01

Lepton Transmutation from a Rotating Mass Matrix

TSOU Sheung Tsun
Mathematical Institute, Oxford University
24–29 St. Giles', Oxford OX1 3LB
United Kingdom.
tsou@maths.ox.ac.uk
周尚真

+ Chen + Bordes hep-ph/0006338
+ Chan + Bordes + Faridani hep-ph/0007304

ICHEP200 Osaka PA-15: 29/07/2000

Rotating mass matrix
= mass matrix undergoes unitary transformations
through scale changes

Standard Model (SM)

$$\frac{dL}{dt} = \frac{3}{128\pi^2}\frac{1}{246^2}\overbrace{(ULU^\dagger)}^{N}\overbrace{(ULU^\dagger)^\dagger}^{N^+}$$

(linearized rotating part)

where U is non-diagonal MNS mixing matrix.

Dualized Standard Model (DSM)

$$m = m_T \begin{pmatrix} x \\ y \\ z \end{pmatrix} (x, y, z)$$

$$\frac{d}{dt}\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \frac{5}{32\pi^2}\rho^2 \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix}$$

- ICHEP98
- +Chan, PRD 57(1998) 2107, hep-th/9701120 ------>

  +Borlac+ Chan+ Faridani hep-ph/0007004

DSM references

- Chan + Tsou, hep-th/9701120, PRD 57(1998) 2037
- Chan + Tsou, hep-th/9702117, PRD 56(1997) 3646
- Bordes + Chan + Faridani + Pfaudler + Tsou
  hep+ astro-ph/9707031, Astropart. Phys. 8(A98) 135
- Bordes + Chan + Faridani + Pfaudler + Tsou
  hep-ph/9712276, PRD 58(1998) 013004
- Bordes + Chan + Pfaudler + Tsou
  hep-ph/9802420, PRD 58(1998) 053003
- Bordes + Chan + Pfaudler + Tsou
  hep-ph/9802436, PRD 58(1998) 053006
- Bordes + Chan + Faridani + Pfaudler + Tsou
  hep-ph/9807277, PRD 60(1999) 013005
- Bordes + Chan + Tsou, hep-ph/9901440, Eur. Phys. J. C10(1999)63
- Bordes + Chan + Gallego + Tsou
  hep-ph/9909321, PRD61(2000)0077702
- Bordes + Chan + Tsou hep-ph/0006338
- Bordes + Chan + Faridani + Tsou hep-ph/0007004

Mass matrix rotation

SM depends on mixing matrix U

E.g. take U bimaximal

(GeV per decade change in energy)

$$\begin{aligned} \langle \mu|\tau \rangle &\quad \text{changes by} \quad \sim 5.5 \times 10^{-3} \\ \langle e|\tau \rangle &\quad \text{changes by} \quad \sim 1.8 \times 10^{-7} \\ \langle e|\mu \rangle &\quad \text{changes by} \quad \sim 1.1 \times 10^{-8} \end{aligned}$$

DSM explicit calculations

+ Berdes + Chan hep-ph/9901440
Eur. Phys. J. C10 (1999) 63

3 free parameters determined by fitting experimental mass & mixing parameters

($\rightsquigarrow$ sensible predictions for remaining parameters)

$\rightsquigarrow$ present calculations entirely parameter-free

5

Quantity	*ExperimentalRange*	*Predicted CentralValue*	*PredictedRange*
$\|V_{ud}\|$	$0.9745 - 0.9760$	0.9753	$0.9745 - 0.9762$
$\|V_{us}\|$	$0.217 - 0.224$	(0.2207)	*input*
$\|V_{ub}\|$	$0.0018 - 0.0045$	0.0045	$0.0043 - 0.0046$
$\|V_{cd}\|$	$0.217 - 0.224$	(0.2204)	*input*
$\|V_{cs}\|$	$0.9737 - 0.9753$	0.9745	$0.9733 - 0.9756$
$\|V_{cb}\|$	$0.036 - 0.042$	0.0426	$0.0354 - 0.0508$
$\|V_{td}\|$	$0.004 - 0.013$	0.0138	$0.0120 - 0.0157$
$\|V_{ts}\|$	$0.035 - 0.042$	0.0406	$0.0336 - 0.0486$
$\|V_{tb}\|$	$0.9991 - 0.9994$	0.9991	$0.9988 - 0.9994$
$\|V_{ub}/V_{cb}\|$	0.08 ± 0.02	0.1049	$0.0859 - 0.1266$
$\|V_{td}/V_{ts}\|$	< 0.27	0.3391	$0.3149 - 0.3668$
$\|V_{tb}^* V_{td}\|$	0.0084 ± 0.0018	0.0138	$0.0120 - 0.0156$
$\|U_{\mu 3}\|$	$0.56 - 0.83$	0.6658	$0.6528 - 0.6770$
$\|U_{e3}\|$	$0.00 - 0.15$	0.0678	$0.0632 - 0.0730$
$\|U_{e2}\|$	$0.4 - 0.7$	0.2266	$0.2042 - 0.2531$

