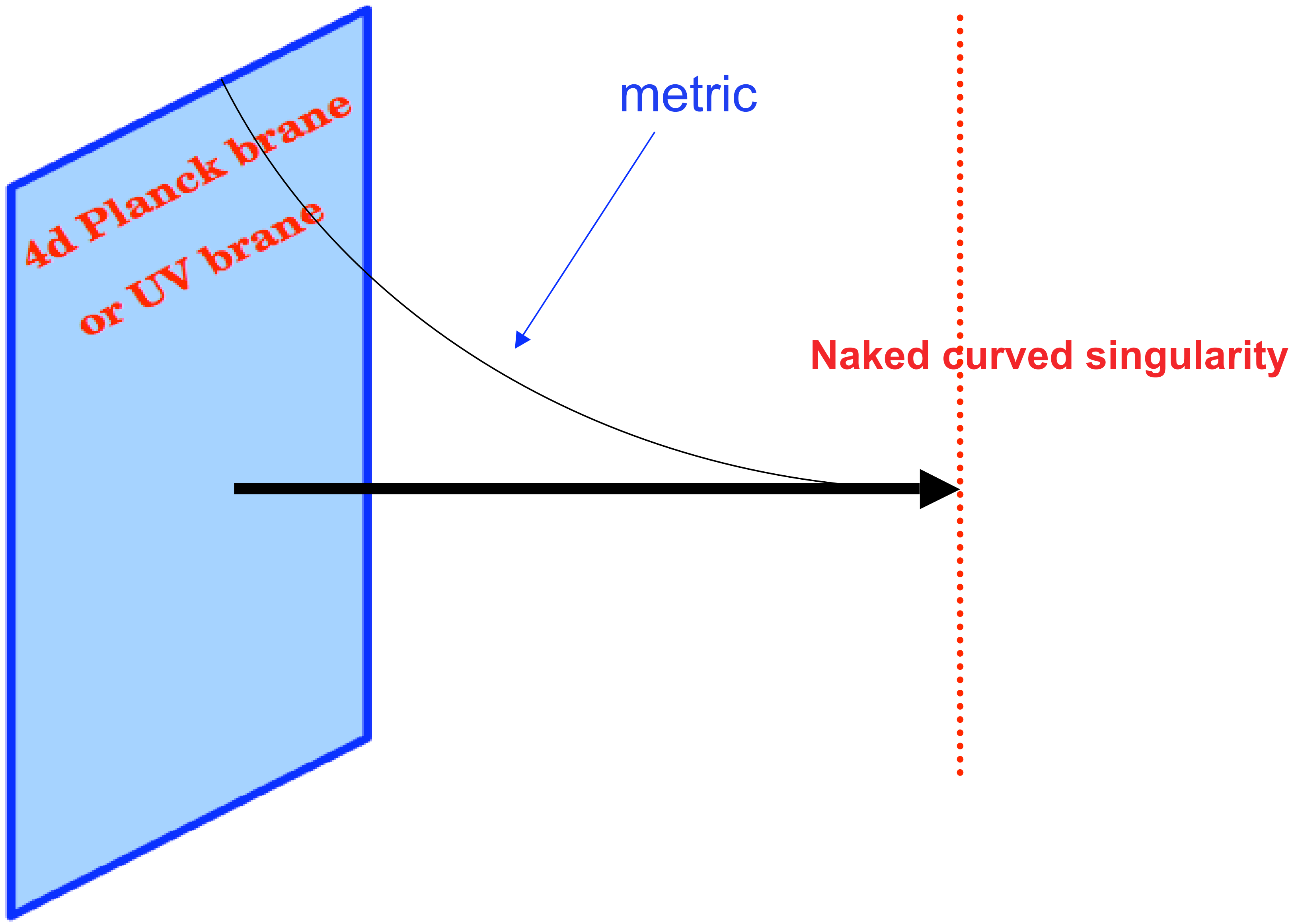

metric
4d Planck brane
or UV brane
Naked curved singularity

Quiros

Soft wall



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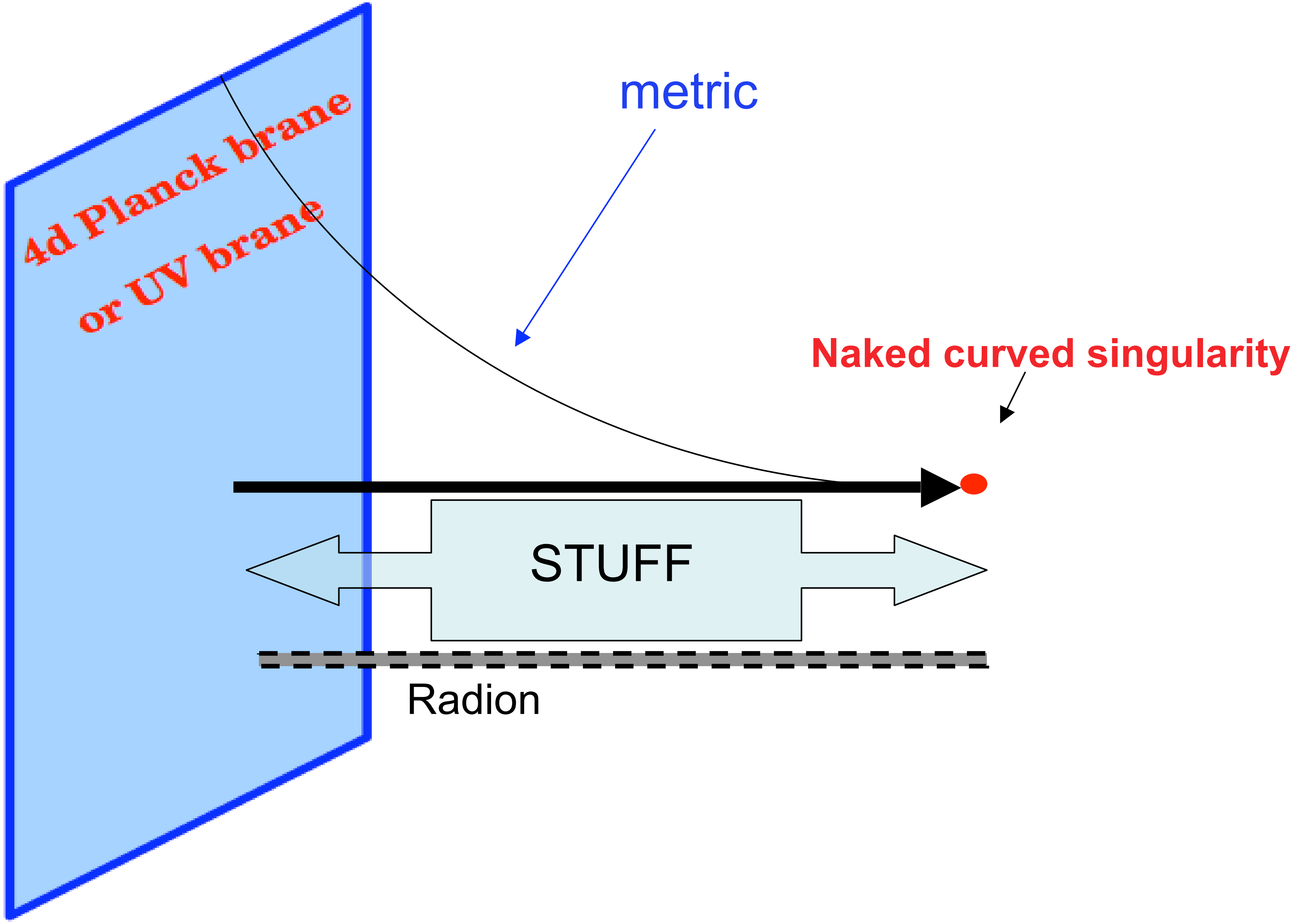

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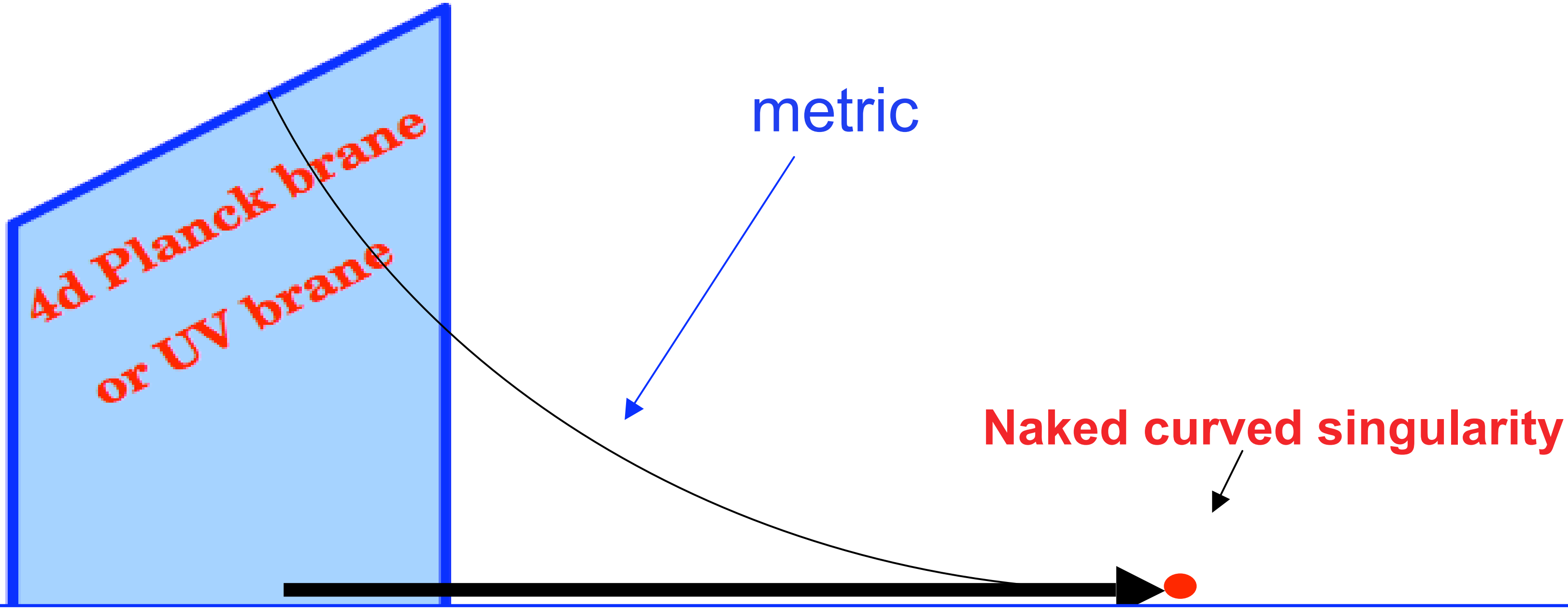


- **Hierarchy: double exponential suppression** Good

- **Heavy Higgs (~1 TeV) and KKs O(#100 GeV) closely packed**

- **FLAVOUR HARD WALL: no improvement**

As we are playing with geometry…

We have only understood gauge int.

***In SM, fermion and scalar representations are set completely by hand**

Schucker: in **non-conmutative geometry**:

* fermions predicted in the fundamental
* scalar representation predicted: only one Higgs
* even gauge groups restricted?

“prediction” “ m_H ~ 170 +- 10 GeV “ (at what scale ??)

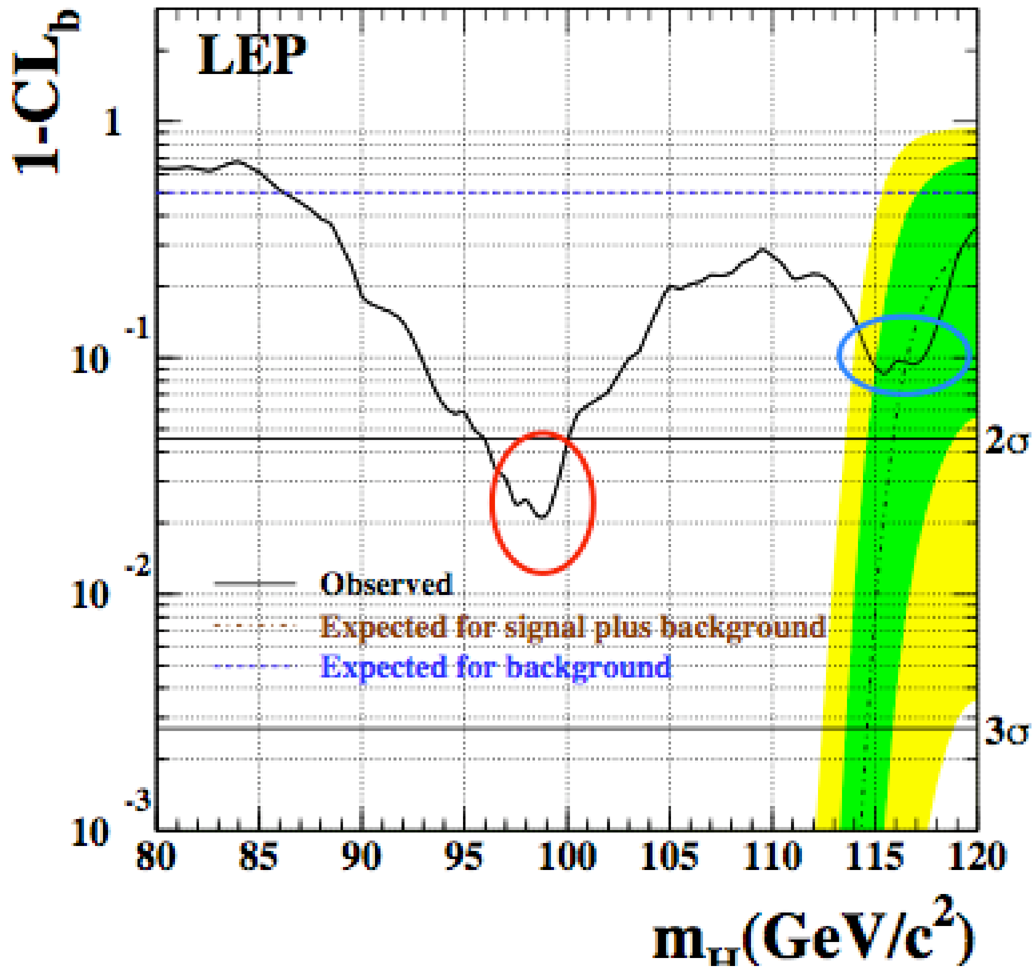
Not yet known how to include QM-field theory…
which is essential to understand data

Can we miss the Higgs?

