MC tools for Hidden Valley

mc4bsm

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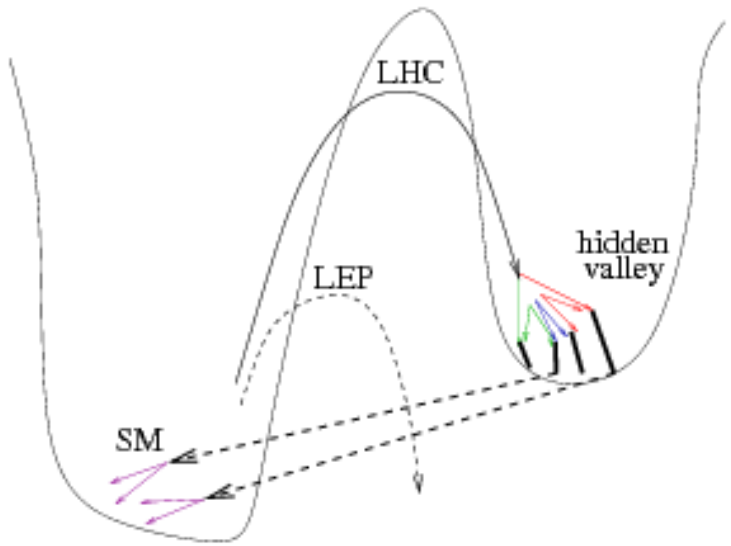
Outline

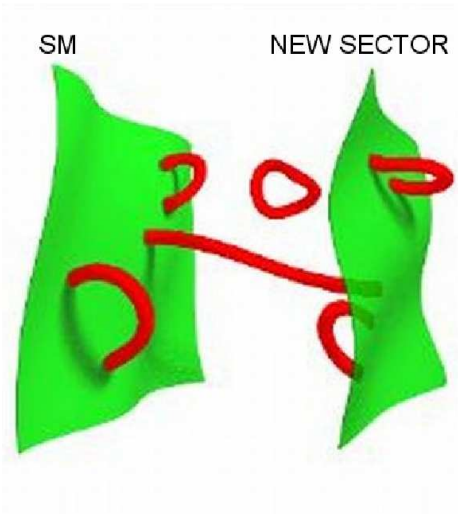
Hidden Valleys [hep-ph/0604261] Strassler,Zurek

- New sector, decoupled from SM
  $\sim$ TeV
- Light particles $\sim$ 50 GeV
- Barrier, small production σ
  $\sim$ 100 fb
  - coupling via very heavy communicators $\sim$ TeV
  - small direct coupling
  - loops of heavy communicators



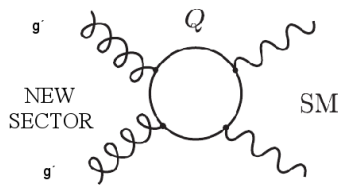
Motivation

Many theories predict new hidden sectors with decoupling at TeV : SUSY, LH, ED...



(Kang, Luty 2008)

Hidden sector = light "glueballs"



$$\Rightarrow \quad \mathcal{L}_{\text{eff}} \sim \frac{g^2 g'^2}{16\pi^2 m_Q^4} F_{\mu\nu}^2 F_{\rho\sigma}'^2$$

Very decoupled from SM

Studying hidden sector can provide insight about gauge groups, particle content, symmetry breaking mechanisms

Hidden Valley Radiation and BSM

- What if there is Hidden radiation?
- Consequences on visible particle kinematics?
- Can we still distinguish between two different BSM models?

$\Downarrow$

specific class of models

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Hidden Valley in PYTHIA 8

Hidden Valley sector

- Gauge Group

$SU(N_c)$	$U(1)$
unbroken	broken/unbroken
g_v	γ_v
$\downarrow$	$\downarrow$ $\quad$ $\downarrow$
$M_{g_v} = 0$	$M_{\gamma_v} > 0$ $\quad$ $M_{\gamma_v} = 0$

α_v free parameter, no running

- Particle Content

  q_v massive $s = 0, 1/2, 1$ belongs to $(\mathbf{1}, \mathbf{N_c})$ of $G_{SM} \times SU(N_c)$

