ML4Jets 2021

Super-Resolution for QCD and Top Jets

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July 7, 2021

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Preprint: `https://arxiv.org/abs/2012.11944`

Motivation

K0»j_§_njI ~«q0} |0 n€«§_nj

In single image super resolution (SISR) the goal is to predict a sensible high resolution (HR), super resolved (SR) version of a given low resolution (LR) image

- Use established SR method as starting point: ESRGAN [1]
- Generative Adversarial Network [2] setup

(a) High Resolution (b) Low Resolution (c) Bicubic Upsampling (d) Super Resolution

Figure: Super resolution on the STL-10 [3] testset using the ESRGAN

(a) High Resolution (b) Low Resolution (c) Bicubic Upsampling (d) Super Resolution

w«0 §_nj

Can an upsampled jet image include more information than the original, low-resolution image?

Dataset

- Use p´§_9 [4] to generate ʙʙ ̋Ẽnd QCD dijet events
- Center of mass energy of J ̄ æ ; /2 TeV
- Run KOeq\O [5] with standard ATLAS card ̋Ω HR version (/4. Φ /4.)

Dataset

- Use p ´ § _9 [4] to generate ʙʙ̄ ̏Ｆand QCD dijet events
- Center of mass energy of ٮ̄æ ; /2 TeV
- Run K0eq\0 [5] with standard ATLAS card ̏Ω HR version (/4. Φ /4.)
- Perform downsampling step (sum pooling ɣ ; 6) ̏Ω LR version (0. Φ 0.)
- Run anti-kt jet algorithm using S9 §`0§ [6] on HR & LR
- Filter: Jet ″ ̮ گ Ɏ33.* 43.[W0 - , z z_{jet} : 0 and ה ; م ɸ) ɸ : .,/

We end up with paired dataset of LR & HR images of the same event.

Dataset

Sparse images: 77,6. # empty
Individual constituents can have transverse momenta of up to " ; 3.. GeV, but over 63# have " : 0. GeV
% Sharp and wide distribution, hard to learn for network
Solution: Raise image to a power " ک&.*/' in a pixel-wise fashion

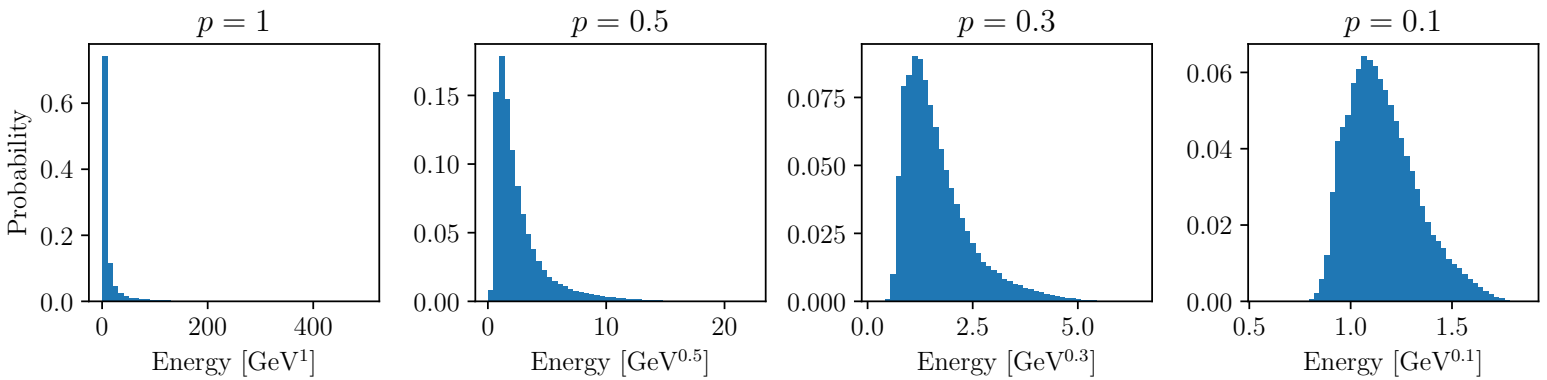


Figure: Energy distribution behaviour when raising it to different powers "