We better don’t……

The threat is serious….

Maybe **NOT** finding supersymmetry at the LHC will be a signal of supersymmetry **?**



1-CL_b
LEP
1
10^-1
10^-2
10^-3
2σ
3σ
Observed
Expected for signal plus background
Expected for background
80
85
90
95
100
105
110
115
120
m_H(GeV/c^2)

Can we miss the Higgs at LHC ?

THE VAN DER BIJ MALEDICTION

* 1980 Van der Bij + A. Hill

Can we miss the Higgs at LHC ?

THE VAN DER BIJ MALEDICTION

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resurfaced in Moriond 2010 disguised as $\left\{ \begin{array}{l} \text{NMSSM} \\ \text{Gaugephobic} \\ \text{Unhiggs} \\ \text{Effective ops.} \end{array} \right.$

Extended standard model (with A. Hill)†

Van der Bij

Higgs-sector

Higgs doublet

$$\mathcal{L} = -\frac{1}{2}(D_\mu \phi)^\dagger (D^\mu \phi) - \frac{\lambda_1}{8}\left(\phi^\dagger\phi - f_1^2\right)^2$$

$$-\frac{1}{2}(\partial_\mu x)^2 - \frac{\lambda_2}{8}\left(2 f_2 x - \phi^\dagger\phi\right)^2$$

Scalar singlet

$$M_W = \frac{g f_1}{2}$$

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Scalar singlet

* The Higgs ϕ and x mix
* x is a SM singlet

$\Rightarrow$ **2 diluted resonances**

Ellwanger: **NMSSM**

2) the singlet-like CP-even scalar can mix with the SM-like CP-even scalar, and have a mass below 114 GeV (allowed by LEP!)

Ellwanger: **NMSSM**

Lessons/Hints from LEP

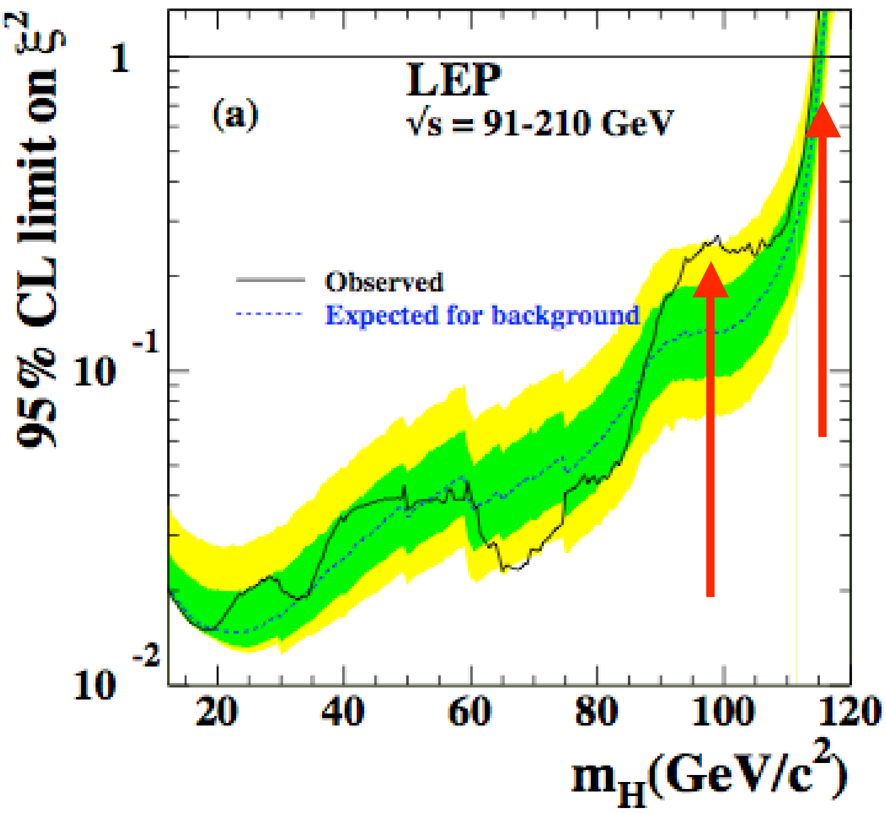
Search for $H \to b\bar{b}$, $\tau^+\tau^-$ (comb. 4 exp., LEP-Higgs Working Group):

Light excess of events for $m_H \sim 95 - 100$ GeV ($\sim 2.3\,\sigma$)
If such an H exists, it must possess:

$\longrightarrow$ Either a reduced coupling $g_{HZZ}/g_{HZZ\_SM} \equiv \xi \lesssim 0.4 - 0.5$

$\longrightarrow$ or a reduced BR to $b\bar{b}$: $BR(H \to b\bar{b})/BR_{SM} \lesssim 0.2$

$\longrightarrow$ $BR(H \to A_1 A_1) \sim 80 - 90\%$?
(Dermisek, Gunion: solution of the "little finetuning problem" of the MSSM)



Missing the Higgs

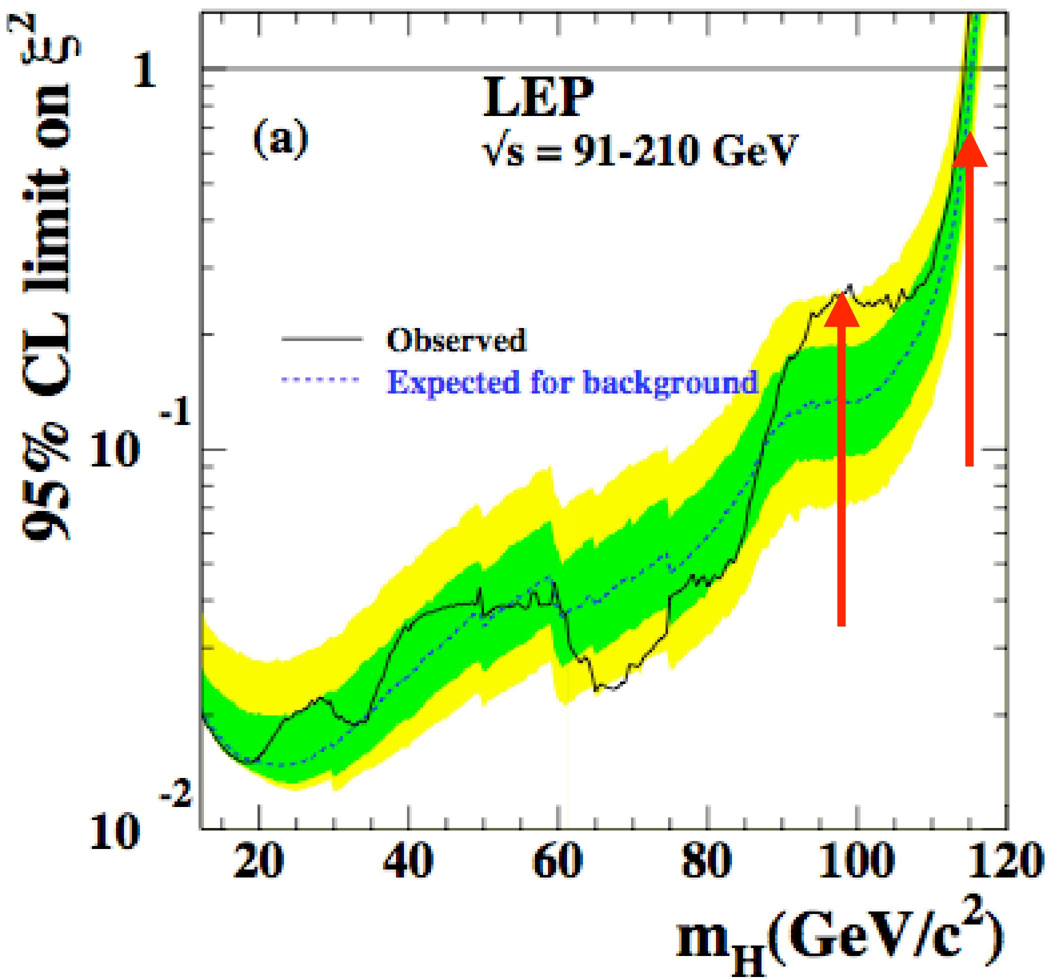
$$\xi^2 \equiv \frac{\sigma(e^+e^- \rightarrow HZ)}{\sigma_{SM}}$$

a light

Gaugephobic/Unhiggs

could have been

missed at LEP



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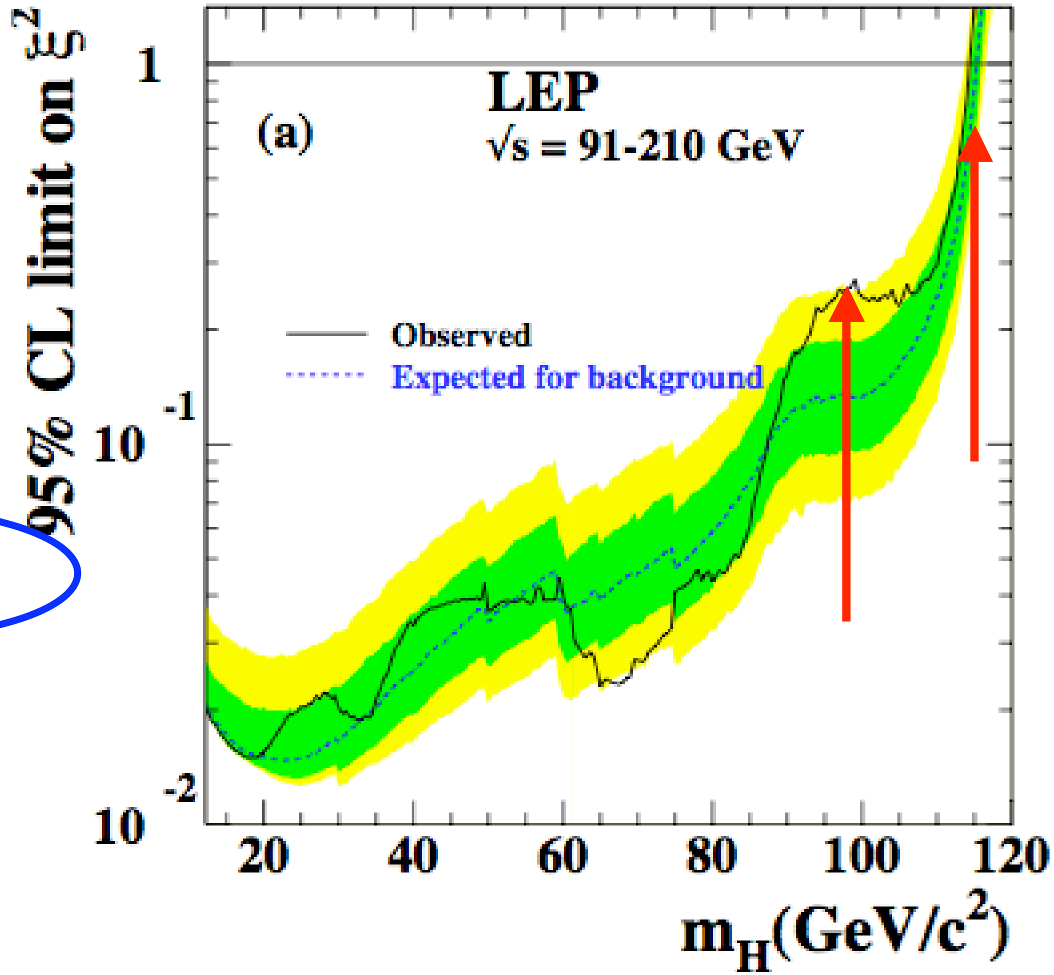
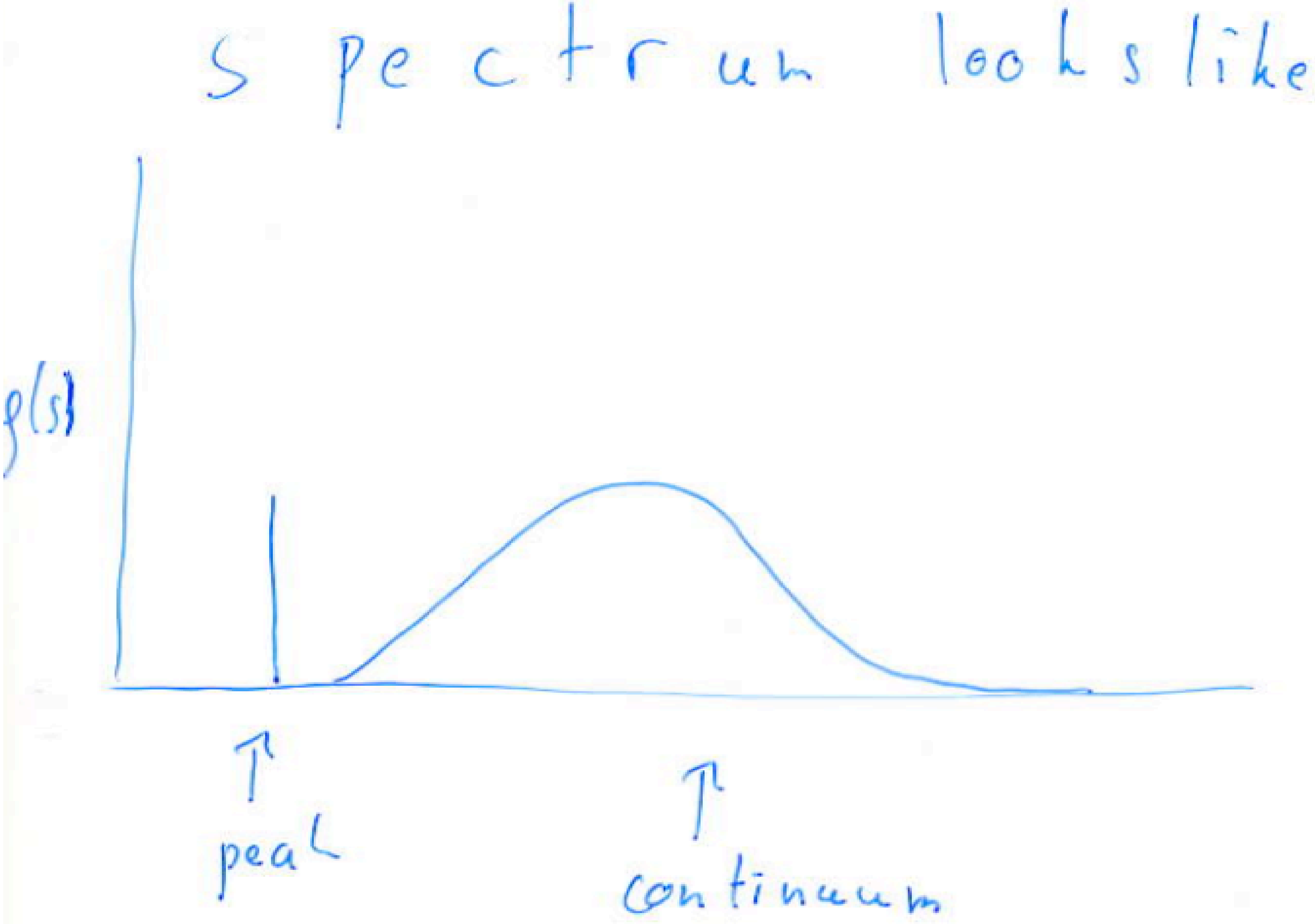