Table 1: Predicted CKM matrix elements for both quarks and leptons

Transmutational decays

- $Z^0 \to \tau^- \mu^+$

DSM	(SM)	experimental bound
4×10^{-8}	4×10^{-10}	1.2×10^{-5}

- $\pi^0 \to \mu^- e^+$

DSM	(SM)	experimental bound
3×10^{-9}	far below	1.7×10^{-8}

- $\psi \to \mu^+ \tau^-$

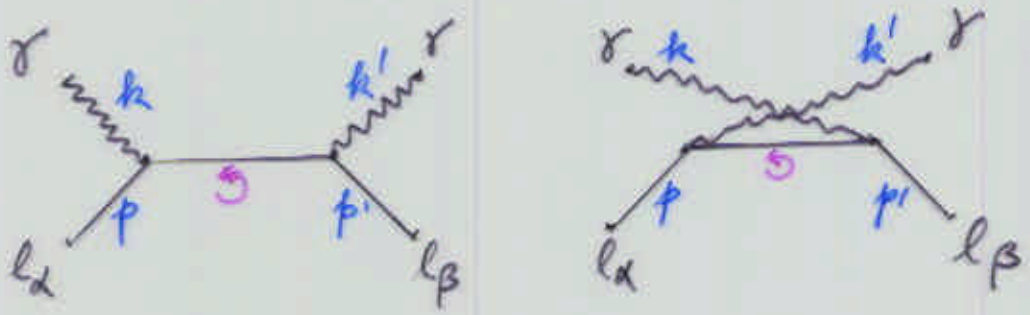
DSM	(SM)	experimental bound
6×10^{-6}	1×10^{-8}	not given

- $\mu^- \to e^- \gamma$

DSM	(SM)	experimental bound
0	?	4.9×10^{-11}

Photo-transmutation

$$\gamma + l_\alpha \to \gamma + l_\beta, \qquad l_\alpha \neq l_\beta$$



Lepton states

- must diagonalize the mass matrix
- eigenvectors depend on scale
- no canonical recipe

Fixed scale diagonalization

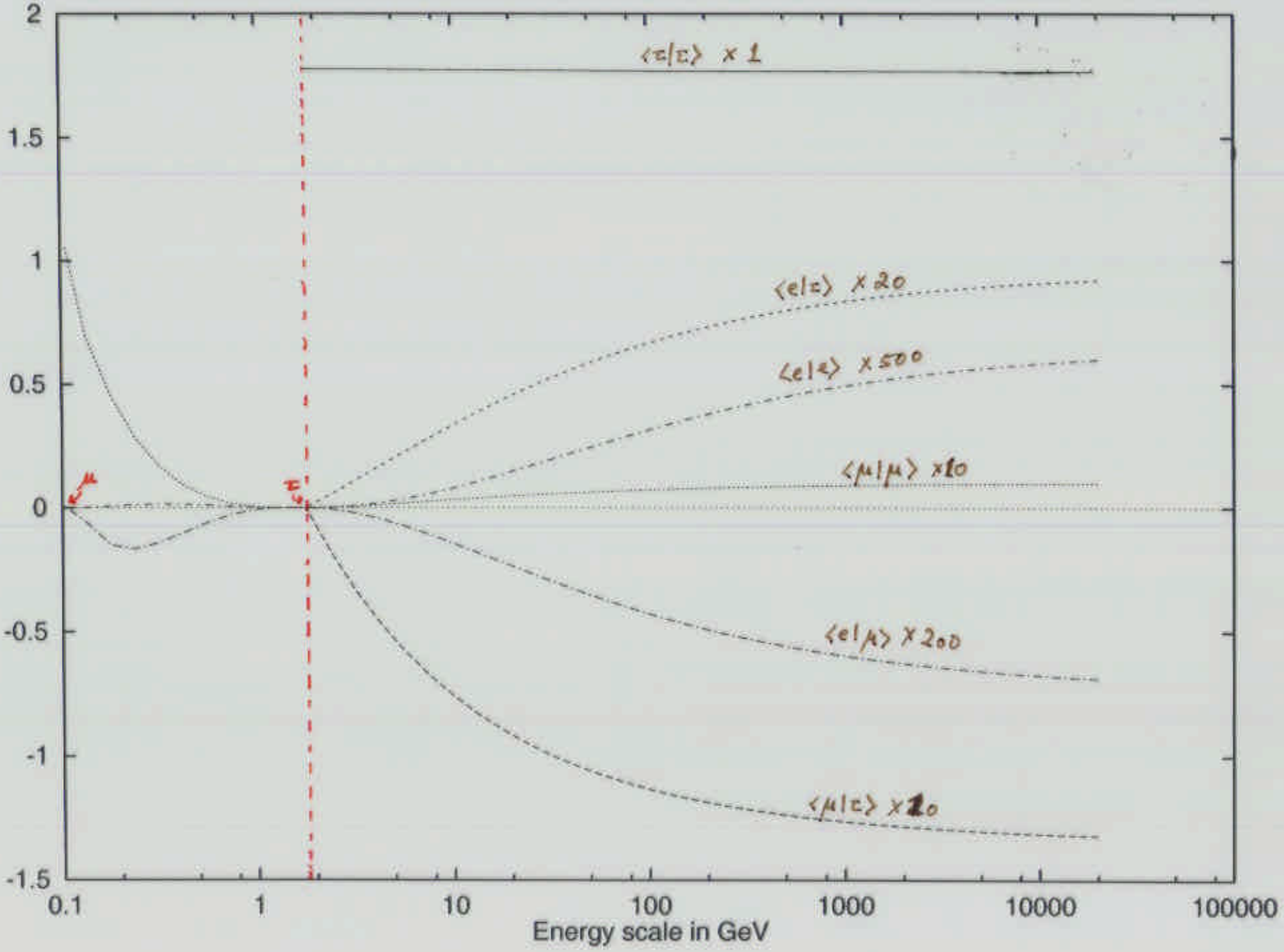
- state vectors fixed from a chosen scale
- applicable to SM