Communicator sector

- massive communicators:

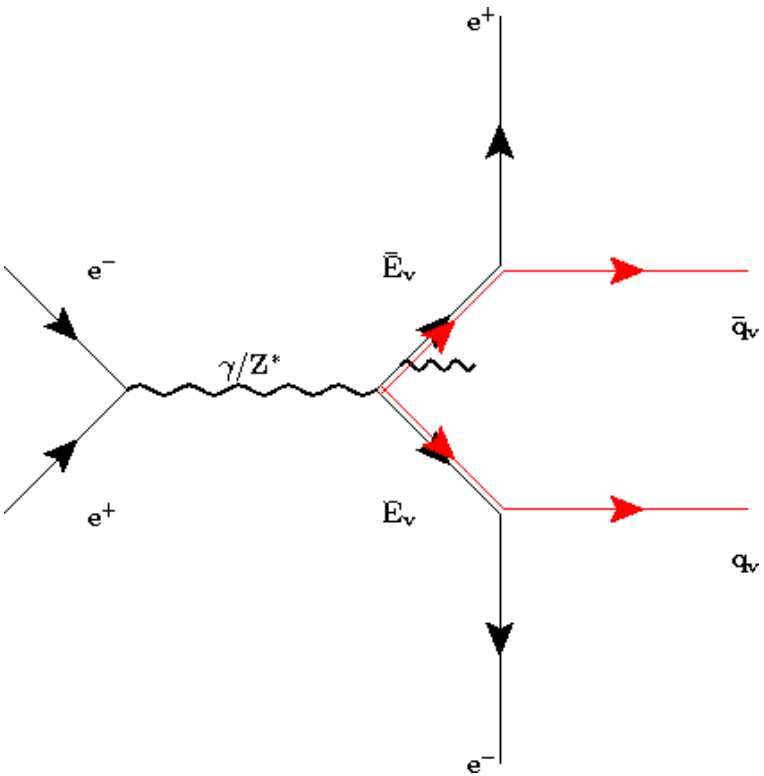
$$\underbrace{SU(2) \times U(1)}_{SM} \times SU(N) \qquad \begin{pmatrix} E_v \\ \nu_{E_v} \end{pmatrix} \quad 2^{nd} \quad 3^{rd}$$

$$\underbrace{SU(3)_c \times SU(2) \times U(1)}_{SM} \times SU(N) \qquad \begin{pmatrix} D_v \\ U_v \end{pmatrix} \quad 2^{nd} \quad 3^{rd}$$

  with $s = 0, 1/2, 1$

- production: $f\bar{f} \to \gamma^\star/Z^\star \to F\bar{F}_v$
  $gg \to Q_v\bar{Q}_v$
  $q\bar{q} \to Q_v\bar{Q}_v$
- decay: $F_v \to f\, q_v$, coupling is a free parameter

Parton Showers: interleaved radiation



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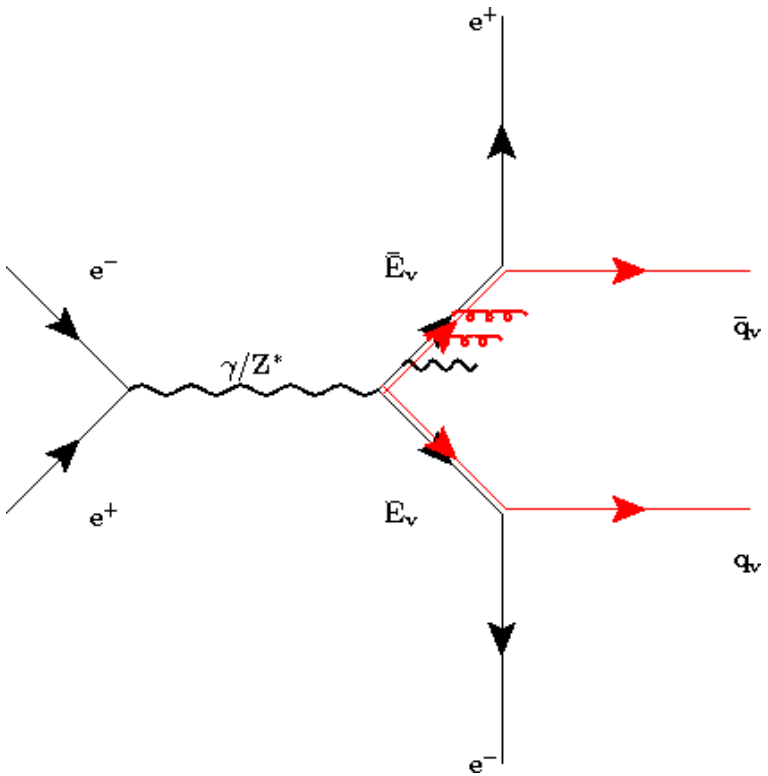
Parton Showers: interleaved radiation