Van der Bij Moriond 07: instead of one state, many ?

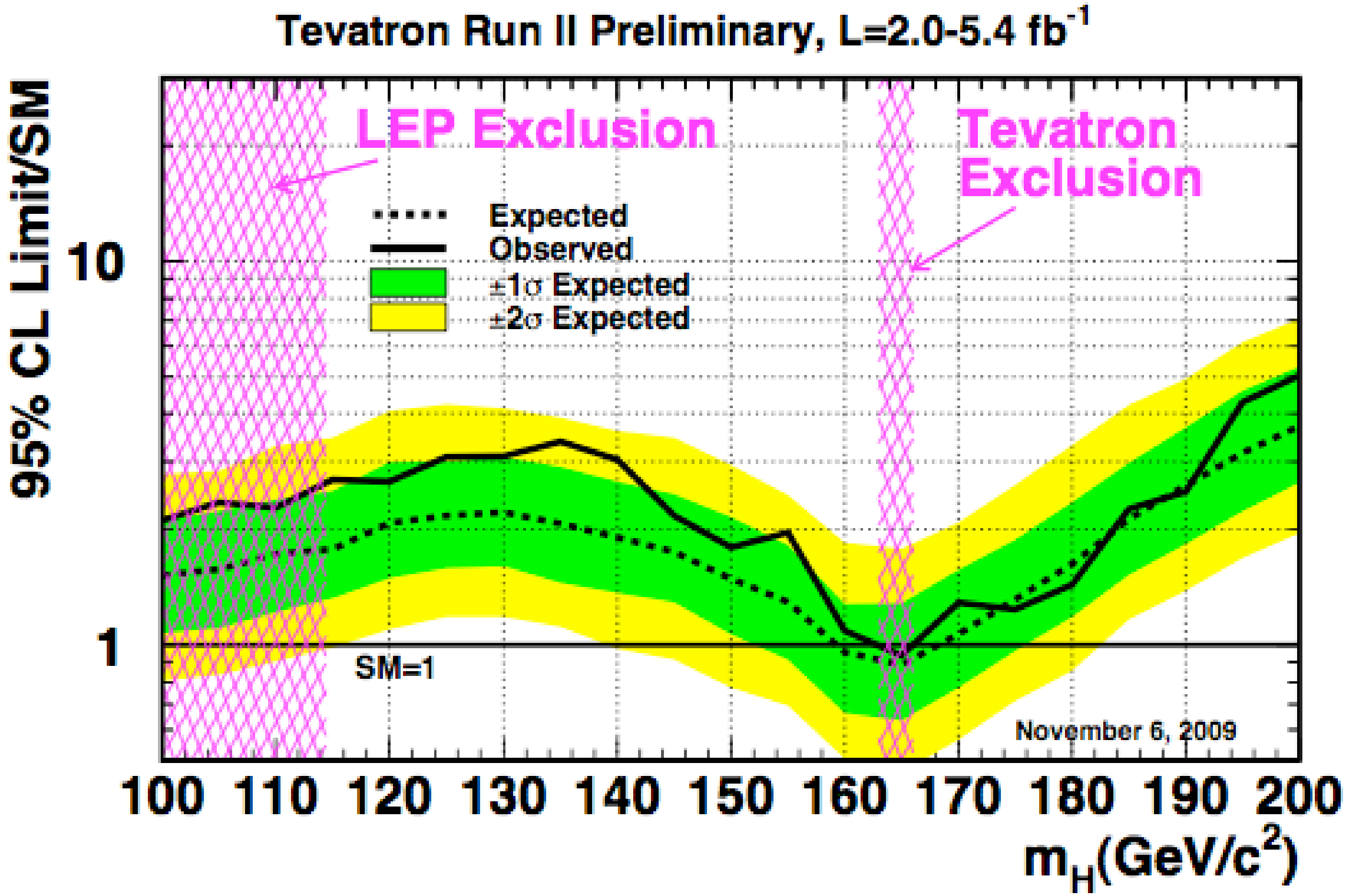


Yes, we can…

Yes, we can… miss the Higgs

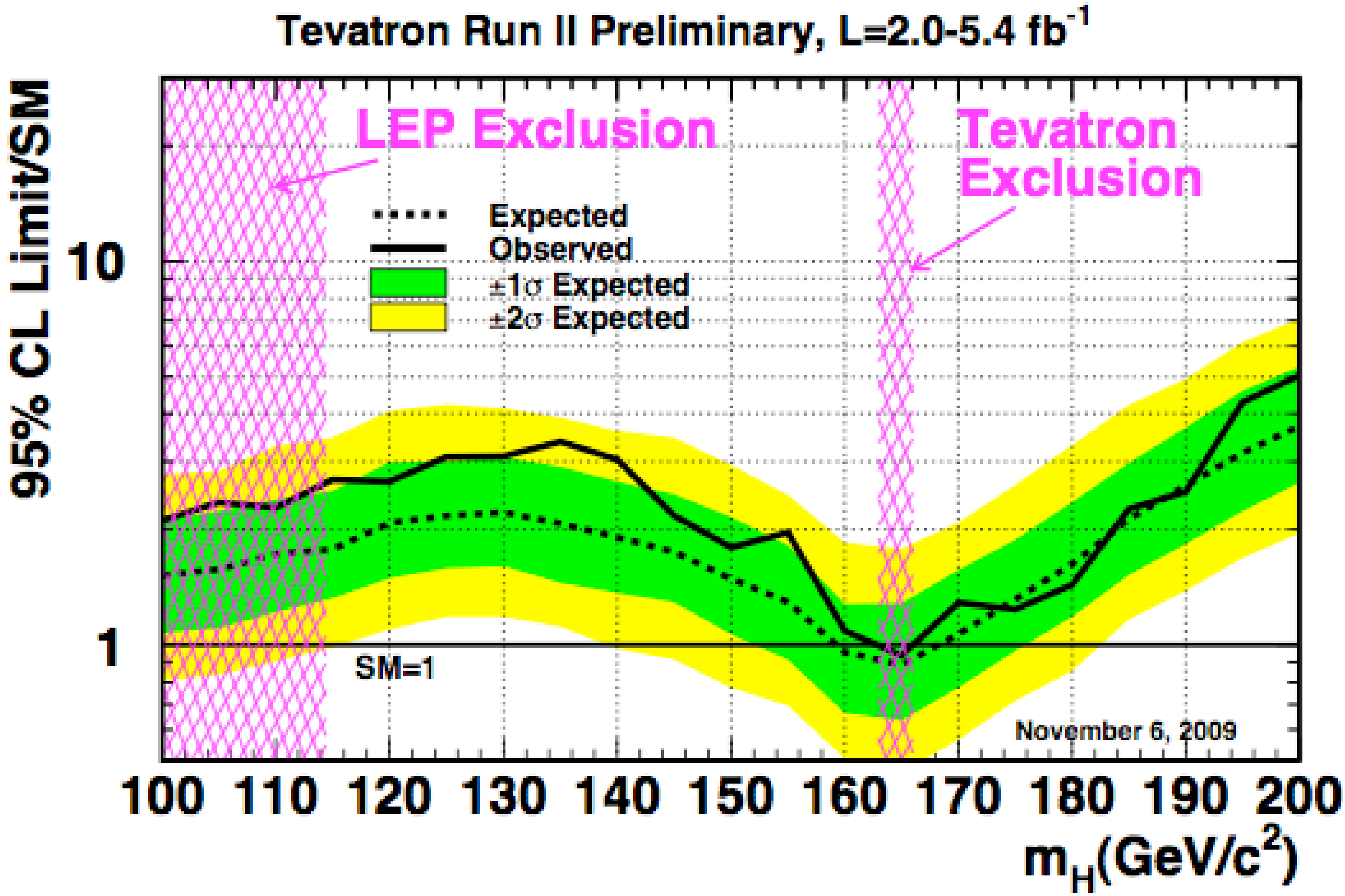
i.e. it is enough to add singlet scalar(s) to SM

Higgs search at the Tevatron



Btw: if this data are combined with LEP2 ones… what happens?

Higgs search at the Tevatron



Btw: if this data are combined with LEP2 ones… what happens?

ask Patrick Janot

BSM why nots

BSM why nots

Villadoro

* Go for simplicity: **SM + Z'**

$$Z'_\mu \left(g_Y J_Y + g_X J_X\right)^\mu$$

*** *only 3 new parameters:*

$$M_{Z'}, g_Y, g_X$$

*** *Z – Z' mixing angle:*

$$\tan\theta' = -\widetilde{g}_Y \frac{M^2_{Z^0}}{M^2_{Z'} - M^2_{Z^0}}$$

BSM why nots

Villadoro

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X= B - L

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BSM why nots

Villadoro

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X= B - L

X= B - 3L$_e$

X= B - 3L$_\mu$

X= L$_e$ - L$_\mu$

BSM why nots

Villadoro

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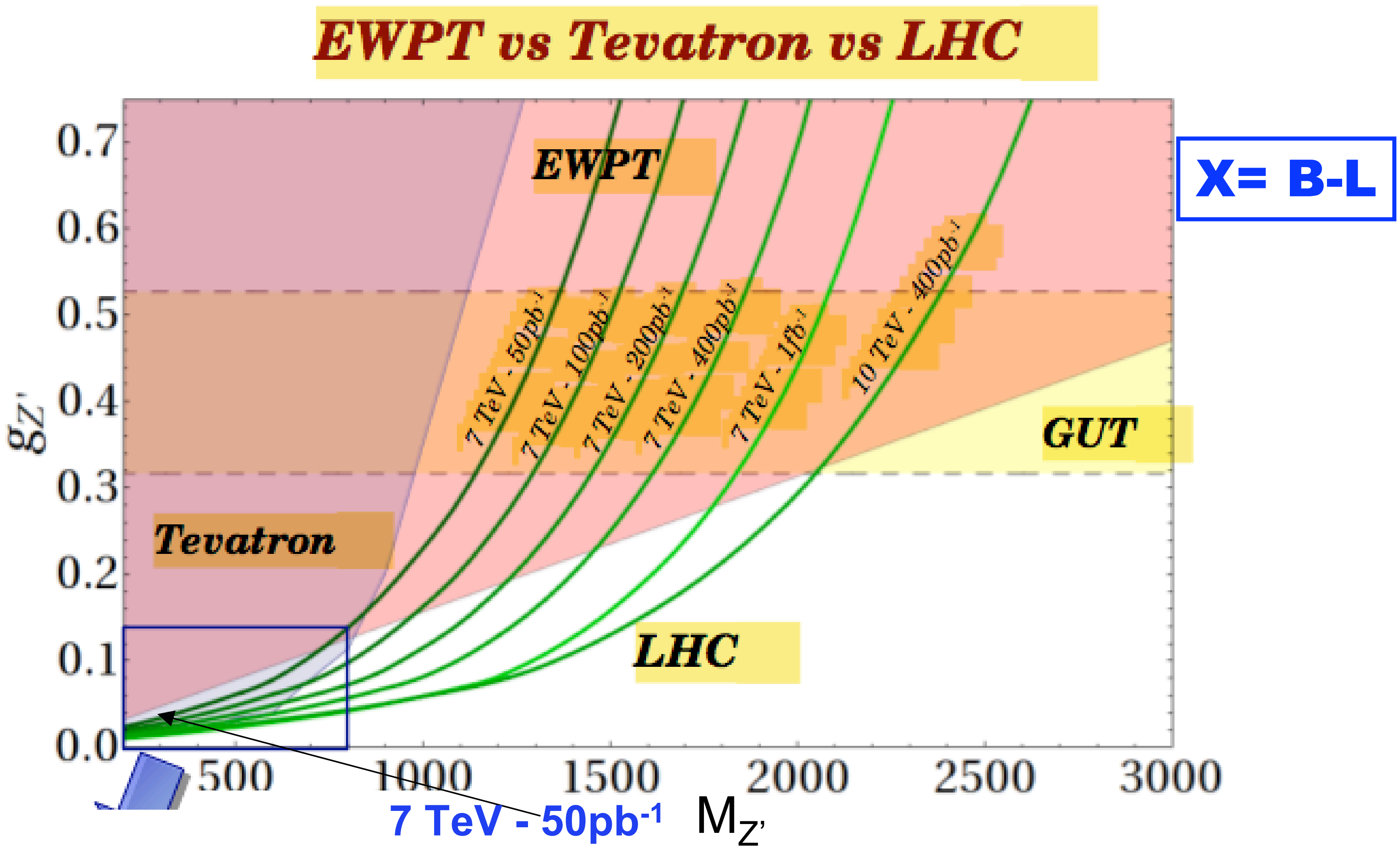


