High Energy Collider Working Group Report

Dark Forces Workshop @ SLAC
Sept. 25, 2009

Andy Haas + Jay Wacker

High Energy Collider Working Group Report

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Tevatron (for now)…. but will apply to LHC as well

Production Modes

New scalars
or pseudo-scalars

W+ Dark photon

Lepton Jet + SM Jet

Jet + Dark DY

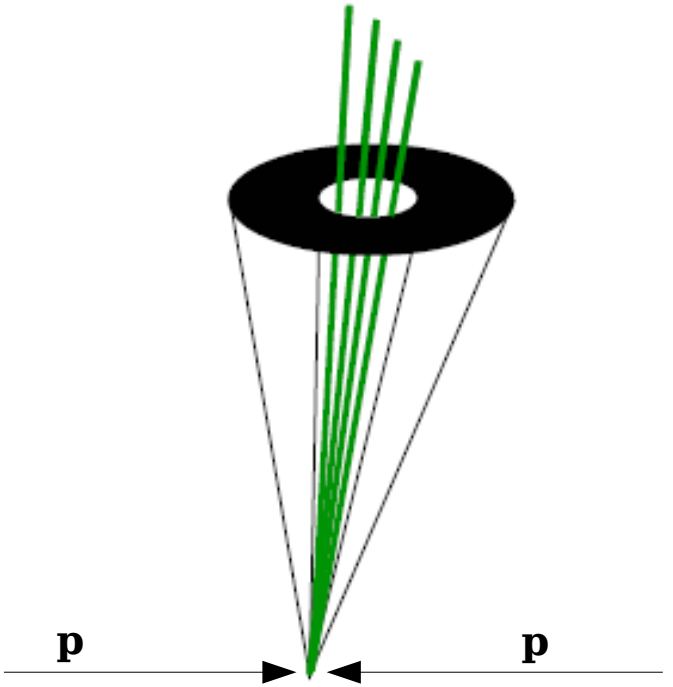
2 lepton Jets (+ MET) (+SM Jets)

Susy LSP to dark sector

Z/Z' to dark particles

Direct dark particle production

mSUGRA
GMSB
EW-ino
...



Lepton Jet + (Photon/Iso Leptons)

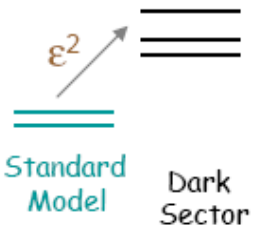
(Shih &Thomas to appear)

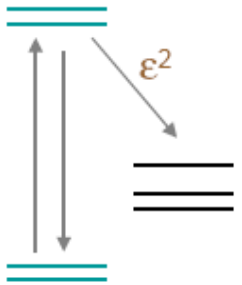
Milli-charged particles?

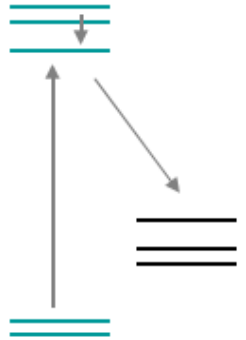
Production Modes

Dark Sector Production at High Energy Colliders

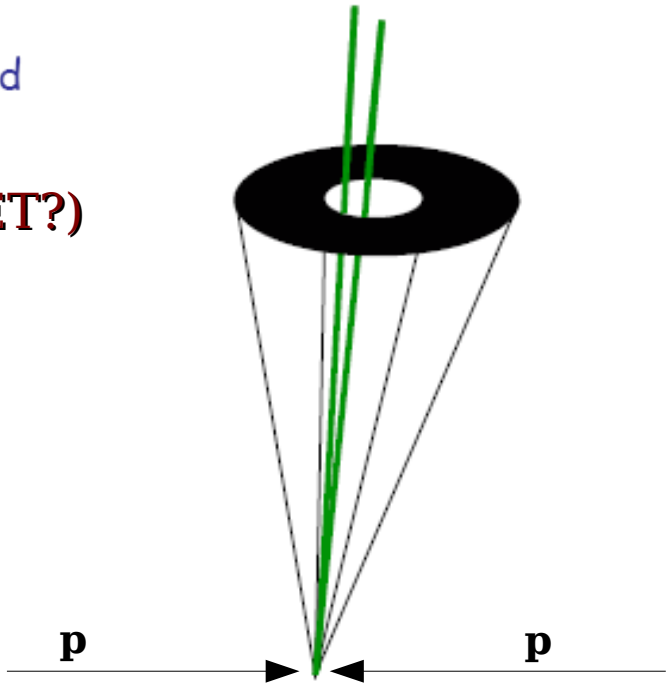
Direct Production	Indirect Production	Indirect Production with Shared Conserved Quantum Number
jet + lj	Z-> lj lj	SUSY-> lj lj (+MET?)