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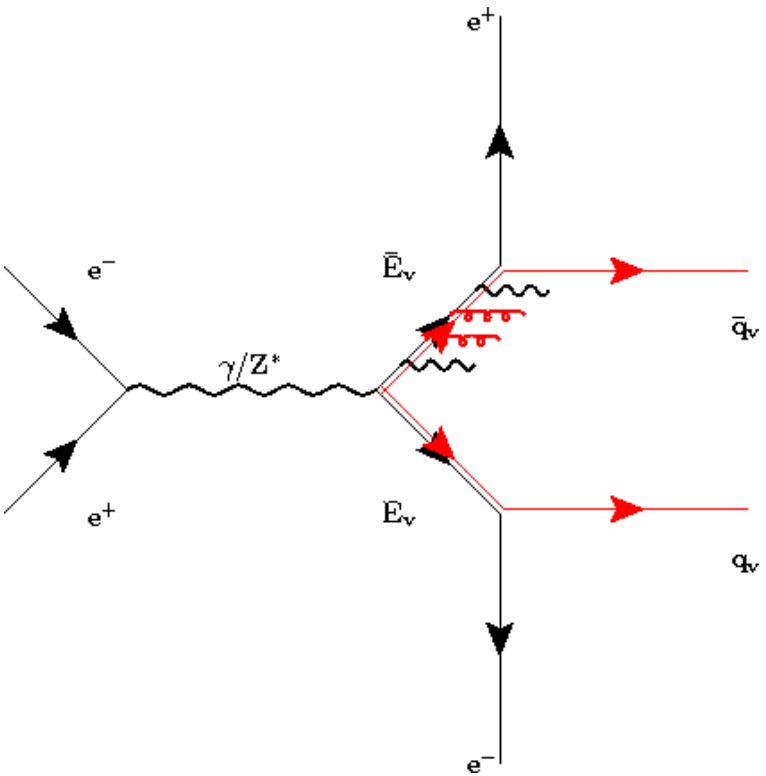
Parton Showers: interleaved radiation



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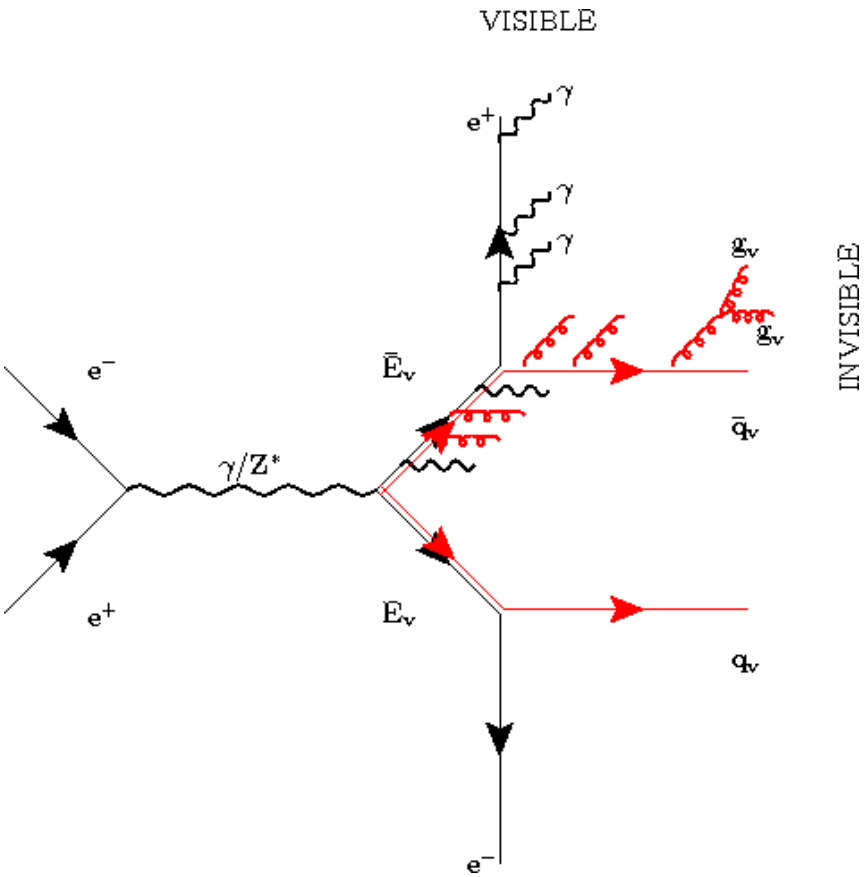
Parton Showers:



- v-color flows from E_v to q_v

$\Downarrow$

q_v emits a g_v

$\Downarrow$

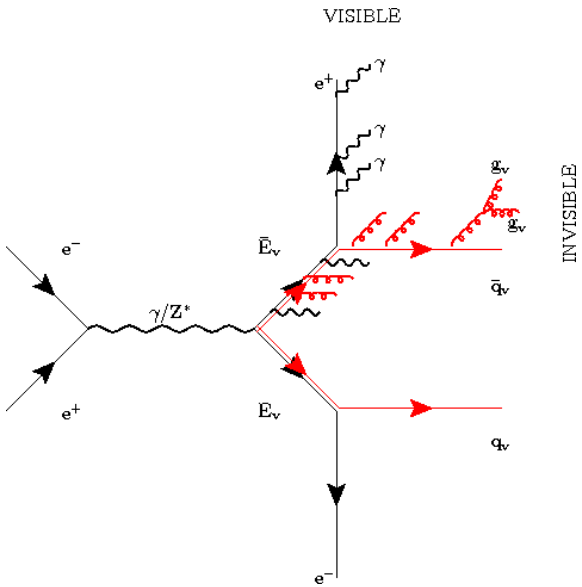
$m^{eff}_{q_v}$ changes

$\Downarrow$

the e^+ distribution changes

Model

Can v-radiation affect visible kinematics?



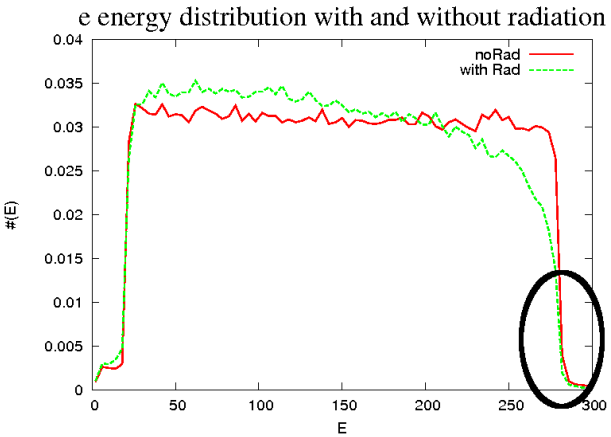
- unbroken $SU(3) \Rightarrow m_{g_v} = 0$
- E_v charged under $SU(3) \times G_{SM}$
- $E_v \longrightarrow e\, q_v$
- parameters: $\alpha_v, M_{E_v}, M_{q_v}$