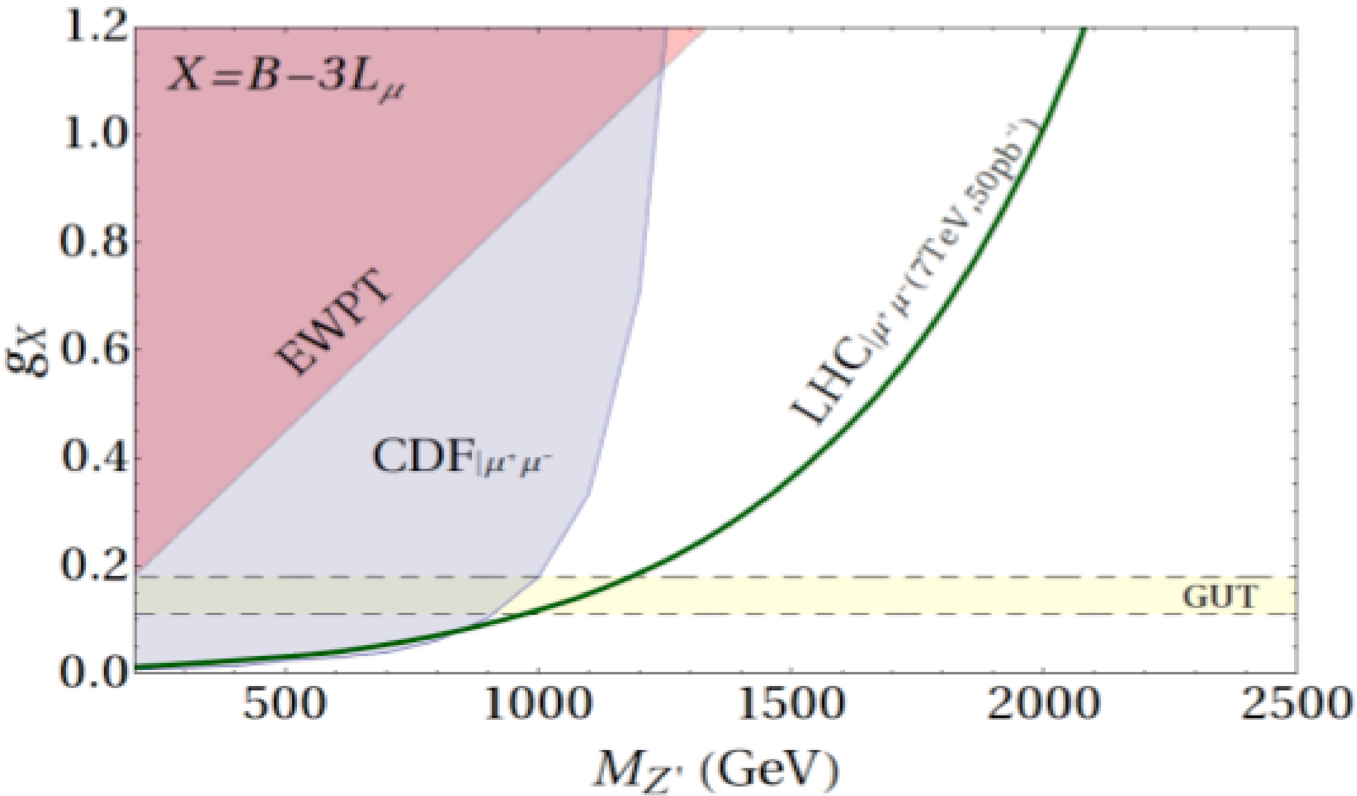
Villadoro

$X = B - 3L_\mu$

Gauge inv. -->FCNC OK

easily accessible at very early LHC

***e.g.* 7 TeV & 50 pb^{-1}**



FLAVOUR news

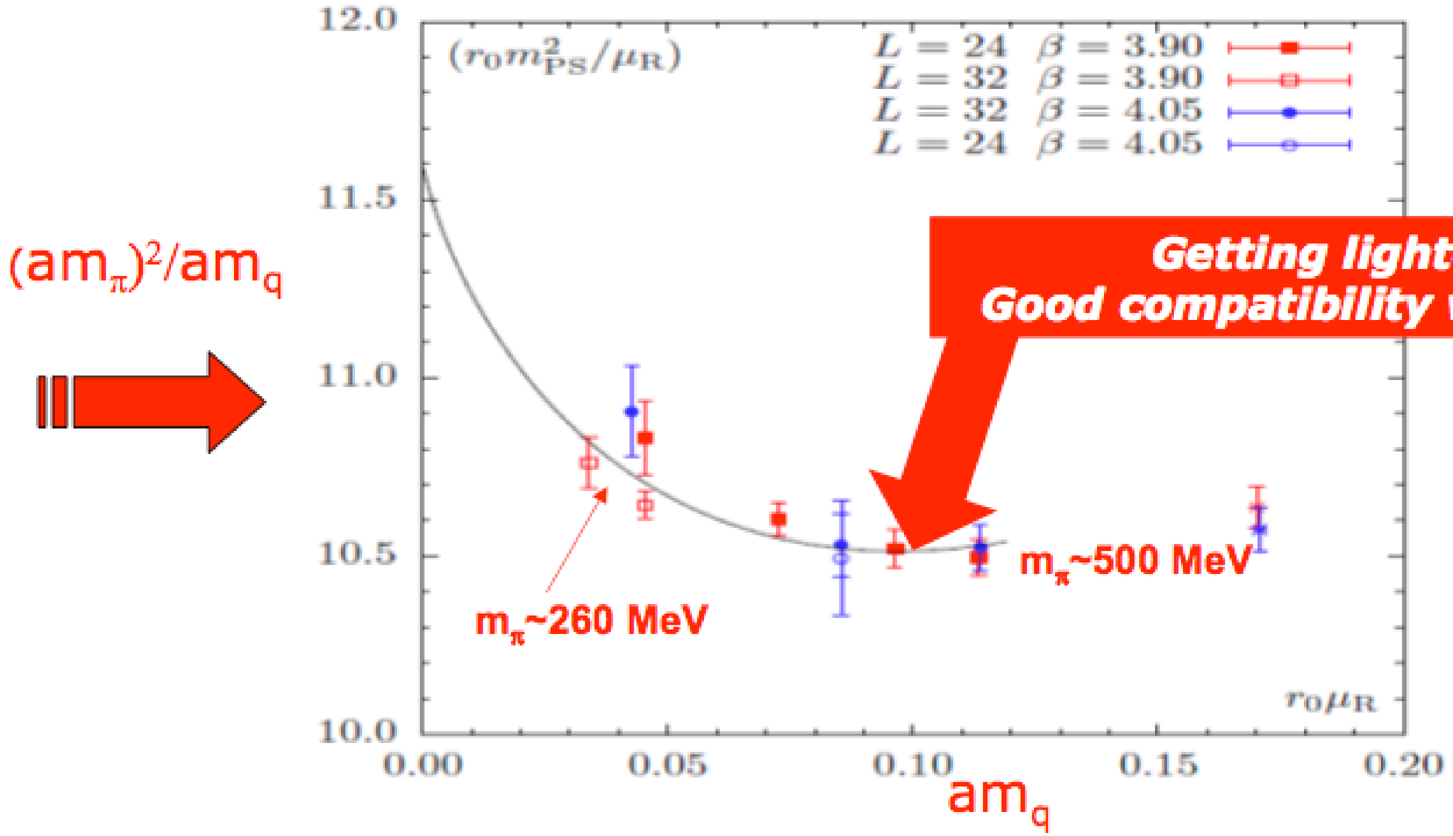
FLAVOUR news
From Lattice QCD

Lattice QCD

Now you SEE the chiral logs

Mescia

$$m_\pi^2 = M^2\left[1+\frac{M^2}{32\pi^2F^2}\log\left(M^2/\Lambda_3^2\right)+\ldots\right], \quad M^2 = 2Bm$$



ETMC arXiV:0803.0224

2008, unquenched, Wilson-like fermions

Pion mass in the lattice down to 156 MeV !

Pion mass in the lattice down to 156 MeV !

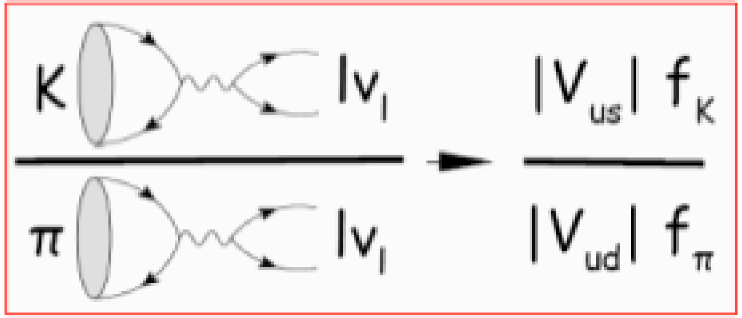
Large impact of chiral improvement on

weak matrix elements on the lattice

which are essential to extract V_{CKM} from data

Lattice enters high precision era

f_K/f_π: an example of Modern lattice measure



Hadronic uncertainties from

$$\langle 0|\bar{s}\gamma^\mu\gamma_5 u|K\rangle = p^\mu f_K$$

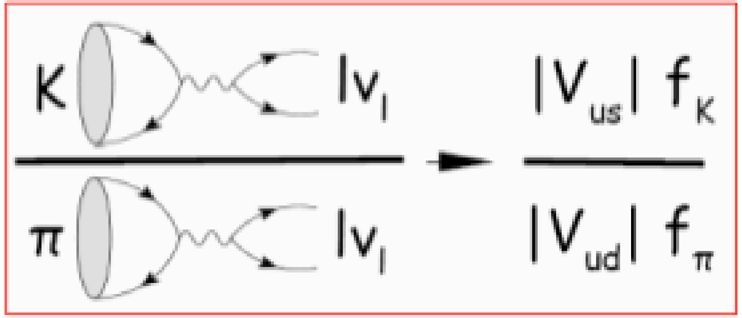
$$\langle 0|\bar{d}\gamma^\mu\gamma_5 u|\pi\rangle = p^\mu f_\pi$$

Mescia

Lattice enters high precision era

< %

f_K/f_π: an example of Modern lattice measure



Hadronic uncertainties from

$$\langle 0|\bar{s}\gamma^\mu\gamma_5 u|K\rangle = p^\mu f_K$$

$$\langle 0|\bar{d}\gamma^\mu\gamma_5 u|\pi\rangle = p^\mu f_\pi$$

$K\rightarrow l\nu$: exp. err 0.2% ★★

lattice err. on f_K/f_π :

2-3% (2006)→**0.7%** (2010)

$$f_K/f_\pi = 1.192 \pm 0.009 \ \ [0.75\%]$$

More quark flavour

Minimal Flavour violation (MFV)

- Flavour data (i.e. B physics) consistent with all flavour physics coming from Yukawa

MFV Hypothesis $\equiv$ The Yukawas are the only sources (*irreducible*) of flavour violation. in BSM