* mass matrix diagonal only at chosen scale

Step-by-step diagonalization

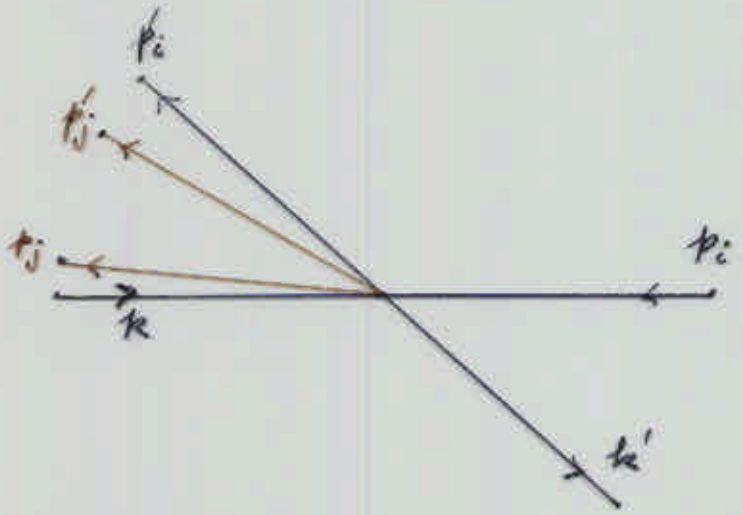
- a working criterion
  - lepton state vectors always orthogonal
  - rotation matrix always unitary
- must be used in DSM
- 3 steps:
  1. run m to scale where $\mu = m_3(\mu)$
  2. corresponding e-vector is state vector v_3
  3. do same with 2×2 remaining submatrix

* mass matrix diagonal at scales m_τ, m_μ, m_e


2
1.5
1
0.5
0
-0.5
-1
-1.5
0.1
1
10
100
1000
10000
100000
Energy scale in GeV
⟨τ|τ⟩ x 1
⟨e|τ⟩ x 20
⟨e|e⟩ x 500
⟨μ|μ⟩ x 10
⟨e|μ⟩ x 200
⟨μ|τ⟩ x 20
μ
τ

DSM calculations

- kinematics: unfamiliar
  - l_α and l_β lin. comb. of τ, μ, e states
  - how are momenta related?
  - s, t as variables (same for all channels in a given process)
- amplitudes
  - cannot use standard γ traces formulae
  - individual spin, polarization
  - sum by hand



c.m. frame of channel i

$p^2 = p'^2 = m^2$

Comments on numerical results

DSM

- $\gamma + e \to \gamma + \mu$ $\quad\quad$ $\gamma + e \to \gamma + \tau$

  $\gamma + \mu \to \gamma + e$ $\quad\quad$ $\gamma + \mu \to \gamma + \tau$

  (above τ threshold)

- $\frac{d\sigma}{d\Omega}$ (not $\frac{d\sigma}{du}$) $\rightsquigarrow$ X-section $\searrow$ as $s \nearrow$