Training Process

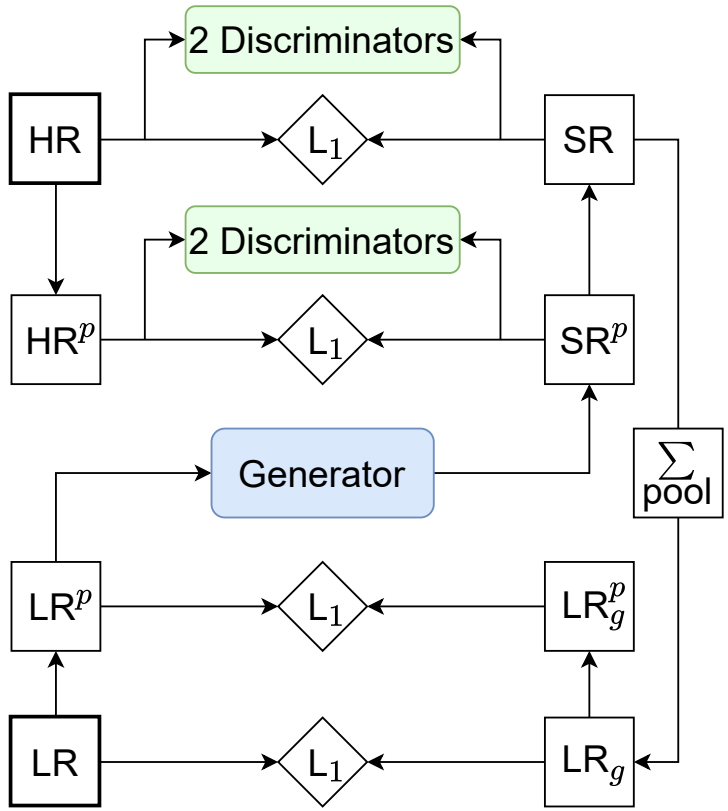


Figure: Training iteration

Patch Loss

Patch loss helps to balance the spread of constituents

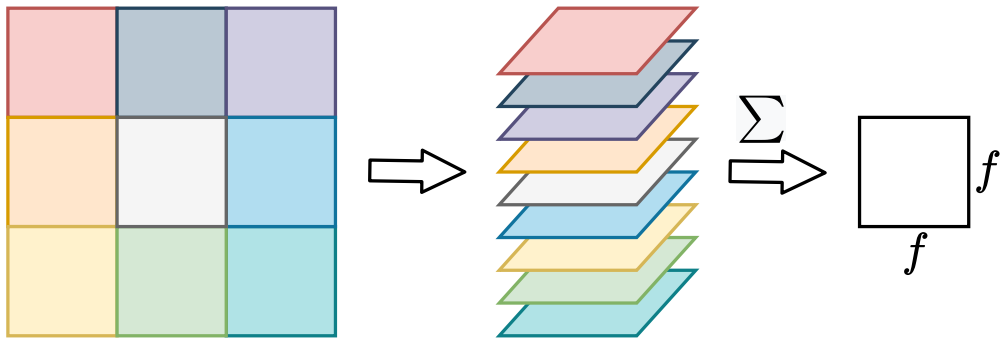


Figure: Patch rearrangement. γ is the upscaling factor

Sum over created dimension.
Compare using **Mean Squared Error**

$$\text{ב}_{\text{q9§H\ }} \; ; \; \text{ב}_{\phi} \,\&\text{q9§H\&\sim} \,|\, '{*}\ \text{q9§H\&[} \,|\, '' \tag{1}$$