R. S. Chivukula and H. Georgi, Phys. Lett. B 188, 99 (1987).

It is very predictive for quarks:

$$O^{d=6} \sim \overline{Q}_\alpha Q_\beta \overline{Q}_\gamma Q_\delta$$

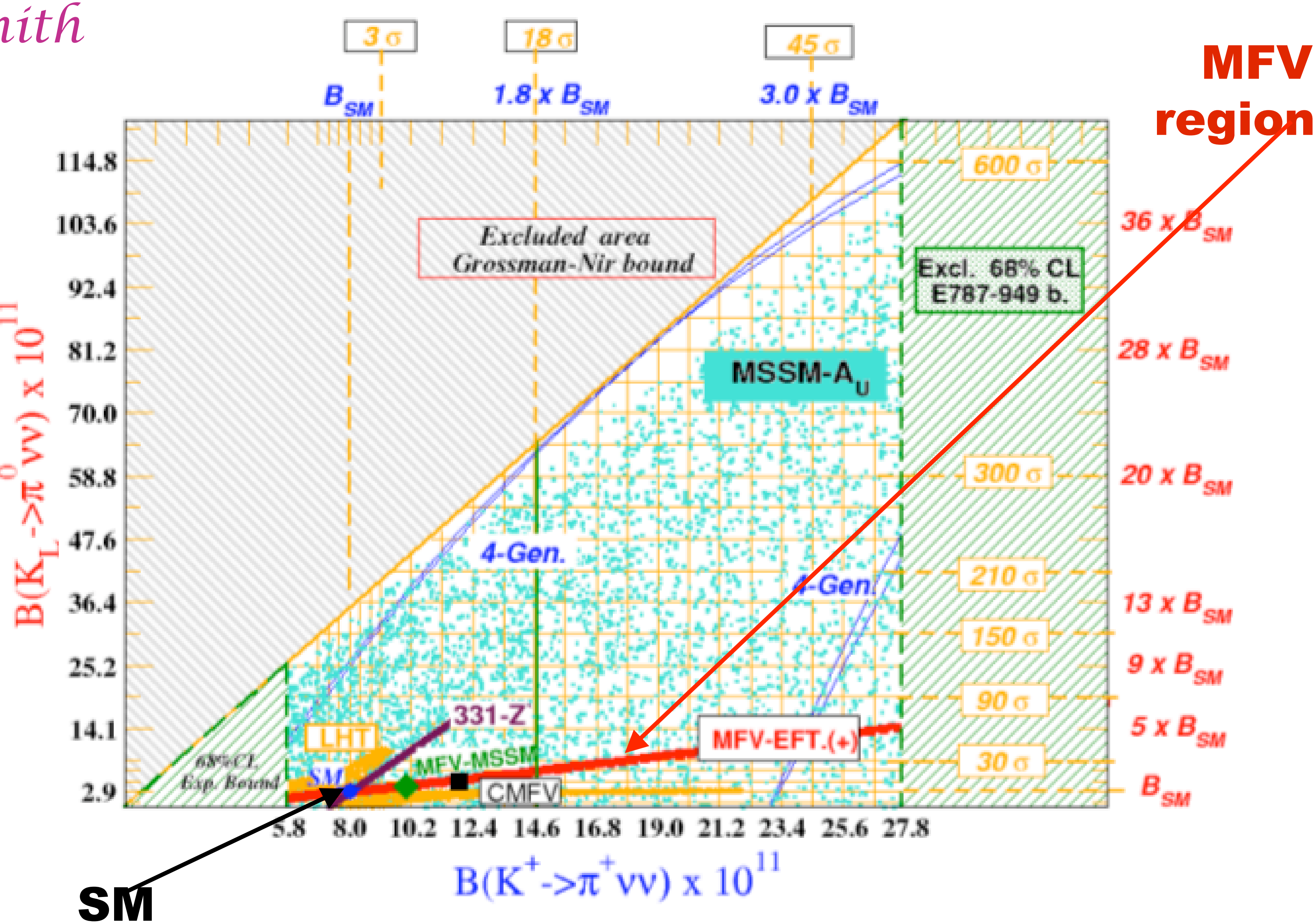
$$\mathcal{L} = \mathcal{L}_{SM} + c^{d=6} \frac{O^{d=6}}{\Lambda^2_{\text{flavour}}} + \ldots\ldots$$

known function of Yukawas

(D'Ambrosio, Cirigliano, Isidori, Grinstein, Wise….Buras….)

I. *NA62 main targets are the rare K decays* ($Br \lesssim 10^{-11}$), *e.g.* $K^+ \to \pi^+ \nu\bar{\nu}$ s

Smith



Gonzalez-Alonso

Minimal Flavour violation (MFV)

•Unitarity of CKM first row:

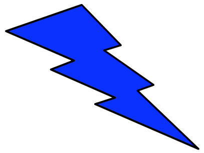
$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9999 \pm 0.0006$$

•*Restrict to flavour blind ops.-> 4 operators

•Correction is only multiplicative to β and μ decay rate

- **The direct experimental limit puts strong constraints on all 4 operators, at the level of the colliders constraints or better.**

$$\Delta_{CKM} = -(0.1 \pm 0.6) \cdot 10^{-3} \Rightarrow \Lambda_i^{eff} > 11\,\mathrm{TeV}\ (90\%\,\mathrm{CL})$$