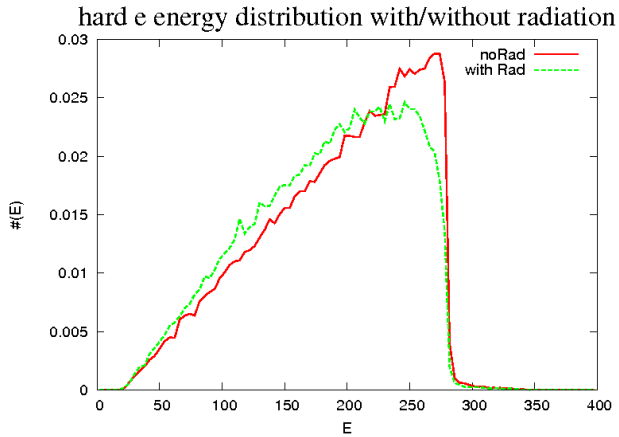
- $q\bar{q}/gg \longrightarrow D_v \bar{D}_v$ and $D_v \longrightarrow d\, q_v$

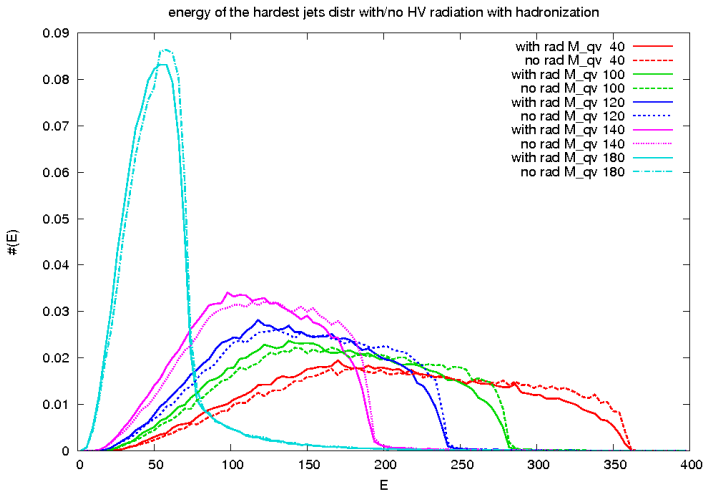
$E_v \longrightarrow e\, q_v$	ILC (800 GeV)	CLIC (3TeV)	$D_v \longrightarrow d\, q_v$	LHC (7 TeV)	LHC (14 TeV)
$M_{E_v} = 300$ GeV	400 fb	44 fb	$M_{D_v} = 300$ GeV	$1.39 \cdot 10^4$ fb	$1.04 \cdot 10^5$ fb
$M_{E_v} = 500$ GeV	-	41 fb	$M_{D_v} = 500$ GeV	$654 \cdot 10^2$ fb	$7.27 \cdot 10^3$ fb
$M_{E_v} = 1$ TeV	-	32 fb	$M_{D_v} = 1$ TeV	3 fb	124· fb

Effects at e^+e^- colliders

- endpoint gives $M_{E_v} \leftrightarrow M_{q_v}$
- low statistics $\Rightarrow$ infer endpoint from shoulder







- radiation changes shoulder $\Rightarrow (M_{E_v}, M_{q_v})$
- more radiation the larger $M_{E_v} - M_{q_v}$, the lighter q_v
- radiation has distinctive features

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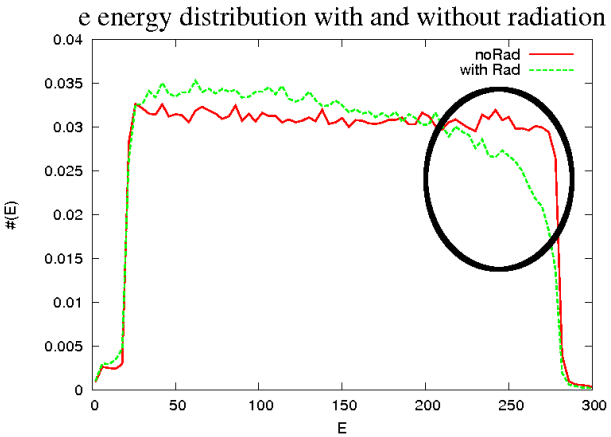