Jet observables

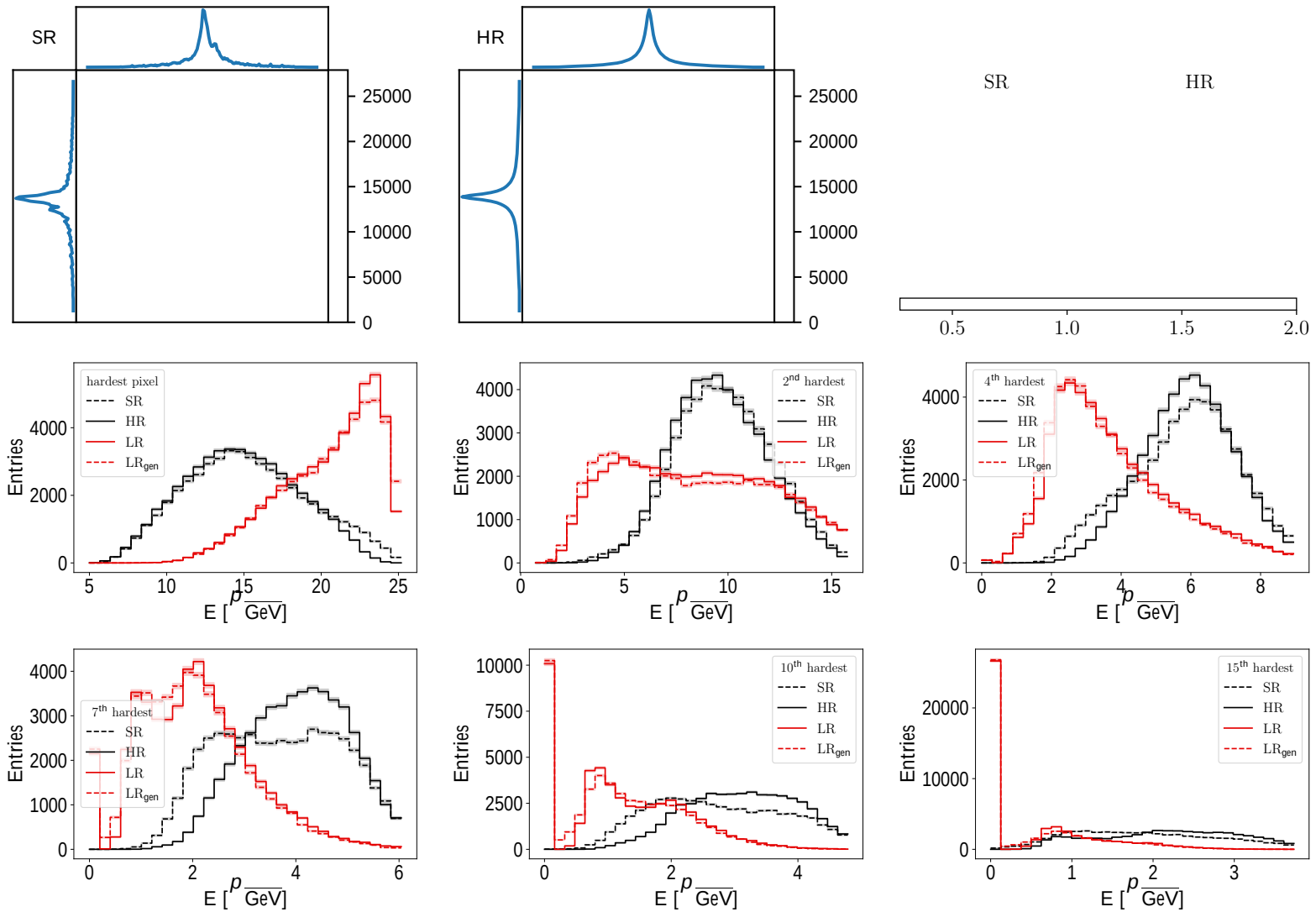
Compare $\prime\prime_{\vdots}$ distribution for the $\prime\prime^{\text{th}}$ hardest jet and set of high-level jet observables [7–10]

$$\prime\prime_{\text{jet}} \quad ; \quad \mathcal{N} \; \mathcal{L}_{u} \; \prime\prime_{u} \; \mathcal{N}$$