- $s + t \sim -u$

- rotation matrix $\rightsquigarrow$

  $\gamma\mu \to \gamma\tau > \gamma e \to \gamma\tau > \gamma e \to \gamma\mu$

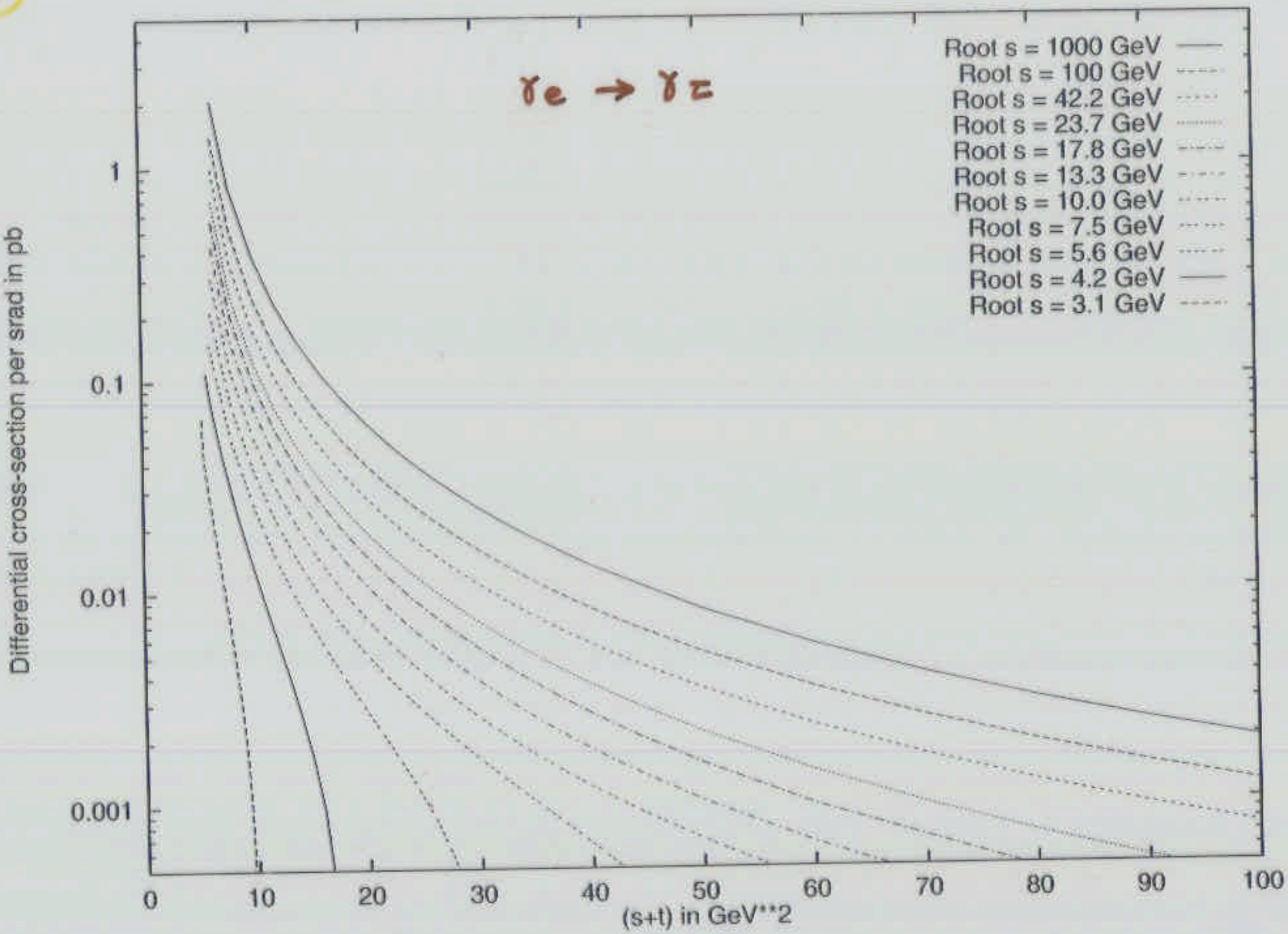
SM with FSD

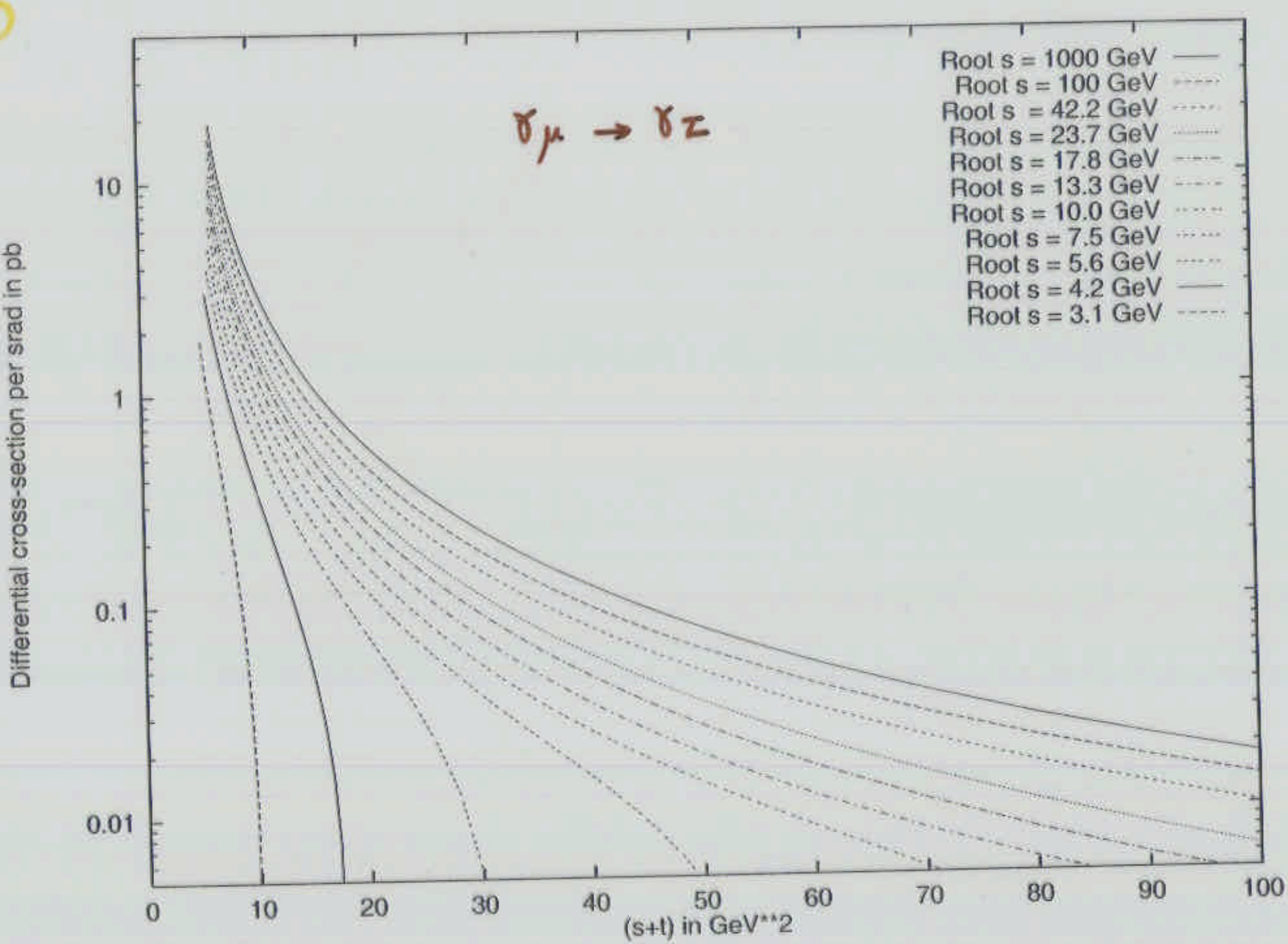
If
- hierarchical masses $m_3 \gg m_2 \gg m_1$
- above τ threshold