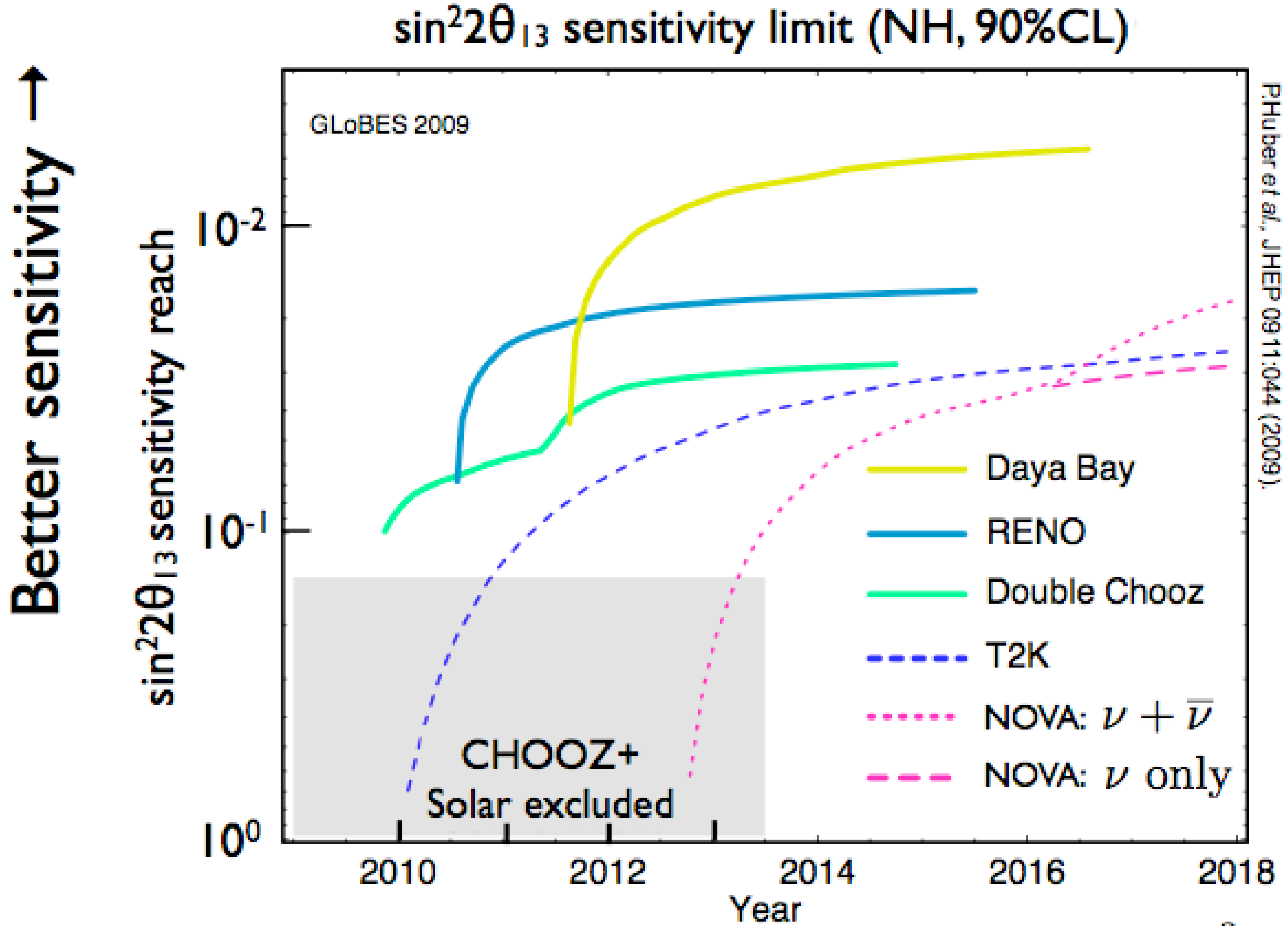


Neutrinos

$$\theta_{13} \neq 0$$

is the remaining key to measure **leptonic CP violation**

After some quiet expt. years…….. > θ_{13}

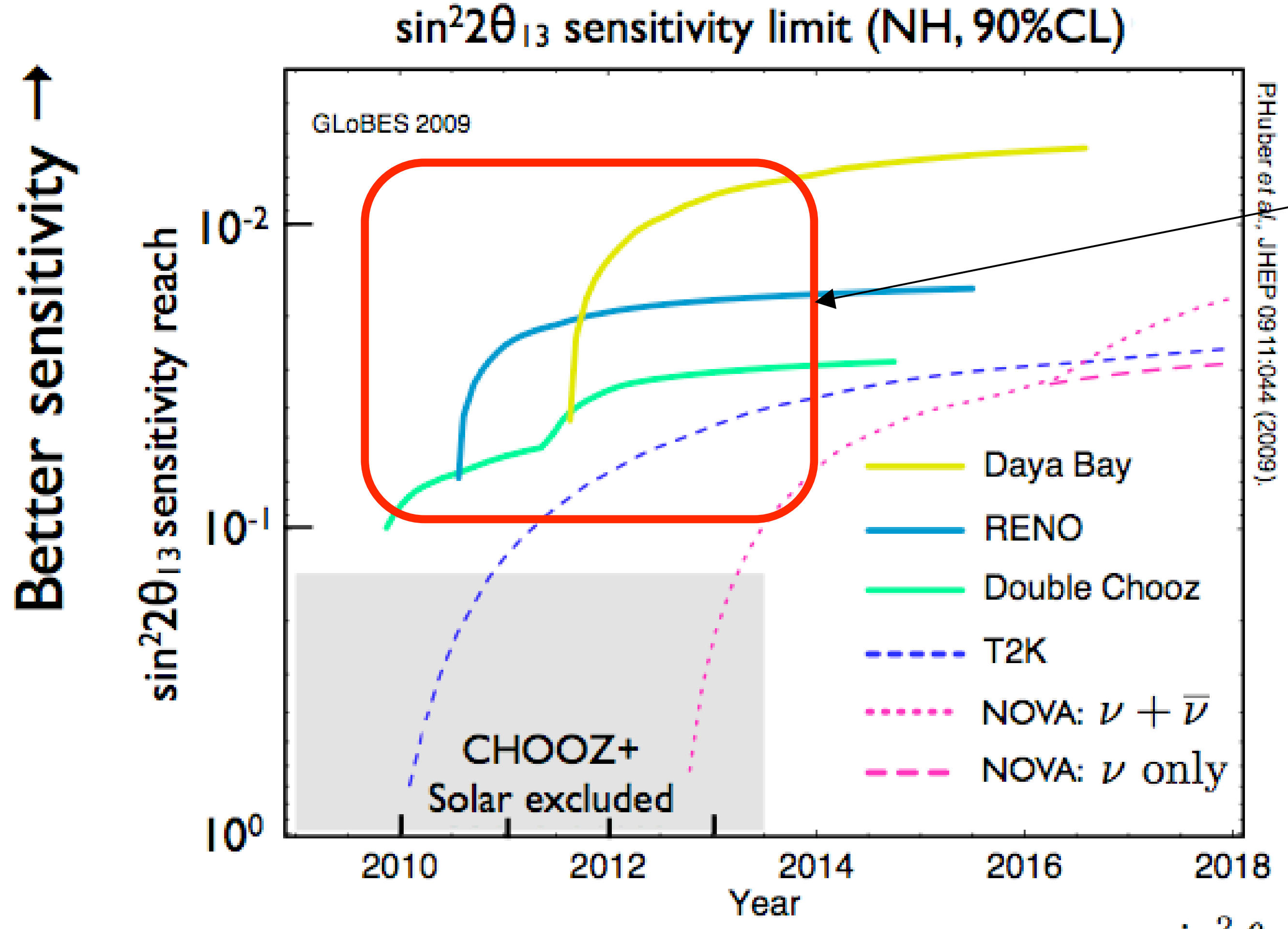


$$\sin^2\theta_{13} \approx \frac{1}{4}\sin^2 2\theta_{13}$$

Reactor experiments will find or put best limit on θ_{13}

After some quite expt. years…….. >

θ_{13}



reactors

Decowski

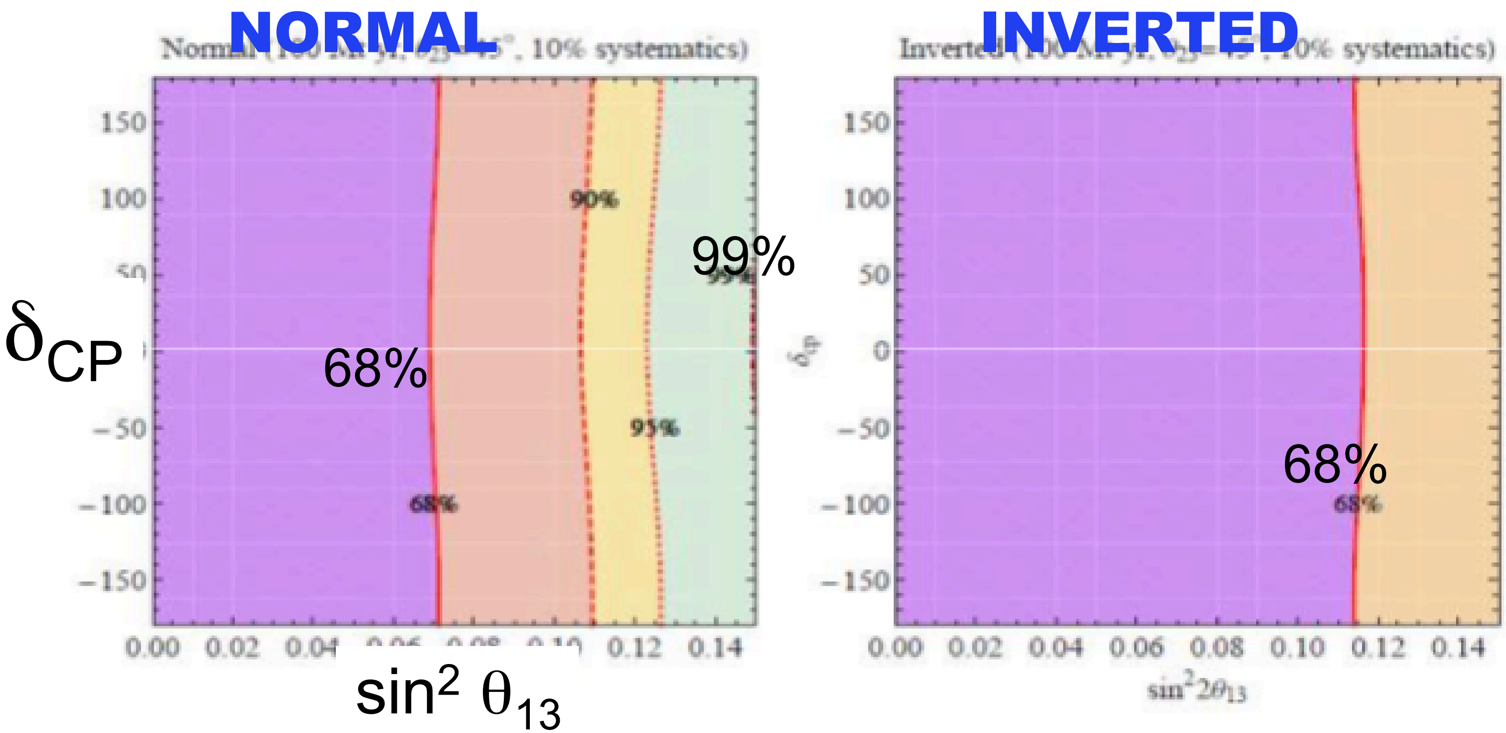
$$\sin^2\theta_{13} \approx \frac{1}{4}\sin^2 2\theta_{13}$$

Reactor experiments will find or put best limit on θ_{13}

** Miciou*

Icecube Deep Core

Sensitivity to **Neutrino hierarchy** if θ_{13} large



A chance to discovery in the next 5-10 years?? Tough

** Dasgupta* : with SN νs, sensitivity to hierarchy even for θ_{13} ->0

Dark matter

Visible matter

We ~understand particles = excitations

We DO NOT understand the vacuum

Dark matter

We ignore both vacuum and excitations

* Dark matter may feel only gravity

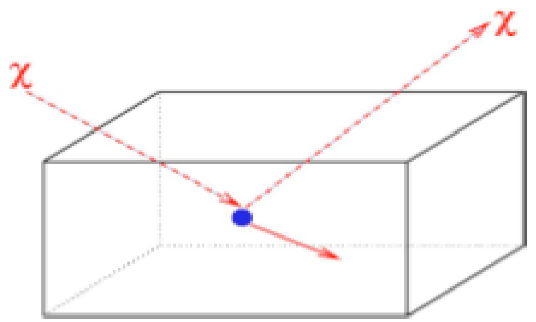
* Yet, it had to be created somehow ---> interactions?

We should look for those interactions.

* Dark matter particles can have any mass down to < GeV

Green'

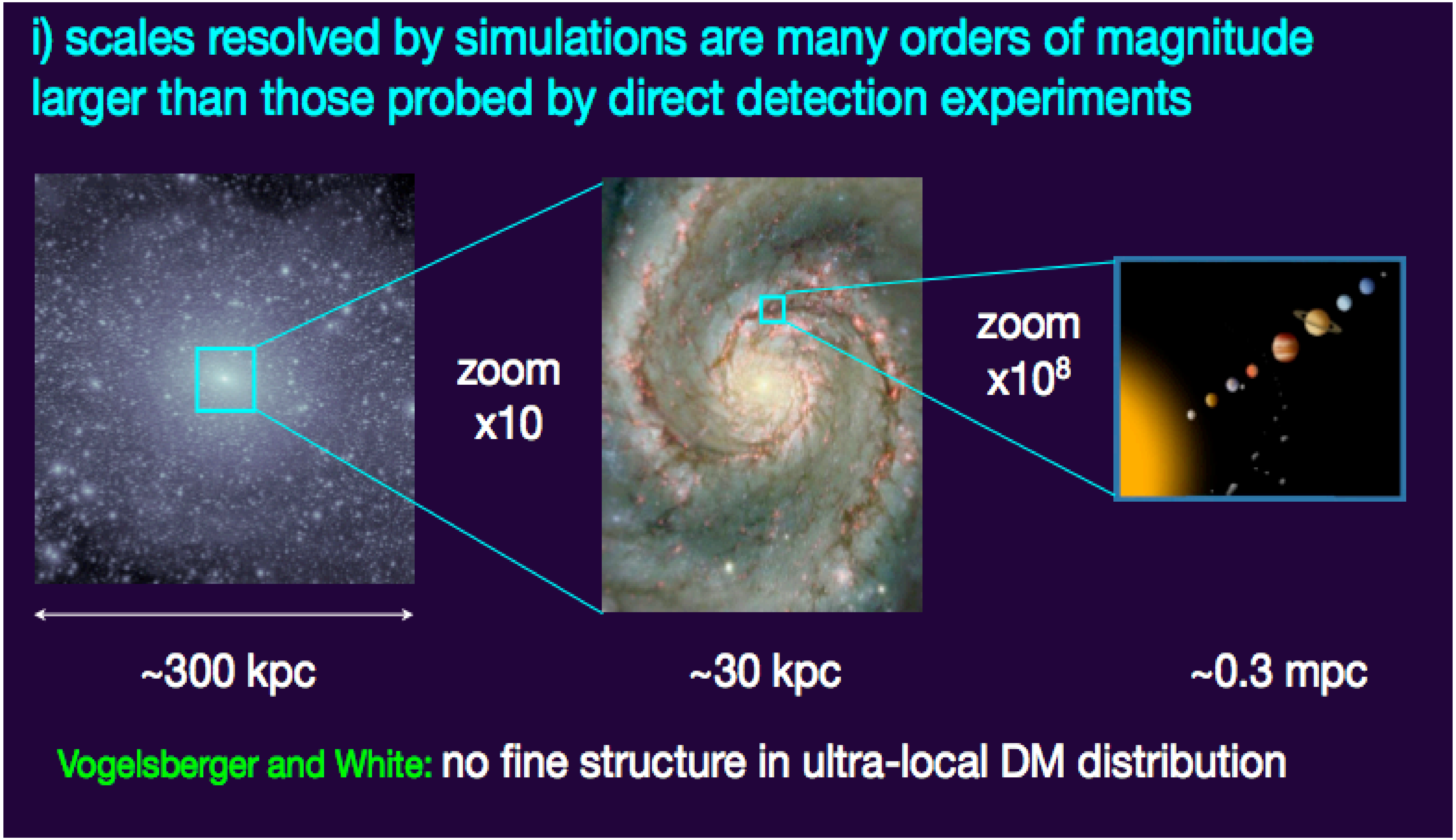
Direct detection is the only way of observing the ultralocal DM distribution



We have got a rough idea of what the density and velocity distributions of dark matter are. (Still mainly without including baryons)