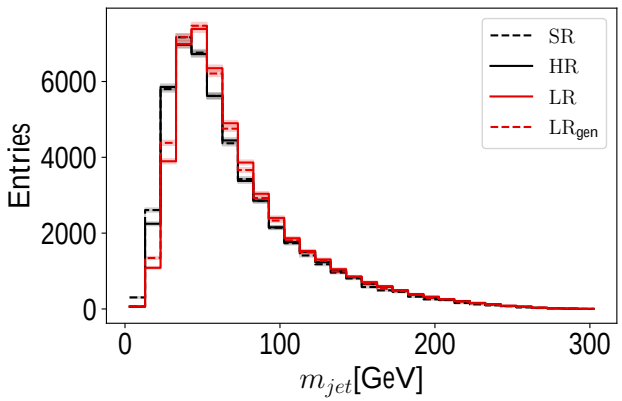
$$\left| \ddot{\imath}_{\cdot} \phi \right. \quad ; \quad \frac{\mathcal{R}_{u \cdot v} \; \prime\prime_{\vdots_{\cdot u}} \; \prime\prime_{\vdots_{\cdot v}} \; \& \; \Pi_{u \cdot v} \; ' \ddot{\imath}_{\cdot} \phi}{\& \; \mathcal{R}_{u} \; \prime\prime_{\vdots_{\cdot u}} \; ' \phi}$$

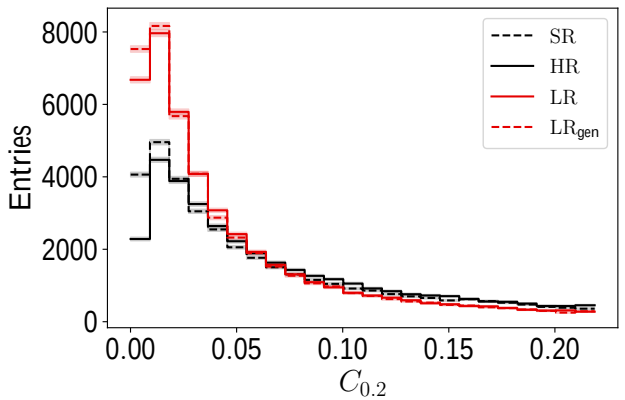
$$_{k} \quad ; \quad \frac{\mathcal{R}_{\beta} \; \prime\prime_{\vdots_{\cdot \beta}} \; \mathrm{h\_j} \& \; \Pi_{E \cdot \beta} \; * \; \mu \; * \; \Pi_{k \cdot \beta} \; '}{\mathcal{R}_{\beta} \; \prime\prime_{\vdots_{\cdot \beta}} \; \Pi_{\ddot{\imath}}}$$