σ » O(ε²)	Br » O(ε²)	σ ¢ Br » O(ε⁰)



Which Dark Sector States Populated - Depends on Production Portals

Portal » ε

Scott Thomas

What's a Lepton Jet?

dR=sqrt(dphi^2+deta^2)

$\Delta R < 0.1$

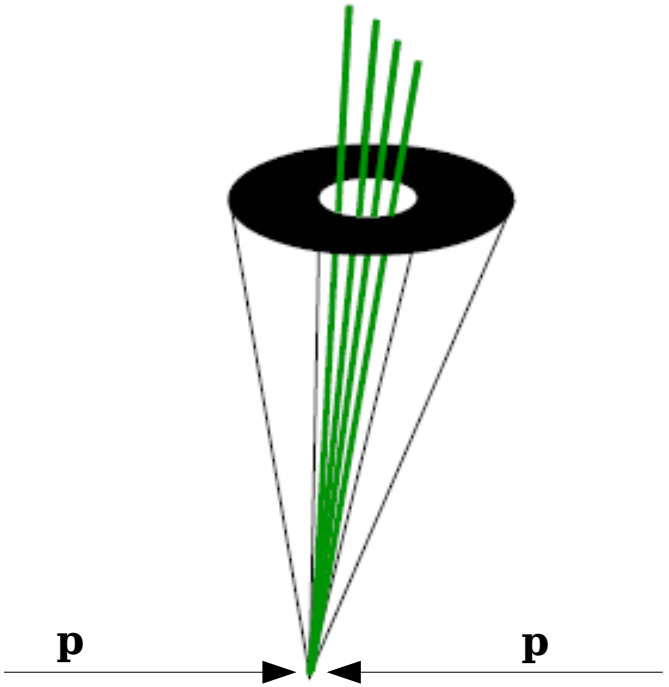
$\geq$ 2 leptons each with $p_T > 10\ \mathrm{GeV}$.

hadronic isolation cut $\Sigma p_T < 3\ \mathrm{GeV}$.

$0.1 < \Delta R < 0.4$,

hadronic/leptonic isolation cut of $\Sigma p_T < 3\ \mathrm{GeV}$

Itay Yavin, Josh Ruderman
(ala BOOST'09)



What's a Lepton Jet?

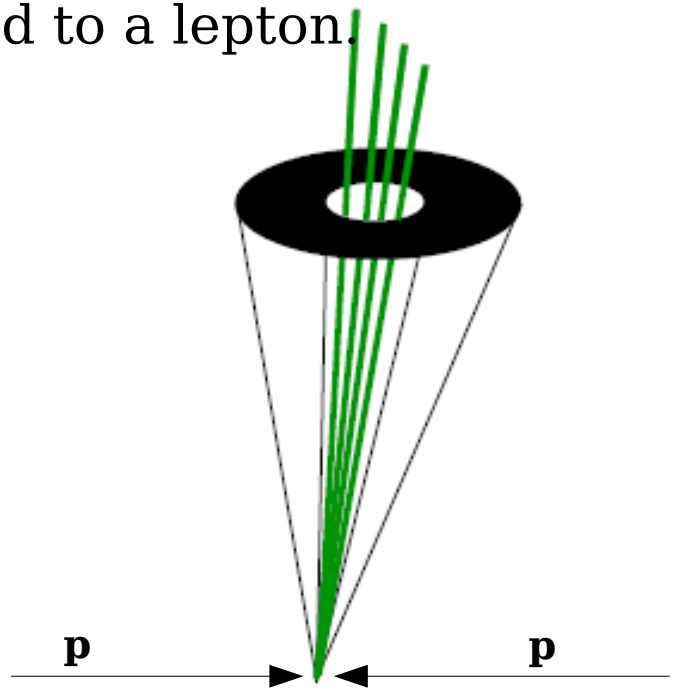
"Low mass lj":