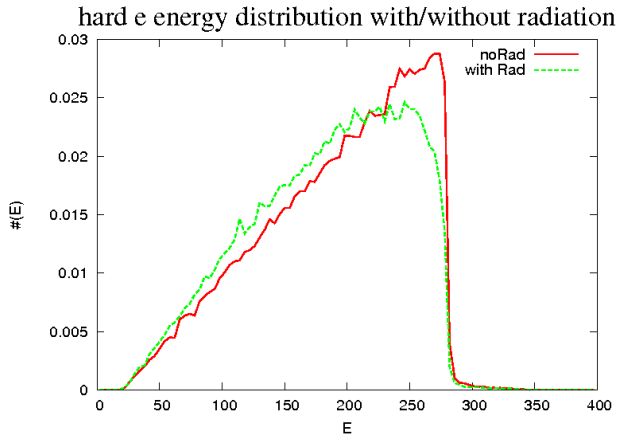

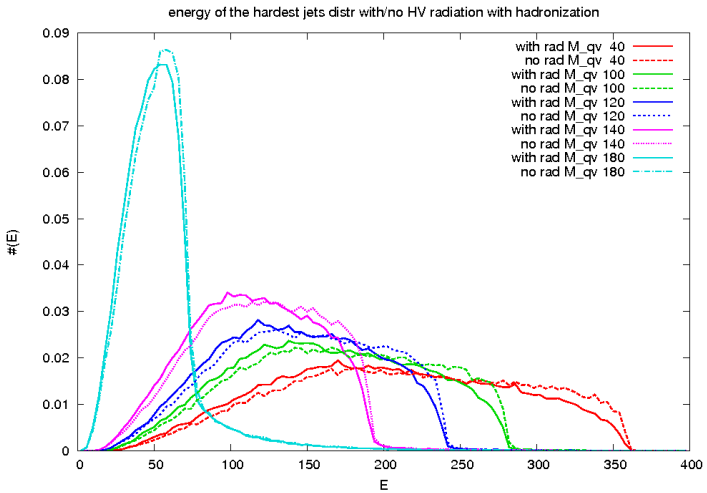

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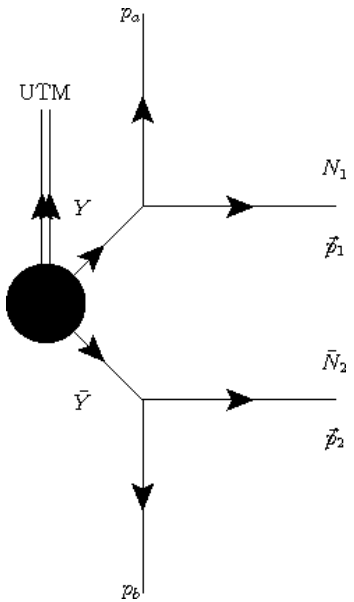
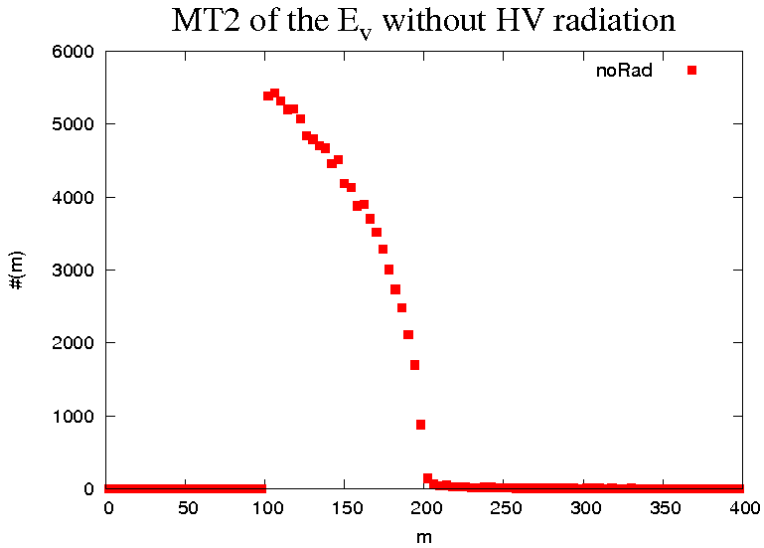
MT2 and MT2$_\perp$ [hep-ph/9906349] Lester-Summers, [hep-ph/0910.3679] Matchev