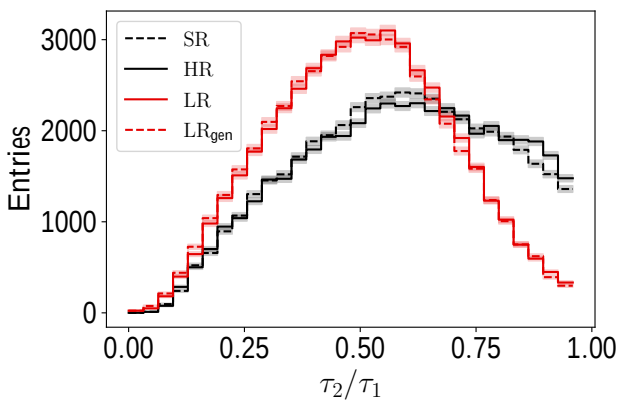
Performance for QCD Jets – Low level

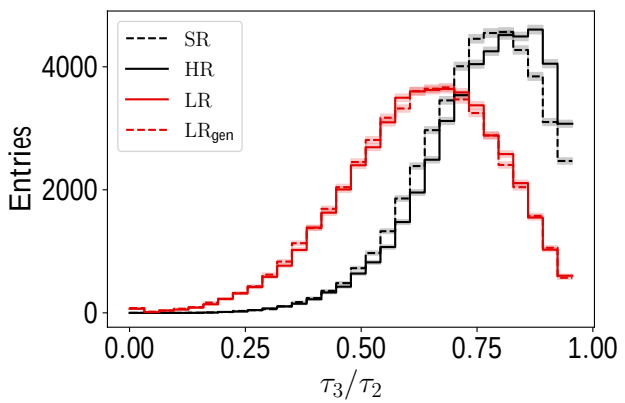


Performance for QCD Jets – High level

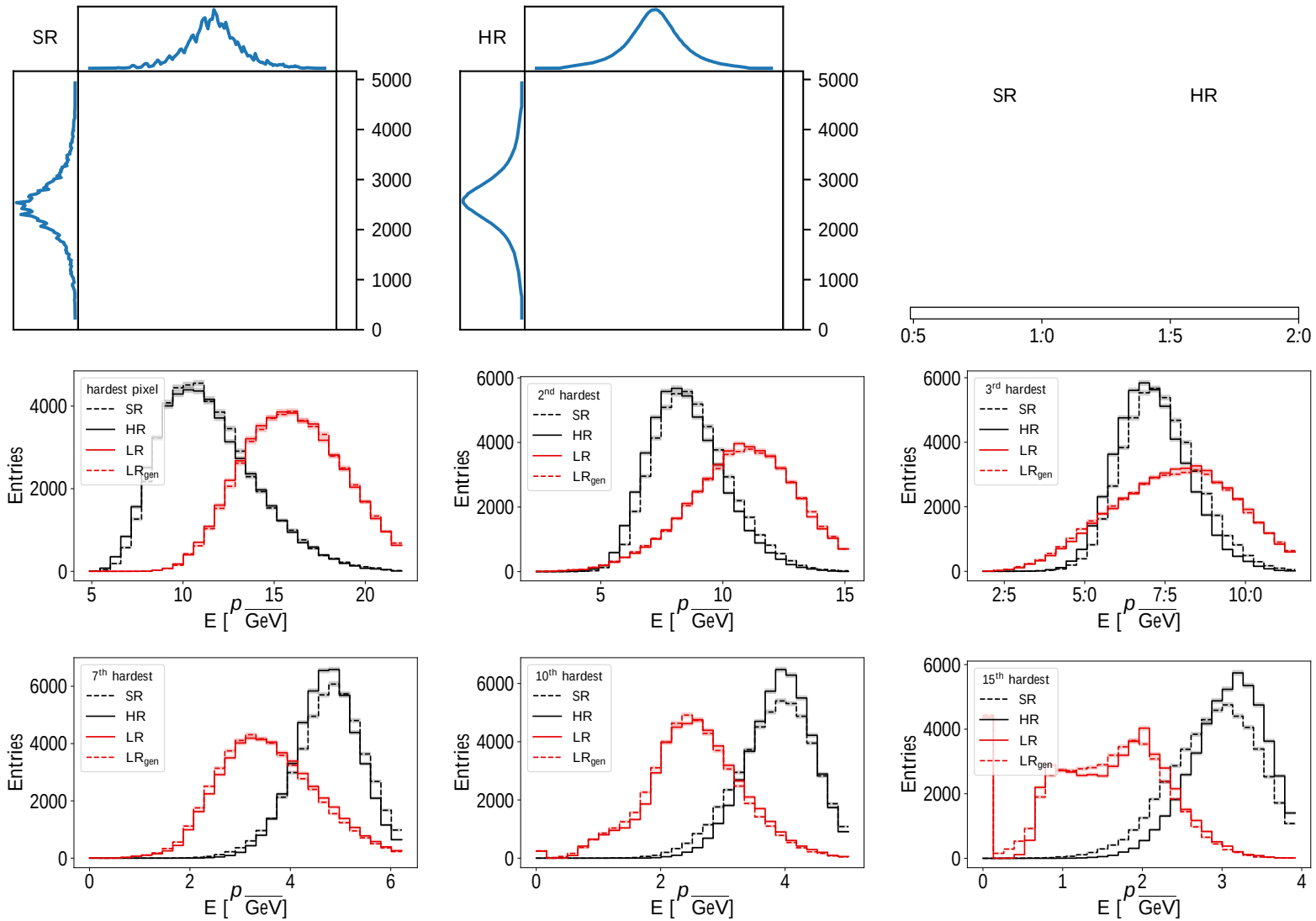








Performance for Top Jets – Low level



amT2`@
_2bQHmiB
Z*. M/ hQ
C2ib

S2`7Q`K M+2 7Q` hQT C2i

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQM

_272`2M+2b

TT2M/Bt

Rk f R

amT2`@
_2bQHmiB
Z*. M/ hQ
C2ib

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQ

_272`2M+2b

TT2M/Bt

lMiBH MQr, .Bbi`B#miBQMb Qp2` 2MiB`2
LmK#2` Q7 b KTH2b /`QrM Qmi BM/BpB/n

Zm2biBQM

.Q2b mT@b KTHBM; // BM7Q`K iBQM iQ

:Q H Bb MQi iQ `2+QMbi`m+i i?2 i`m2 >_
+QMbBrbBi2?G _ D2iX
6Q` ;Bp2M Q#b2`p #H2 HQQF i/2pB iBQ
2p2Mi #v 2p2Mi # bBb

$$\frac{>\_7\,G\_}{>\_} \quad M/ \quad \frac{>\_7\,a\_}{>\_}$$

HbQ HQQF i`2H iBQM Q7 /2pB iBQMb

$$\frac{]>\_7\,a\_\%}{]>\_7\,G\_\%}$$ Ó a_ /2b+`B#2b >_ #2ii2` i
G_ /2b+`B#2b >_ #2ii2` i