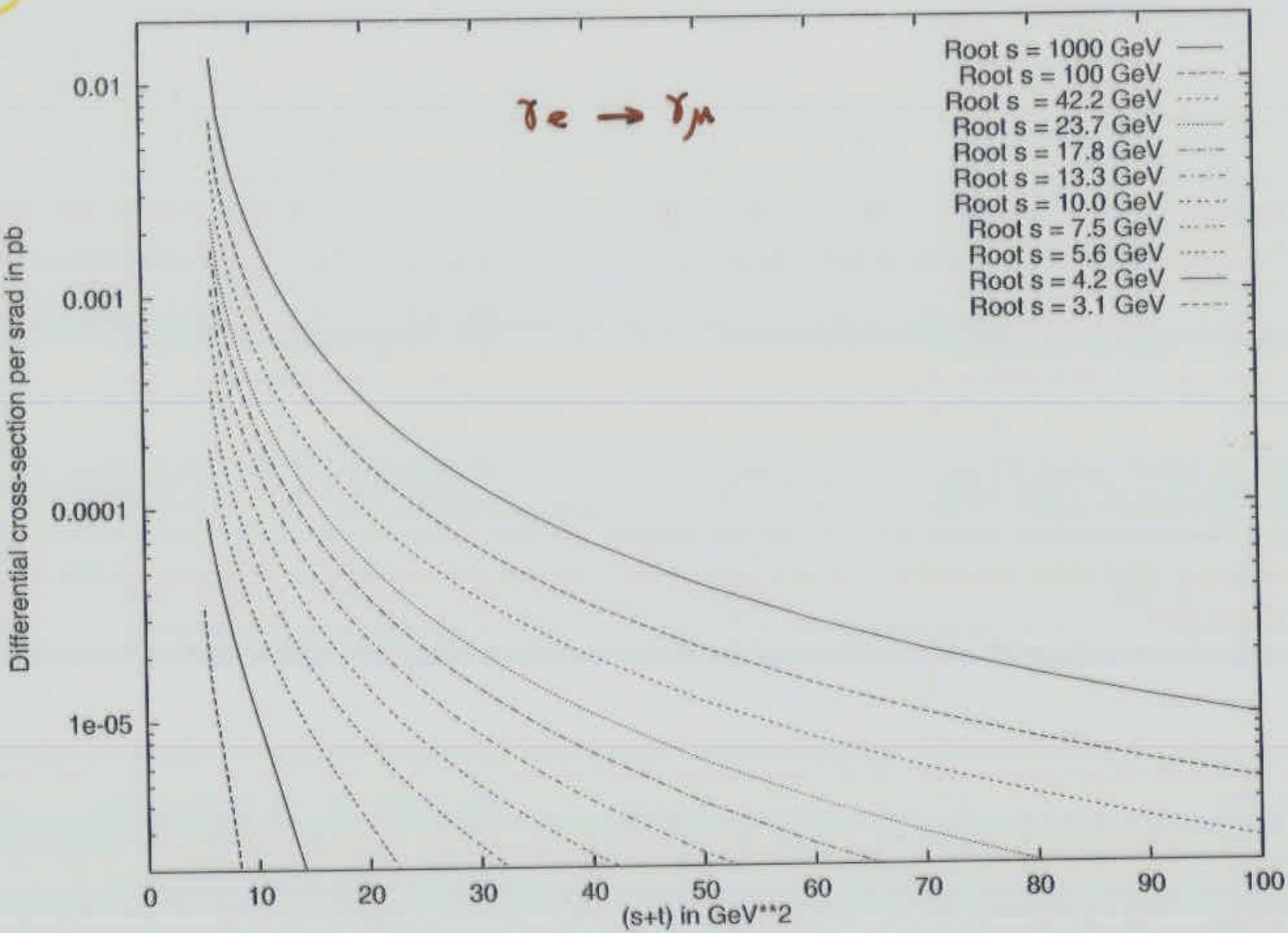
$\rightsquigarrow$ results app. given by scaling with relevant rotation matrix elements