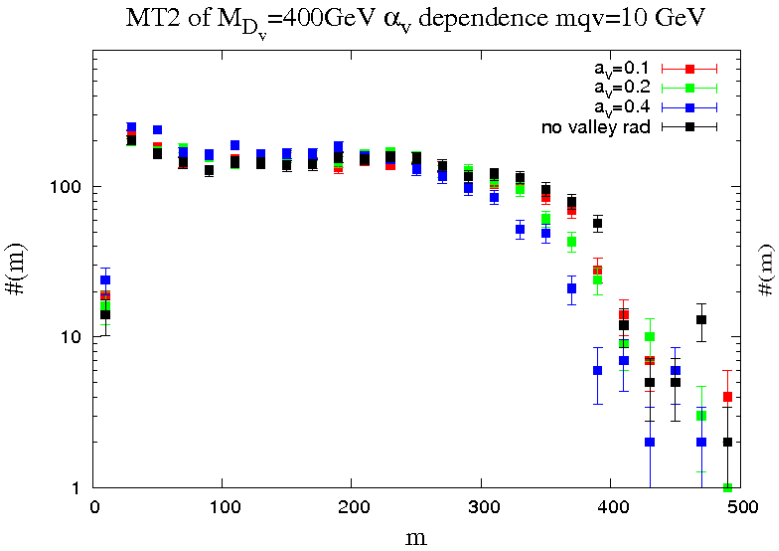
$$\not{\mathbf{p}} = \mathbf{p}'_1 + \mathbf{p}'_2$$
$$m_T^2 = M_e^2 + M_N^2 + 2(E_T^e \not{E}_T^N - \mathbf{p}_T^e \cdot \mathbf{p}_{1T}^N)$$