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQM

_272`2M+2b

TT2M/Bt

6B;mhQT D2ib, _2H iBp2` iBQ 7Q` D2i

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQM

_272`2M+2b

TT2M/Bt

6B;mhQT D2ib, *Q``2H iBQM Q7` iBQb 7

*QM+Hm

GmF b "H2+?2`

- AMi`Q/m+2 M2r TTHB+ iBQM Q7 /22T
- #H2 iQ ;2M2` i2 b2MbB#H2 3@7QH/ b
- amT2`@`2bQHmiBQM M2irQ`Fb + M T iBQM
- * M #2 mb2/ iQ 2M? M+2 D2i K2 bm`2H TQQ` + HQ`BK2i2` `2bQHmiBQM

_272`2M

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQM

_272`2M+2b

TT2M/Bt

R sX q M;- EX um- aX qm- CX :m- uX GBm- *X .QM;- *X *X ó1a_- L, 2M?M+2
bmT2`@`2bQHmiBQM ;2M2` iBp2 /p2`b `B- H M2irQ`Fbô-

k AX CX :QQ/72HHQr- CX SQm;2i@ # /B2- JX JB`x -"X sm- .X q `/2@6 `H2
uX "2M;:2M2` iBp2 /p2`b `B- H M2irQ`Fb

j X uX LX / K *Q i2b >QM ó MAM i`Q/m+iBQM iQ Suh>A 3Xkô-
H2 `MBM;ô-

9 hX aDºbi` M/- aX bF- CX _X *?`BbiB Mb2M- _X *Q`F2- LX .2b B- SX AHi2
*X PX _ bKmbb2M- M/ Só MAMi`Q/m+iBQM iQ Suh>A 3Xkô-
R8N Rdd UkyR8V