* Until about 2 years ago, the halo models were treated analytically

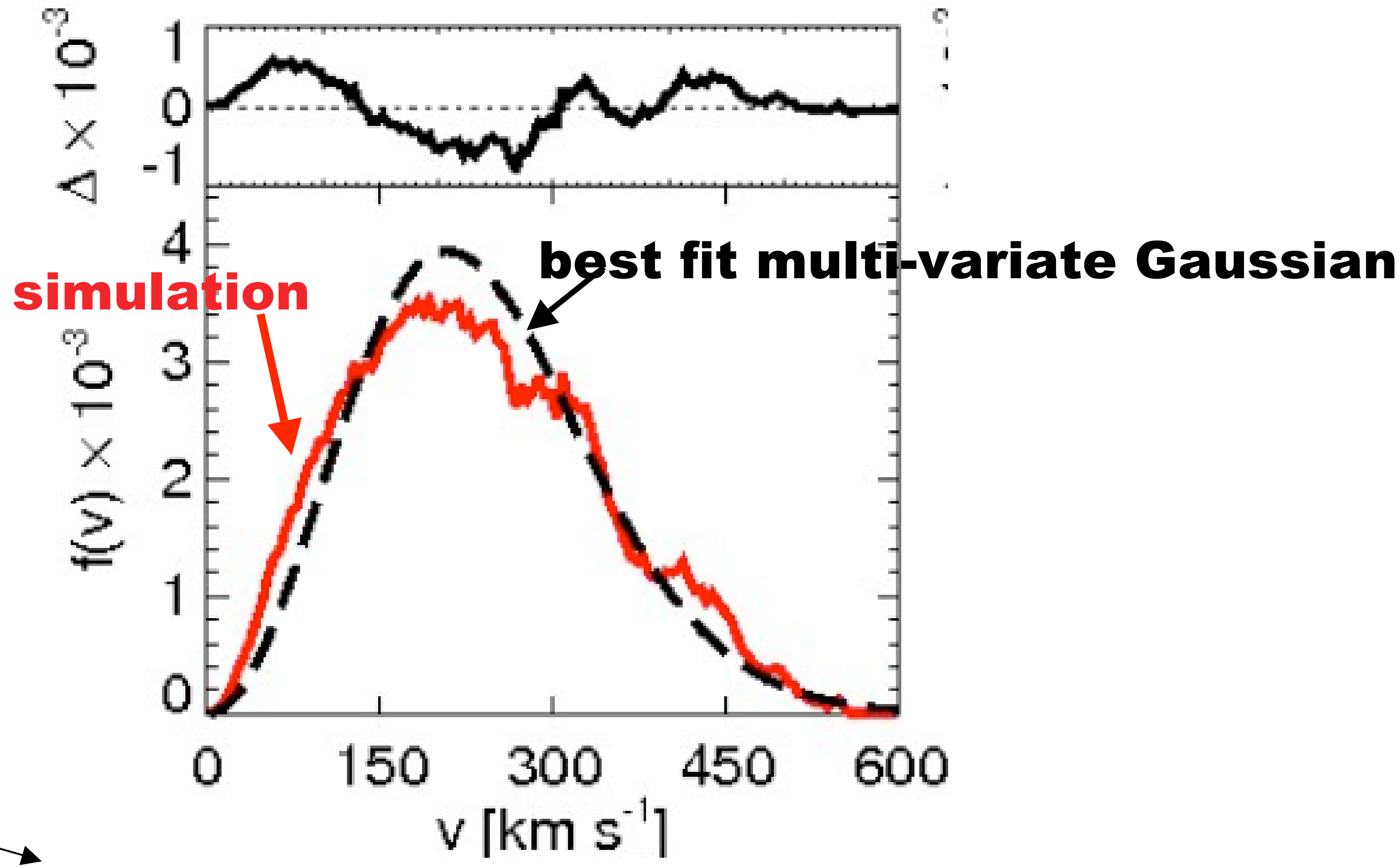
* Simulations are now available



Simulations: deviations from standard halo model smaller than feared

Green

Speed distribution

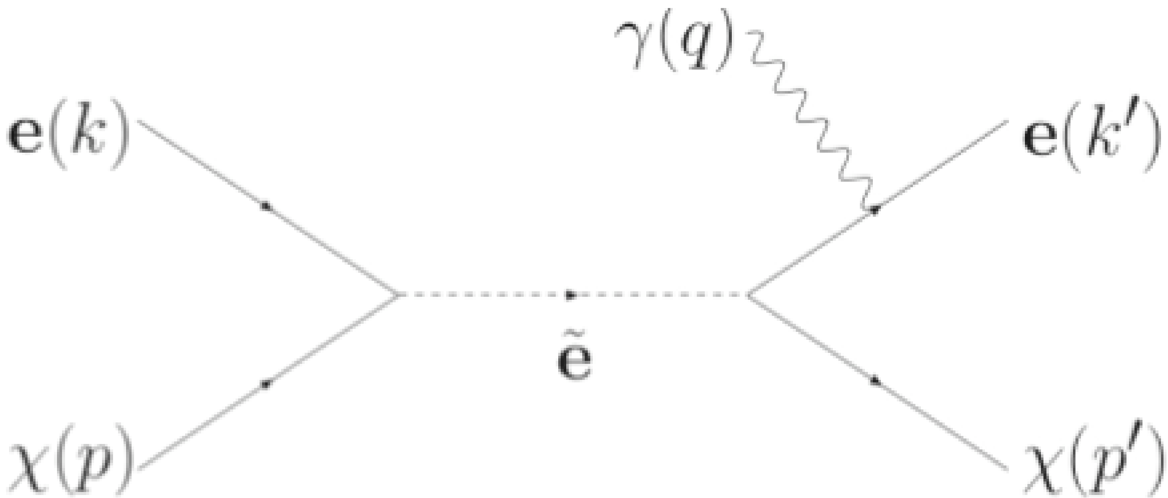


Effect of changing *shape* of speed distribution: <5% systematic

.... error larger for light (GeVs) dark matter mass

- AGN jets and dark matter

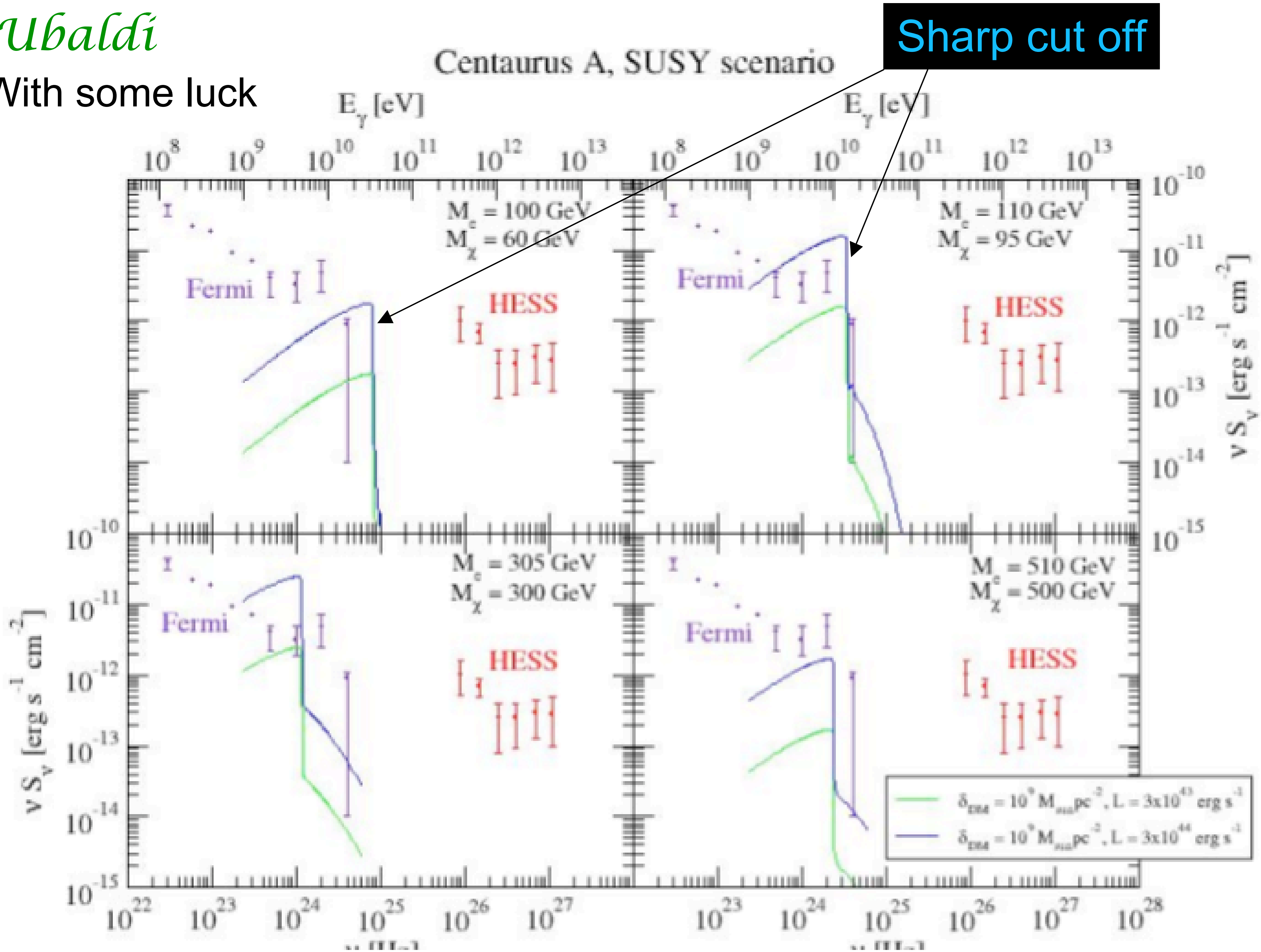
Electron in the jet + DM → selectron →DM+e+**gamma**



(Isotropic) Gamma spectrum cuts off sharply for e at rest

Ubaldi

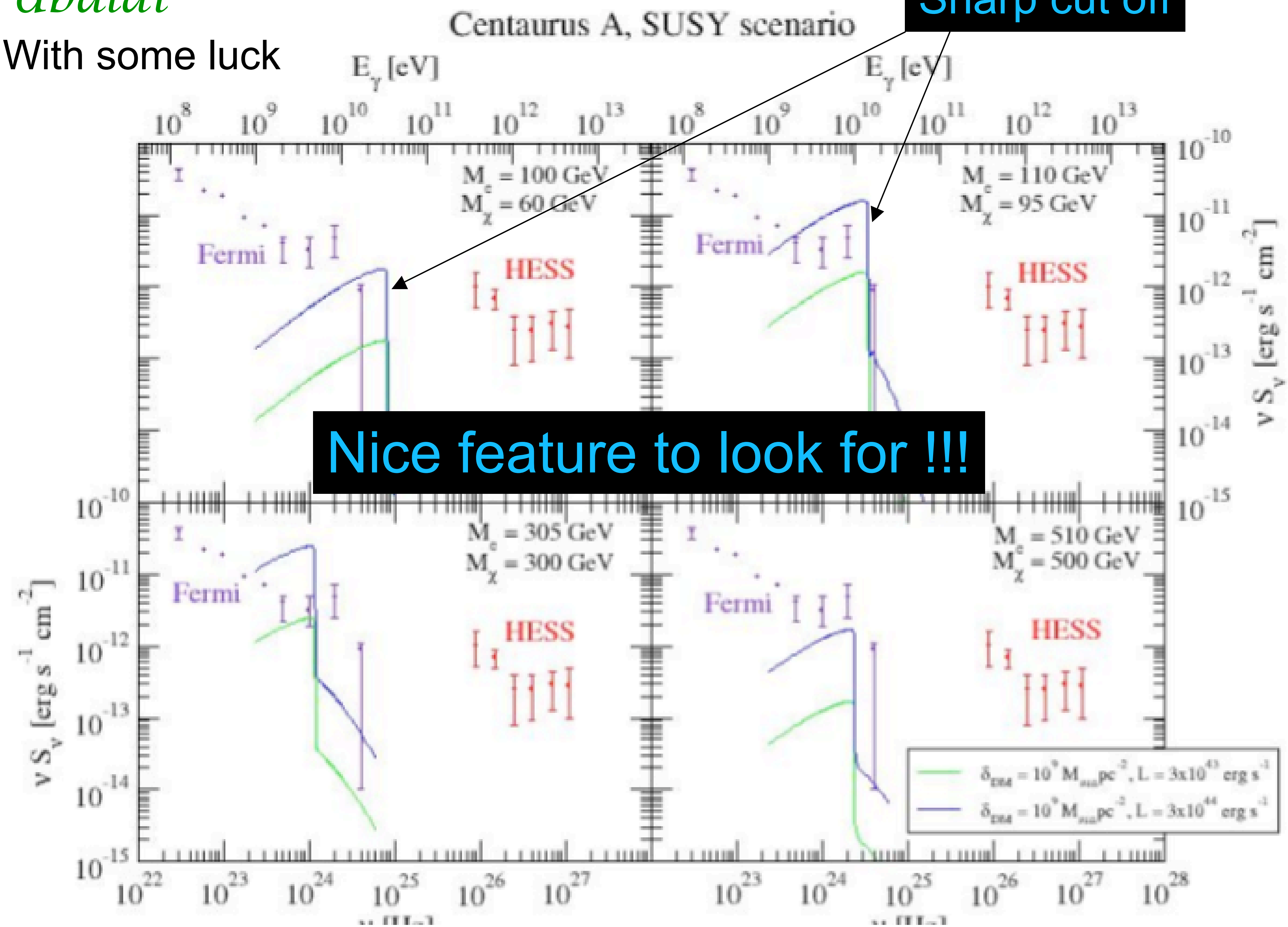
With some luck



Ubaldi

With some luck

Sharp cut off



Nice feature to look for !!!

Servant

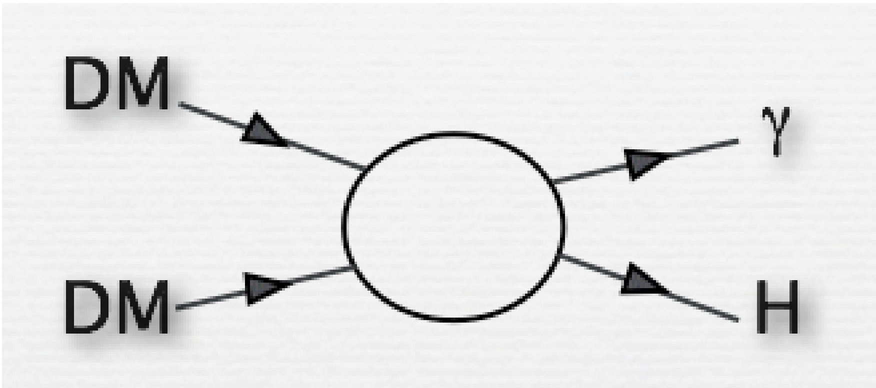
WIMPS ?

→ a particle with a typical Fermi-scale cross section $\sigma_{anni} \approx 1$ pb leads to the correct dark matter abundance.

Are DM and EW symmetry breaking related ? If so, wimps may have enhanced couplings to massive states, top, W/Z, H etc.

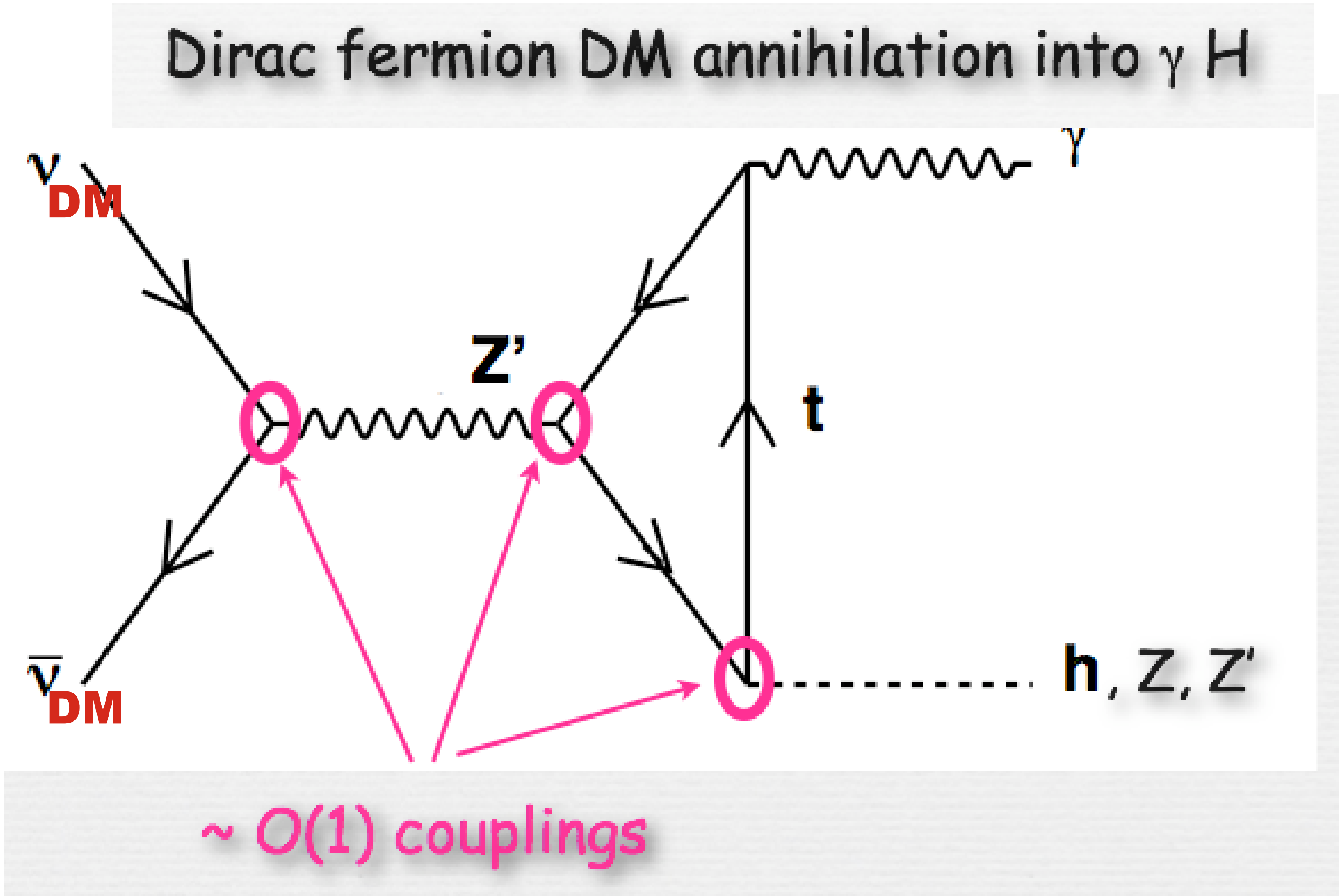
Indirect detection

For



several ad hoc but SIMPLE models

Servant Simple model to explore "Fermi-like" reach



If such signal seen --> DM is Dirac fermion or vector

Fairbarn

DM = Axion-like particles

Magnetic fields in the galaxy convert photons to axions and back

Directional correlations of the foreground magnetic field of the galaxy and distant sources can provide novel information on axion-like particles

Conclusion

Thank you very much

for trying so passionately

to understand nature

Other topics + Back-up

“ Setting to zero those ~100 parameters is not a fine tuning but an ansatz “

Agreed, it is not a fine tuning….

it is a brutal tuning unless a new symmetry is advocated

which one ?