$\Delta R < 0.1$

≥ 2 ~~leptons~~ **tracks** each with $p_T > 10\ \mathrm{GeV}$. >=1 matched to a lepton.

~~hadronic isolation cut $\Sigma p_T < 3\ \mathrm{GeV}$.~~

$0.1 < \Delta R < 0.4$,
hadronic/leptonic isolation cut of $\Sigma p_T < 3\ \mathrm{GeV}$



track impact parameters < ~few cm
(separate analyses needed for long lifetimes...)

***probably* some invariant mass resonances**

all numbers subject to optimization per analysis!

What's a Lepton Jet?

"High mass lj":

$\Delta R < 0.1$

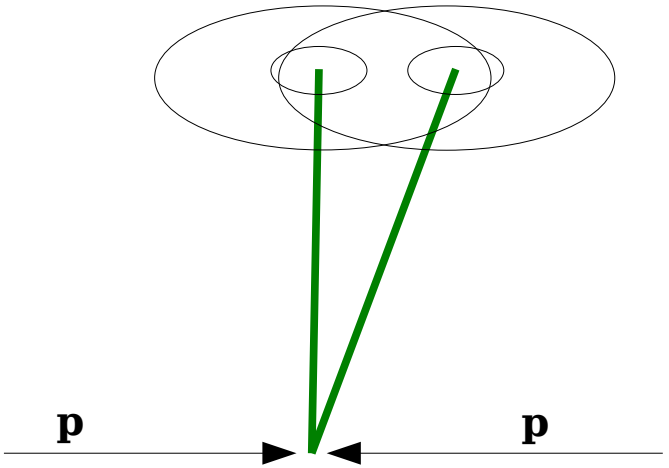
≥ 2 leptons each with $p_T > 10$ GeV.

~~hadronic isolation cut $\Sigma p_T < 3$ GeV.~~

~~$0.1 < \Delta R < 0.4$,~~ **0.1<dR<0.4 around *either* lepton**

hadronic/leptonic isolation cut of $\Sigma p_T < 3$ GeV

"pair calorimeter isolation"



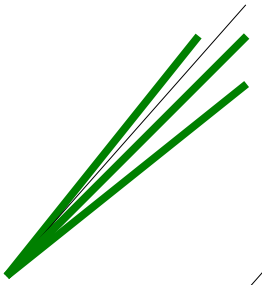
track impact parameters < ~few cm
(separate analyses needed for long lifetimes...)

***probably* some invariant mass resonances**

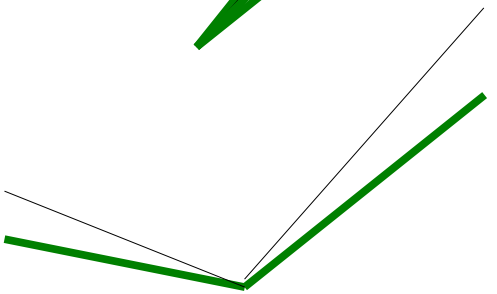
all numbers subject to optimization per analysis!