8 CX /2 6 p2`2 m- *X .2H 2`2- SX .2KBM- X :B KK M+Q- oX G2K Wi`2- X J
ó.2HT?2bj, KQ/mH `7` K2rQ`F 7Q` 7 biBBKmH iBQM Q7Q;2M2`B+Q
1M2`;v S?kyR-RyXRyydfD?2TykUkyRRV8d

e JX * ++B `B- :X SX a H K- ó6/biC2i b2- J Mm `Hô-

d CX : HHB++?BQ- CX >mi?- JX E ; M- JX .X a+?r `ixó JmHiBp `B i2/Bb+`B
M/ i?2 >B;;b Y qfw b2`+?ô-

3 X CX G `FQbFB- :X SX a H K- ó1M2`;v*Q``2H iBQM 6mM+iBQMb 7Q` C2i a
ye Ry3 UkyRjV

N CX h? H2` M/ EX o ó A/2M#B7vBM; "QQbi2/ P#D2+ib rBi?i@bm#D2iBM

Ry :X E bB2+xF - LX EB272`- hX SH2?M- ó Zm `F@XHmQM h;BM;, J +?BM2
.2i2+iQ`ô- BSQbi S-?ye UkyRNV

RR *X G2/B;- GX h?2Bb- 6X >mbx `- CX * # HH2`Q- X SX BiF2M- X h2D MB
óS?QiQ@`2 HBbiB+ bBM;H2 BK ;2 bmT2`@`2bQHmiBQM mbBM; ;2M2`
#bfReyNXyU9k3yyRKeV

GmF b "H2+?2`

6B;m:`2M2` iQ` bi`RRRRRm`2 (

.Bb+`BKB

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

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TT2M/Bt

6B;ɱJ2`FQpB M /Bb+`BKBM iQ`

GmF b "H2+?2`

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6B;mh`2 BMBM; Bi2` iBQM KmHiB@T