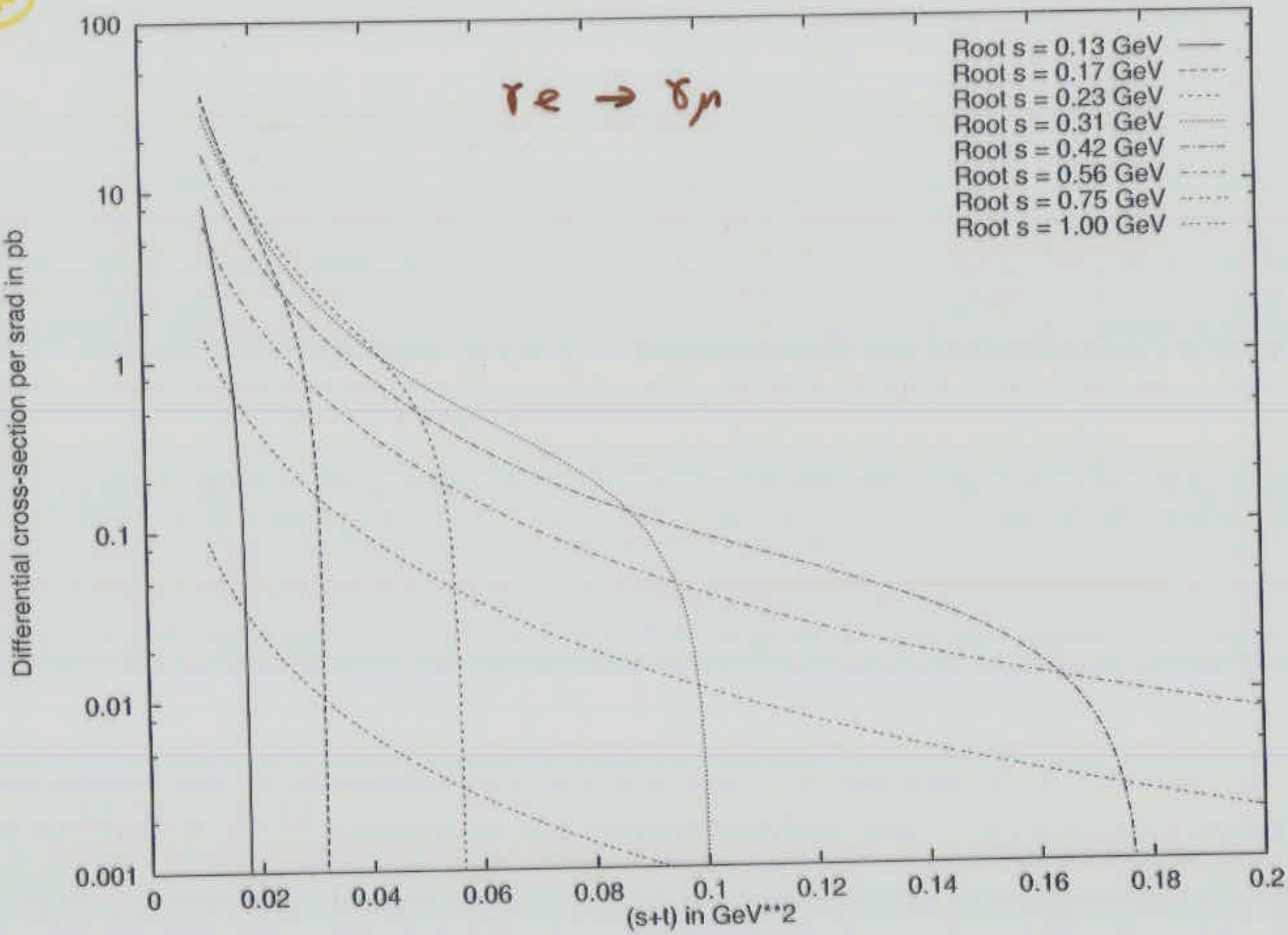
e.g. $\gamma\mu \to \gamma\tau$ at $\sqrt{s} = 17.8$ GeV