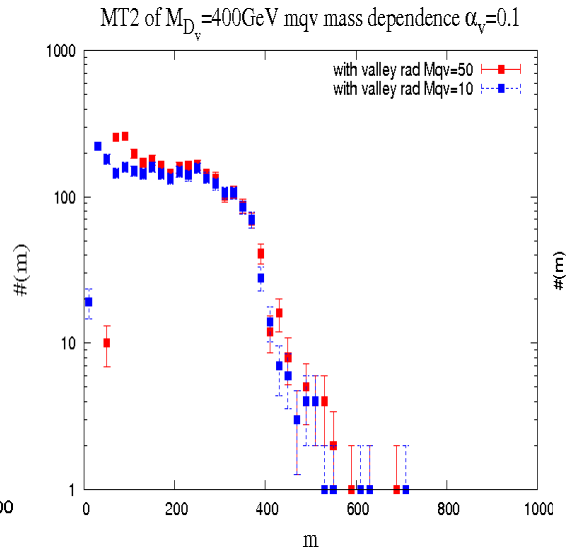


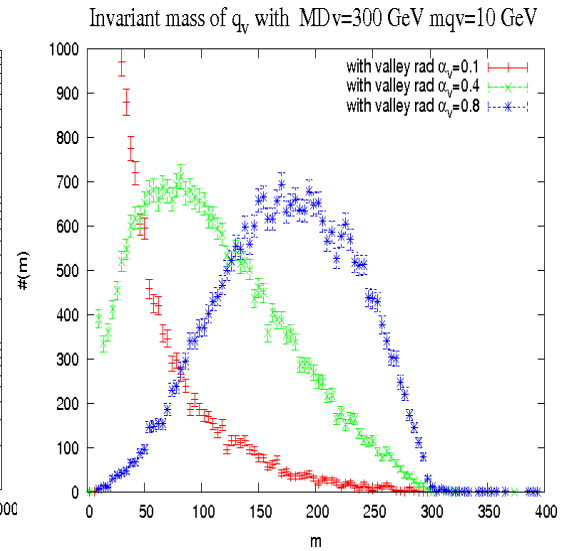


- endpoint $\Rightarrow M_Y \leftrightarrow M_N$
- MT2$_\perp \Rightarrow M_N$

Effects at LHC @ 7 TeV

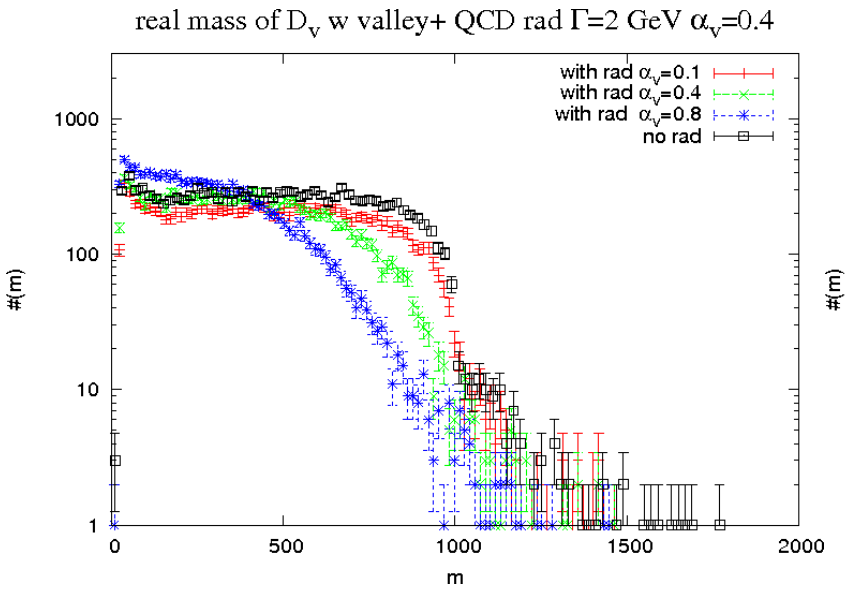


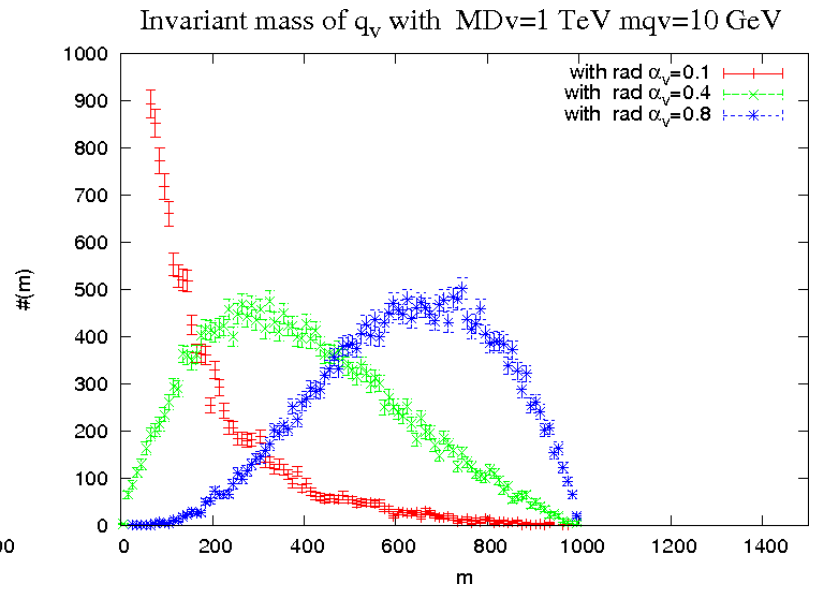




- MT2 distribution for $L = 1$ fb^{-1}, $M_{D_v} = 400$ GeV. Start to see radiation from $\alpha_v \geq 0.2$.
- MT2 Hard to distinguish between $M_{q_v} = 10,50$ GeV.
- $M_{q_v}^{eff}$ shifts from $10 \longrightarrow 300$ GeV.

Effects at LHC @ 14 TeV





- MT2 distribution for $L = 100$ fb^{-1}, $M_{D_v} = 1$ TeV, $M_{q_v} = 10$ GeV and $\alpha_v = 0.1, 0.4, 0.8$. See radiation already with $\alpha_v \geq 0.1$.
- $M_{q_v}^{eff}$ shifts from 10 GeV $\rightarrow$ 1 TeV.

Conclusions

1. MC tools for Valley shower: PYTHIA 8
2. valley radiation affects communicator-invisible particle mass relations
3. first 2 years LHC requires $\alpha \geq 0.2$
4. at LHC 14 TeV already at $\alpha \geq 0.1$

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