amT2`@
_2bQHmiB
Z*. M/ hQ
C2ib

GmF b "H2+?2`

. i b2i

JQ/2H

1p Hm iBQM

*QM+HmbBQM

_272`2M+2b

TT2M/Bt

JmHiB@SQr2` C

6B;mh`2 BMBM; Bi2` iBQM bi M/ `/ H

Multi-Power Learning

Figure: Energy distributions with only the standard loss

Multi-Power Learning

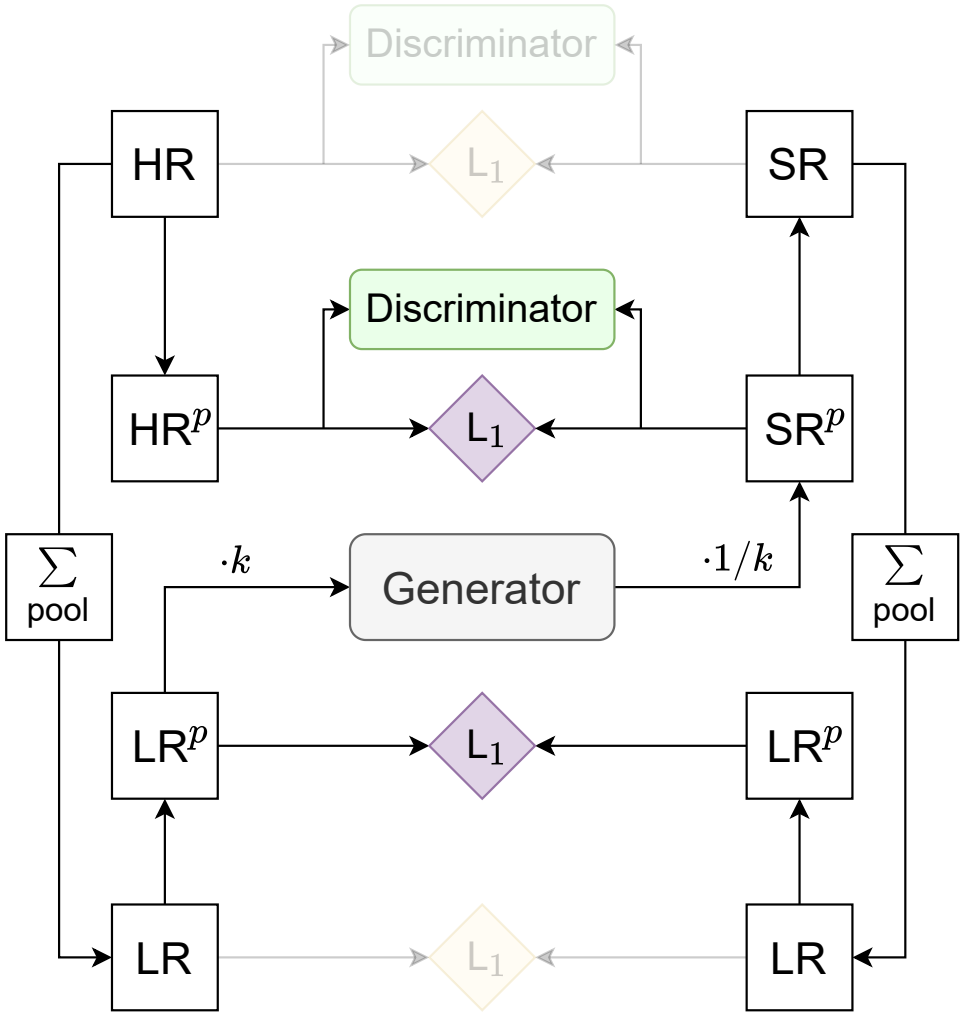

Figure: Training iteration – power loss

Multi-Power Learning

Figure: Energy distributions with only the standard loss

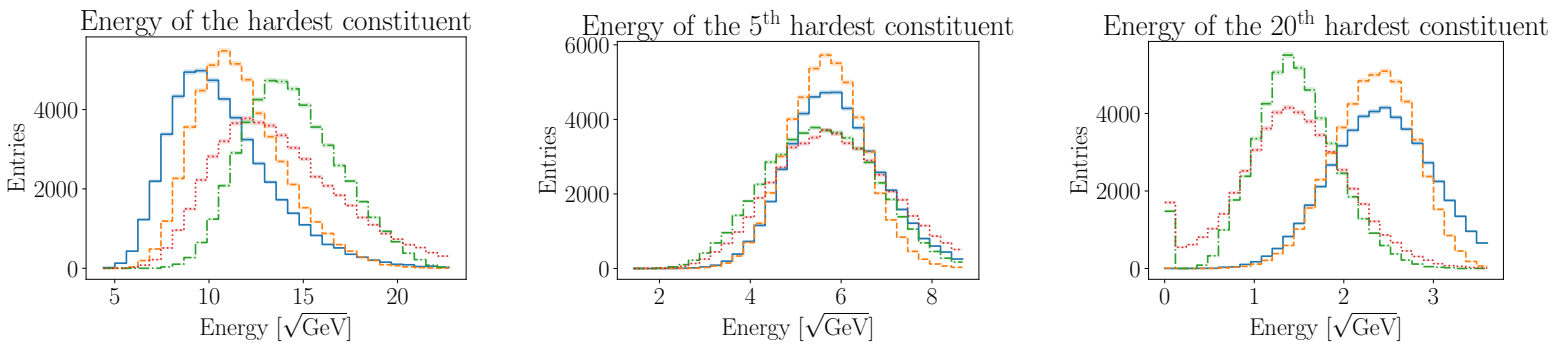

Figure: Energy distributions with only the power loss