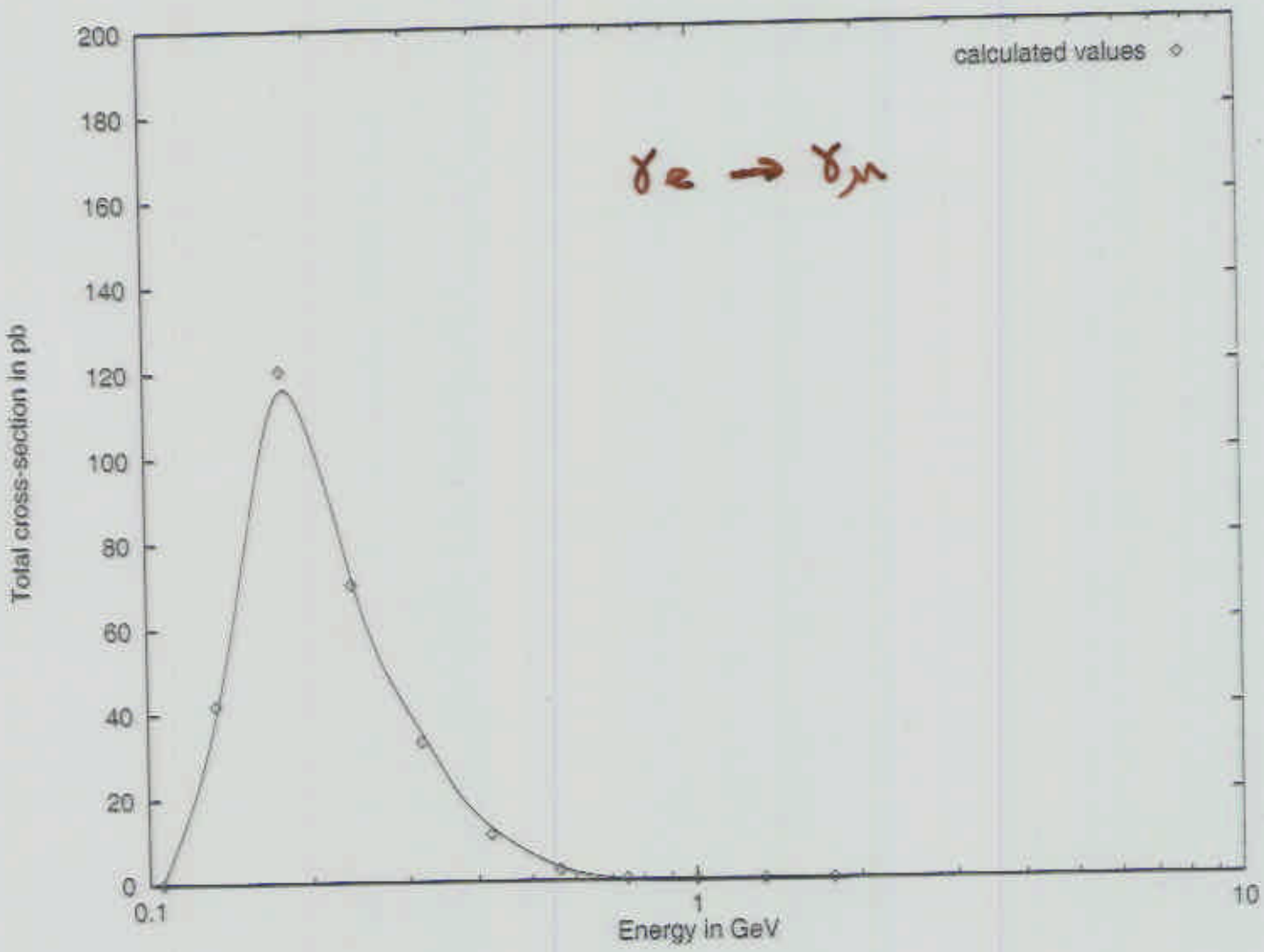
2-3 orders smaller


γe → γz
Root s = 1000 GeV
Root s = 100 GeV
Root s = 42.2 GeV
Root s = 23.7 GeV
Root s = 17.8 GeV
Root s = 13.3 GeV
Root s = 10.0 GeV
Root s = 7.5 GeV
Root s = 5.6 GeV
Root s = 4.2 GeV
Root s = 3.1 GeV
Differential cross-section per srad in pb
1
0.1
0.01
0.001
0
10
20
30
40
50
60
70
80
90
100
(s+t) in GeV**2


$\gamma_\mu \to \gamma_Z$
Root s = 1000 GeV
Root s = 100 GeV
Root s = 42.2 GeV
Root s = 23.7 GeV
Root s = 17.8 GeV
Root s = 13.3 GeV
Root s = 10.0 GeV
Root s = 7.5 GeV
Root s = 5.6 GeV
Root s = 4.2 GeV
Root s = 3.1 GeV
Differential cross-section per srad in pb
10
1
0.1
0.01
0
10
20
30
40
50
60
70
80
90
100
(s+t) in GeV**2


$\gamma e \rightarrow \gamma \mu$
Root s = 1000 GeV
Root s = 100 GeV
Root s = 42.2 GeV
Root s = 23.7 GeV
Root s = 17.8 GeV
Root s = 13.3 GeV
Root s = 10.0 GeV
Root s = 7.5 GeV
Root s = 5.6 GeV
Root s = 4.2 GeV
Root s = 3.1 GeV
Differential cross-section per srad in pb
0.01
0.001
0.0001
1e-05
0
10
20
30
40
50
60
70
80
90
100
(s+t) in GeV**2


γe → γp
Root s = 0.13 GeV
Root s = 0.17 GeV
Root s = 0.23 GeV
Root s = 0.31 GeV
Root s = 0.42 GeV
Root s = 0.56 GeV
Root s = 0.75 GeV
Root s = 1.00 GeV
Differential cross-section per srad in pb
100
10
1
0.1
0.01
0.001
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
(s+t) in GeV**2


calculated values
$\gamma_e \rightarrow \gamma_\mu$
Total cross-section in pb
Energy in GeV
200
180
160
140
120
100
80
60
40
20
0
0.1
1
10

Possible tests (near future ?)

- may use virtual γ from e^+e^- colliders
- above τ threshold, more profitable to look for τ (study underway) LEP or BEPC ?
- at low energy, more profitable to look for $e \to \mu$ transmutation, ~ cm energy 200 MeV

  (DSM $\Rightarrow$ peak of ~ 100 pb)

  BEPC ?

  ↓

  (need 46GeV γ_e !)

Conclusions

- Necessary consequence
- SM calculations
  - in general smaller than DSM
  - some uncertainties
- DSM calculations
  - parameter-free
  - working hypothesis with internal consistency
  - no violations with data so far
  - experimental tests
    * $e \to \tau$
    * $e \to \mu$ (below τ)
  - other transmutational processes:
    e.g. $e^+e^- \to e^+\mu^-$, decays
- Exciting new physics to be explored