Inclusive (as possible) Signatures

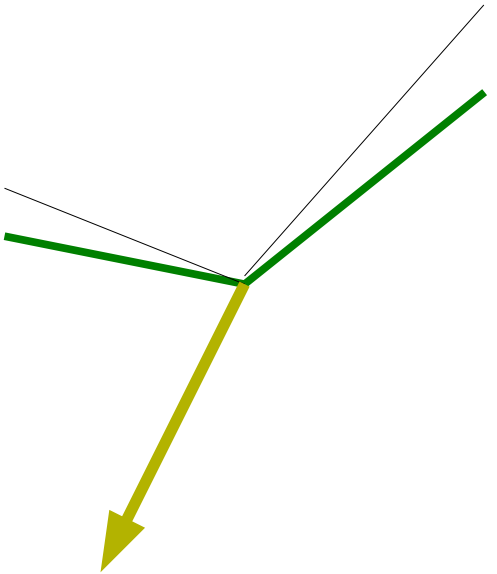
lj + X
- Have to look for >=2 leptons
  and/or look for di-lepton mass resonance



2 lj + X
- Can loosen to >=1 leptons (per lj)



And look for additional objects:
- MET
- Additional (isolated) leptons, photons
- Jets?



And study important event variables:
- #lj, #l, MET, METphi, M_lj, M_total
- track impact parameters

This will also let us disambiguate our signal amongst models!