If you do not care about naturalness, fine

But then: why did you start this game?

Gripaios

Composite ----> Strong dynamics

Strong dynamics is good to give masses to W, Z

i.e. Technicolor , etc.

The main trouble also here used to be the FERMION WALL

Gripaios

Composite ----> Strong dynamics

Global symmetry $SO(6)/SO(5)$ BMG, A. Pomarol, F. Riva, J. Serra, 0902.1483

- Light d. o. f.: SM Higgs plus singlet
- The singlet can be light
- Non-standard Higgs decays: $h \to 2\eta \to 4f$

Higgs is a ~goldstone boson of the global symmetry

FCNC remedy …….. fermion masses through heavy sector

Linearly: $\mathscr{L} \subset y_L f_L \mathscr{O}_R + y_R f_R \mathscr{O}_L + g \mathscr{O}_L \mathscr{O}_H \mathscr{O}_R$

strong sector

D. B. Kaplan, 1991

In other words: SM fermions mix with heavy fermions

Gripaios

Strong sector scale Λ , alike to Λ_{QCD}, $\Lambda \sim 4 \pi v$

FCNC + EWcorrections --> Λ ~3 TeV --> v ~500 GeV

but we need v = 250 GeV

---> tuning of 20% in v^2

What is the complete theory? ... problems postponed

Signals: ~ 50% modified Higgs couplings to fermions, W´s, g´s...

-----> Δ_{ijH} analysis in *Rauch's* talk (plus exotics) mass(ν) $\neq$ 0 ---> **new physics** scale

plausibly Majorana

- Discover other new physics in neutrino interactions **?**

Unfortunately **no** smoking gun of seesaw(s) expected within reach

Whay not try anyway ?

i.e. Neutrinos are optimal probes of environmental new forces

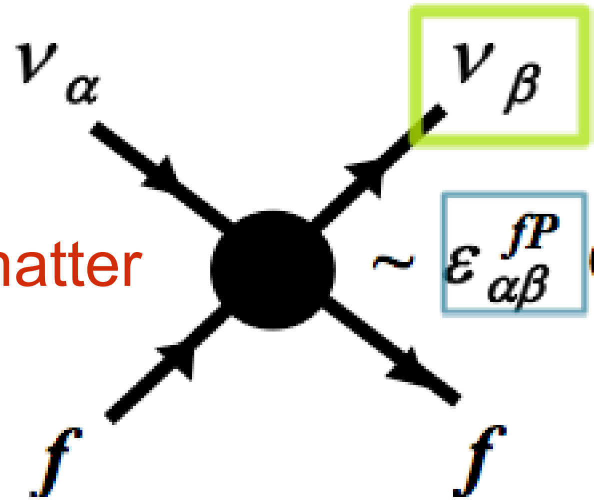
Oki

Neutrino Oscillation with Non Standard Interaction

NSI

$$L^{NSI}_{eff} = -\boxed{\varepsilon^{fP}_{\alpha\beta}}\, 2\sqrt{2} G_F (\bar{\nu}_\alpha \gamma_\rho L \nu_\beta)(\bar{f} \gamma^\rho P f')$$

Interaction **only** in matter



$\sim \boxed{\varepsilon^{fP}_{\alpha\beta}}\, G_F$

Can mimic θ_{13}?

T2KK may bound/measure $\boxed{|\varepsilon_{ee}| \leq 1.0\,,\ |\varepsilon_{e\tau}| \leq 0.15}$

Interaction **only** in matter

And not also in production and detection

requires tuning/cancellations among higher order gauge invariant operators

??

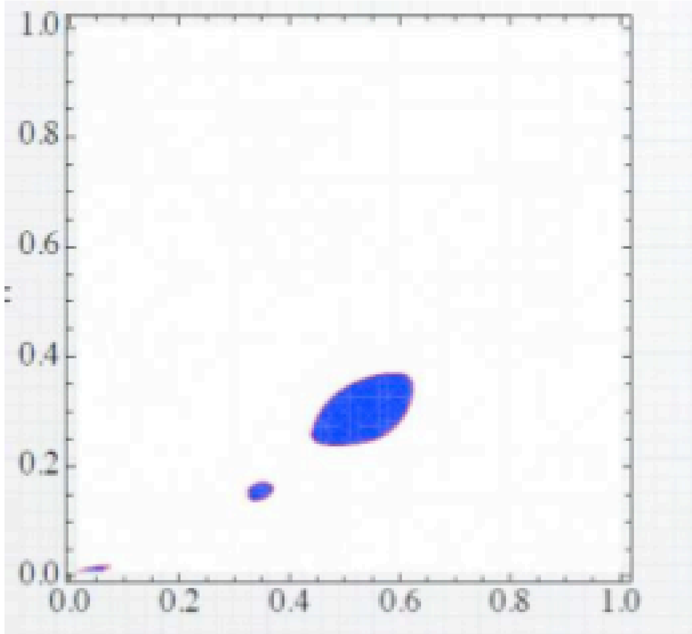
i.e. in the (unobservably small) the NSI interactions characteristic of seesaws,

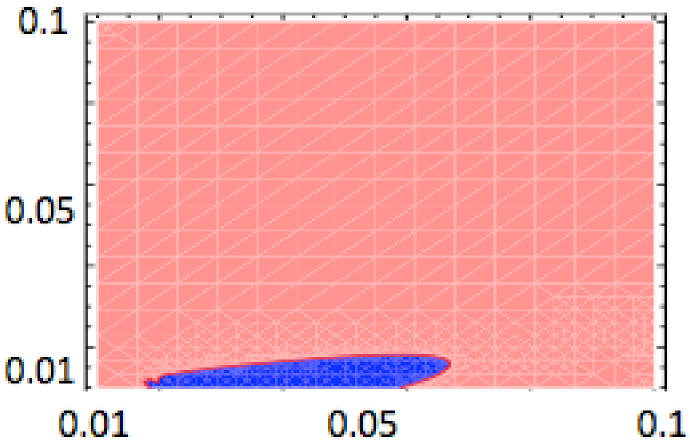
production + propagation + detection

ARE correlated

Miciou

Again interaction **only** in matter

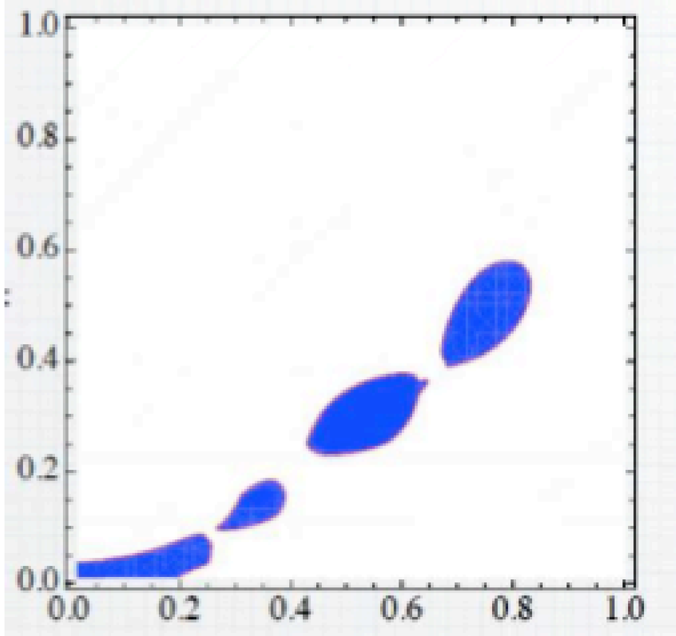




$\varepsilon_{e\tau}$ - $\varepsilon_{\tau\tau}$

Preliminary

Icecube Deep Core



Comparable to *Oki*'s sensitivity to T2KK ?

Nemevsek

Triple spin correlations

in muon decay

- Form a triple spin correlation $(\vec{s}_\mu \times \vec{s}_e) \cdot \vec{p}_e$

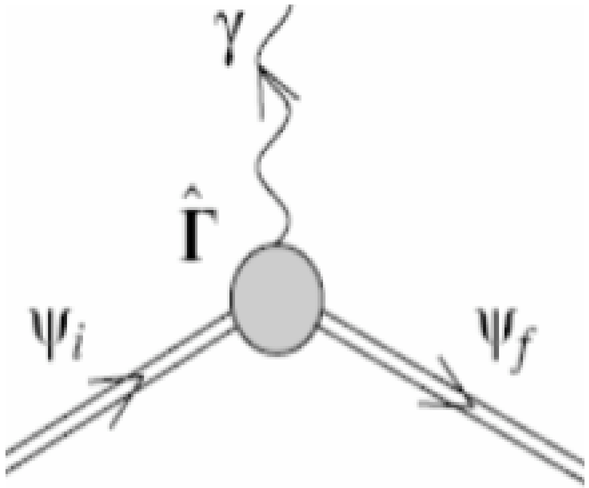
Maybe CP-violation signal in L-R seesaw models

Even if measured, how can we differentiate seesaw-related CP from ? other CP sources

Lokhov

$$\boxed{\nu_i \rightarrow \nu_j + \gamma}$$

$$\boxed{m_i \neq m_j}$$



- γ is coupled to ***neutrinos*** by transition magnetic moment μ_ν
- high density of matter $n \sim 10^{37} \div 10^{40}\ cm^{-3}$

(neutron stars)

Billard

Directional detection of DM

MIMAC, DRIFT, DM-TPC and NEW AGE
will measure the nuclear-recoil direction

Backgrounds are isotropic !
(or have a tractable angular distribution)

A neat Likelihood analysis allows one to reconstruct the INCOMING DM-particle's directional distribution

➔ The direction planet Earth is moving in an assumed Non-rotating Galactic halo

Back up

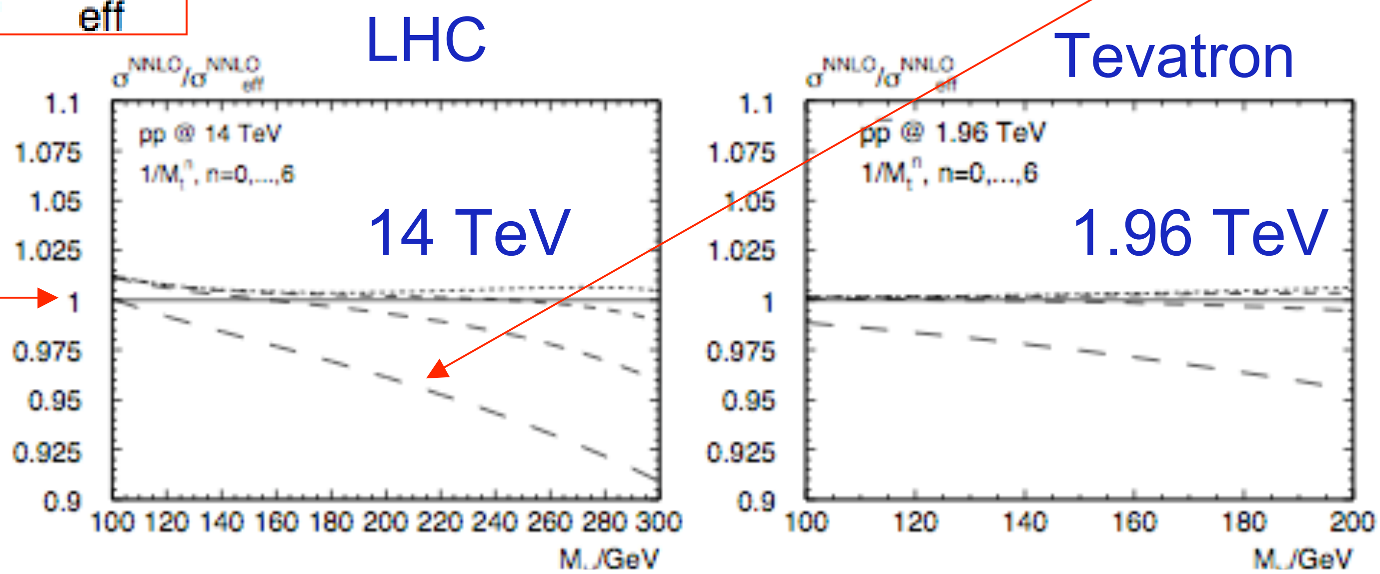
Schucker

$$\begin{tikzcd}
\text{noncommutative geometry} \arrow[rr, "\text{Connes}"] & & \begin{array}{l}\text{gravity} \\ \;+\text{ Yang-Mills-Higgs ansatz} \\ \;+\text{ constraints}\end{array} \\
\text{Riemannian geometry} \arrow[u, hook, "\text{Connes}"] \arrow[rr, "\text{Einstein}"] & & \text{gravity}
\end{tikzcd}$$

Harlander

Higher orders in $1/m_{top}$

$\sigma^{NNLO}/\sigma^{NNLO}_{eff}$



The itchiness (or Higgchiness?)
in the air
of the Tevatron era

… as we are almost "touching" the vacuum
quantum numbers