Simulation

For realistic tests of models, we need accurate simulations

- Dark higgs and dark photon decays to SM understood

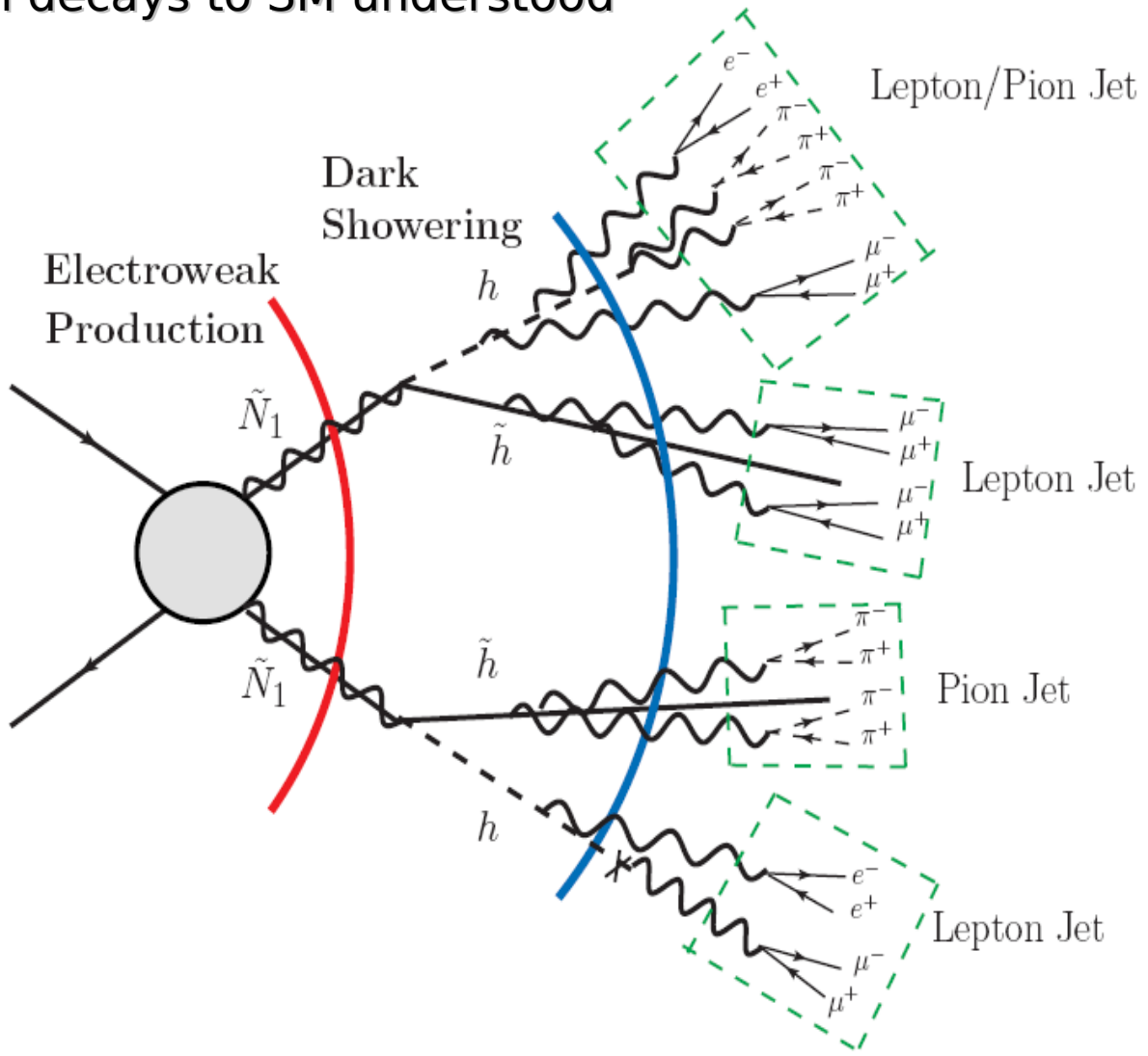
Dark radiation

$$N_{\gamma_d} \sim \frac{\alpha_d}{2\pi} \log\left(\frac{M^2_{\text{decay}}}{M^2_{\text{dark}}}\right)^2$$

Itay Yavin, Josh Ruderman

Showering in the dark

- **Abelian**
- Non-abelian



Simulation

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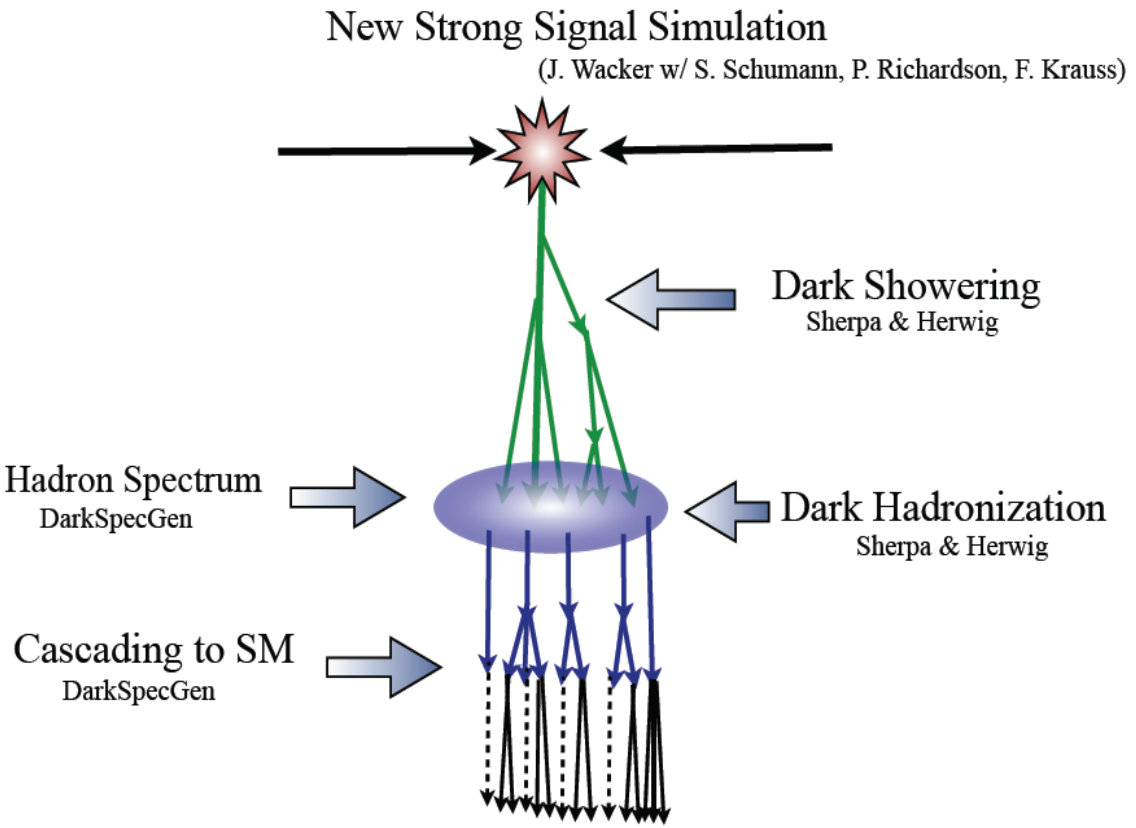
Dark radiation



Showering in the dark

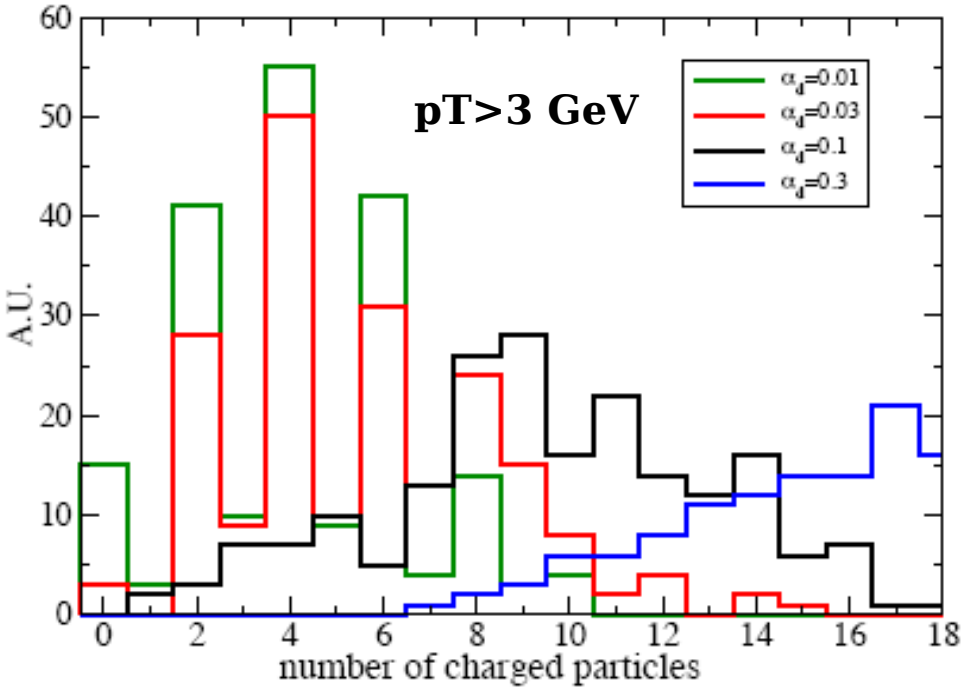
- Abelian
- **Non-Abelian**

Simulation

For Abelian model, showering + decay gives realistic results

Very happy with this!
But, to do:

- Verify details of code
- Make LHE events available (private Mathematica code)



Itay Yavin, Josh Ruderman

Princeton group has offered to generate MadGraph events

- Various production modes
- ~2 dark couplings (.1, .3)
- ~3 dark mass combinations (thus BR(->pions)

... and shower/decay them
... and give experimentalists LHE files

Let dark higgs give MET? Or make it decay quickly?

With these simulations, we can begin to tune our experimental analyses !

...from BOOST '09

Advances to improve theoretical prediction

Showering & Hadronization
(Abelian & Non-Abelian)

Parameterization/Categorization of Lepton jets &
Production modes for benchmarks

Implementation of benchmarks into MCs

highlighting sensitivity differences between
Tevatron/LHC/B-factories/Fixed Target/LHCb

...from BOOST '09

Advances to improve experimental sensitivity

Tuning selection criteria to improve sensitivity of benchmark 4-lepton lepton jet parameterization

Underway

Separating electron lepton jets from EM rich QCD jets

Underway

Mixed 2mu+2e lepton jet study

Hadronic isolation to prevent losses from additional dark radiation

Shouldn't be a big problem

CDF and D0 are both studying their data and backgrounds...

Summary

Good theoretical understanding of production models

Definition(s) for “lepton jets”
- efficient for a wide range of models and parameters

Outline of experimental analyses to perform
- which are as inclusive as possible
- and experimental variables to study

Dark decays and showering can be simulated

Next step: perform Tevatron analyses

Thanks to everyone who contributed!